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Theory of mind in relation to other cognitive abilities

Edited by
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Published in
Frontiers in Psychology

ISSN 1664-8714
ISBN 978-2-83251-531-0
DOI 10.3389/978-2-83251-531-0

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Theory of mind in relation to other cognitive abilities

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Citation
Dowker, A., Tsuji, H., Frye, D., eds. (2023). *Theory of mind in relation to other cognitive abilities*. Lausanne: Frontiers Media SA. doi: 10.3389/978-2-83251-531-0

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frontiers | Frontiers in Psychology

TYPE Editorial
PUBLISHED 18 January 2023
DOI 10.3389/fpsyg.2022.1123321

Check for updates

OPEN ACCESS

EDITED AND REVIEWED BY
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SPECIALTY SECTION
This article was submitted to Cognitive Science, a section of the journal Frontiers in Psychology

RECEIVED 13 December 2022
ACCEPTED 29 December 2022
PUBLISHED 18 January 2023

CITATION
Dowker A, Frye D and Tsuji H (2023) Editorial: Theory of mind in relation to other cognitive abilities. *Front. Psychol.* 13:1123321.
doi: 10.3389/fpsyg.2022.1123321

Editorial: Theory of mind in relation to other cognitive abilities

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KEYWORDS

theory of mind, child development, adults, individual differences, executive functioning, language, schizotypy, autism

Editorial on the Research Topic
Theory of mind in relation to other cognitive abilities

Theory of mind and its development have been the subject of much research over the last 40 years. Theory of mind is generally thought to be very important in cognitive and social development. However, there is still much debate as to how it should be defined and even as to whether it is a single entity. In particular, there is controversy around the extent to which it should be seen as a specific cognitive function (Gopnik and Astington, 1988; Perner, 1991; Wellman, 2004), or rather as dependent on, or mutually developing with, other cognitive abilities and characteristics, such as language (Tager-Flusberg, 2000; Milligan et al., 2007; Ebert, 2020), metacognition (Kuhn, 2000), executive function (Frye et al., 1995; Carlson and Moses, 2001; Sabbagh et al., 2006; Pellicano, 2010; Devine and Hughes, 2014), and cognitive and perceptual styles that emphasize gist vs. detail ("strong" vs. "weak" central coherence) (Jarrold et al., 2000; Happé and Frith, 2006). It is also possible that theory of mind itself has several different components, which may be related to different degrees of different cognitive abilities and characteristics. Relationships between theory of mind and other cognitive characteristics may also vary with age and may differ between typically developing children and those with autism and other atypical conditions. Gaining a greater understanding of these issues is important to increasing our understanding of theory of mind itself, the nature of cognitive development, the similarities and differences between typically and atypically developing children, and whether it may be possible to devise interventions to improve theory of mind, either directly or by improving other abilities. The goal of the current Research Topic is to bring together articles on various aspects of theory of mind and any concurrent and longitudinal relationships with other cognitive abilities and characteristics.

This Research Topic includes studies of theory of mind in relation to other abilities in children's development, typical adults, and clinical populations. It includes several studies of the relationships between theory of mind and other characteristics in typically developing children. The other characteristics investigated include working memory, vocabulary, fluid intelligence, and various aspects of social competence and understanding. The studies also include discussion of factors other than theory of mind itself which may influence performance in false belief tasks. Children's theory of mind abilities might be underestimated because of the difficulty they experience with the conversational pragmatics of the tasks or overestimated because they may succeed in tasks by reasoning about perceptual access rather than about beliefs.

Wang and Frye investigate young children's concepts of learning and their associations with theory of mind development. In their first study, 75 children between four and six were asked to judge whether characters had learned something. They tended to attribute learning not only to those who had experienced a genuine knowledge change but also sometimes to those who had not but had experienced accidental coincidences. Their performance in this task correlated both with age and with performance in a false belief task. However, after controlling for age, the correlation between performance in the learning attribution task and in the false belief task ceased to be significant. In another study, 72 children between 40 and 90 months were asked to judge whether story characters intended to learn and whether they eventually learned. Children suggested that story characters over-attributed learning intention to situations where learning occurred without explicit intention (discovery learning and implicit learning) and had difficulty with stories where there was a conflict between the learning intention and the outcome. Once again, their performance in the learning attribution task correlated with their false belief task performance, but the correlation ceased to be significant after controlling for age.

Both Baratgin et al. and Pesch et al. investigate the factors that may cause young children to experience difficulty in theory of mind tasks, coming to somewhat different conclusions. Baratgin et al. investigate the possible role of conversational pragmatics in young children's difficulties with the first-order false belief task. The authors point out that being questioned by a presumably knowledgeable adult about "where Maxi will look for the chocolate" might be interpreted as an attempt to test the child's knowledge about the whereabouts of the object, rather than a question about the protagonist's beliefs. They carried out a study of 62 three-year-olds, who were given the task either in its traditional form or where the human adult was replaced by an "ignorant and slow" robot, to whom the child needed to be a mentor. Performance was significantly better in the robot condition than in the human condition, suggesting that the pragmatic difficulty of the standard task may indeed be affecting children's performance.

Pesch et al. argue that children's performance in false belief tasks may involve their reasoning about a protagonist's perceptual access to a set of events, rather than the protagonist's beliefs (Fabricius and Khalil, 2003). They investigated 85 four- and five-year-olds' performance in traditional and modified false belief tasks, true belief tasks, and one component of executive function: working memory. The modified false belief tasks were more complex than the traditional tasks in that they included three or four options rather than just two. Children performed worse in the true belief tasks and the modified false belief tasks than in the traditional false belief tasks. Moreover, when they failed the modified false belief tasks, they were more likely to select irrelevant options than reality options. Performance in the modified tasks was better when they involved contents rather than location, and working memory was related to performance in contents but not location. The authors conclude that their results support the perceptual access theory.

Aspects of theory of mind continue to develop in later childhood. Rosso and Riolfo investigate the performance of 112 middle-grade children in the Reading the Mind in the Eyes Test and test the relationships between performance in this test and age, sex, family characteristics, receptive vocabulary, and fluid intelligence, as measured on the Raven's Matrices. The Reading the Mind in the Eyes Test did not correlate with any family characteristics. It did correlate with both vocabulary and fluid intelligence, but only fluid intelligence turned out to be a significant independent predictor in multiple regression.

O'Grady and Nag conduct a review of 31 studies of typically developing children, mostly of primary school age, who were trained in social cognitive skills. The reviewed studies do not seek to train children in false belief understanding, which tends to reach the ceiling in typically developing children beyond a very young age. The dependent variables in these studies mapped onto the following ToM constructs in at least 87% of studies: "Representation of Others and/or Self," "Knowledge/Awareness of Mental States," "Attributions/Explanations of Mental States," "Social Competence," "Predicting Behavior," and "Understanding Complex Social Situations." The authors propose a hierarchy that organizes these constructs as either skills or competencies within the construct of "Representation of Others and/or Self."

Individual differences in theory of mind in typical adults are also an important subject. There is no doubt that adults do show significant individual differences in this area, explained in a wide variety of ways by different theorists (e.g., Baron-Cohen et al., 2001; Apperly et al., 2008; Mason and Macrae, 2008; Conway et al., 2019). There has been a significant amount of research into cognitive and personality correlations of such individual differences, but it is investigated in just one study in the present Research Topic.

Török and Kéri investigate relationships between questionnaire measures of mentalization, mindfulness, working memory, and schizotypal personality traits in 300 adults in the general population. They found that, after controlling for mindfulness and working memory, mentalization was negatively correlated with schizotypy and with all its components of unusual experiences, cognitive disorganization, introvertive anhedonia, and impulsive non-conformity. Low mindfulness was an independent predictor of schizotypy, but low working memory was only vaguely related to schizotypy. The authors conclude that weak mentalization is a core feature of schizotypy, independent of mindfulness and working memory.

Several studies in this Research Topic look at people with neurodevelopmental or psychiatric disorders. Autism has been proposed by many researchers over the years, starting with Baron-Cohen et al. (1985), to be closely linked with theory of mind deficits and delays (e.g., Fombonne et al., 1994; Hale and Tager-Flusberg, 2005; Senju et al., 2009; Hoogenhout and Malcolm-Smith, 2017; Altschuler et al., 2018) and, unsurprisingly, features in this Research Topic. Theory of mind abnormalities have also been proposed to be associated with a number of other disorders, including, but not limited to, schizophrenia (e.g., Frith, 1992; Bora et al., 2006), language disorders (Cardillo et al., 2018; Smit et al., 2019), and borderline personality disorder (e.g., Fonagy and Bateman, 2008; Frick et al., 2012; Baez et al., 2015).

Rosello et al. present a study of 52 children with autistic spectrum disorder without intellectual disability and 37 typically developing children. They were given tests on theory of mind and two vocabulary and memory tests. Their mothers answered questionnaires about applied theory of mind abilities, presence and severity of ASD symptoms, adaptive/social skills, and pragmatic competence. A cluster analysis found two groups of children with ASD with "Lower ToM abilities" and "Higher ToM abilities" profiles on all the ToM measures. After controlling for vocabulary and working memory, both groups of children with ASD showed statistically significantly lower applied ToM abilities than the typically developing group. The "Higher ToM abilities" group of children with ASD performed similarly to the typically developing children in the explicit theory of mind task, while the "Lower ToM abilities" group performed significantly worse. The "Lower ToM abilities" group obtained significantly higher scores on autism symptoms and lower scores on adaptive behavior and pragmatic skills than the "Higher ToM abilities" group.

Isaksson et al. investigate theory of mind in autism and other neurodevelopmental disorders within a wider study of cognitive factors that may be associated with theory of mind and genetic and environmental influences on these associations. They carried out a co-twin control study of 311 pairs of twins, 170 of which were monozygotic, with a mean age of 17; 19. There were 134 typically developing pairs and 177 pairs who were concordant or discordant for autism, ADHD, or other neurodevelopmental disorders. They were given the Reading the Mind in the Eyes Test to assess theory of mind, the Fragmented Pictures Test to assess central coherence, The Tower Test to assess executive functioning, and the Wechsler Intelligence Scales to assess IQ. Across pairs, lower IQ and weak central coherence were associated with lower theory of mind performance. Theory of mind performance was higher in older participants and females. It was not associated with executive function. In within-pair analyses, the association between IQ and theory of mind became weaker and the association between central coherence and theory of mind ceased to be significant. This pattern suggests that genetic factors and shared environment may influence the associations between central coherence, IQ, and theory of mind.

Another study looks at dyslexia. Wright and Wright investigate theory of mind in adults with dyslexia, with the aim of studying causal links between linguistic competencies and theory of mind. Dyslexic and non-dyslexic adults were presented with computer-based and non-computer-based vignettes relating to false belief and were asked to answer four types of questions (factual, inference, first-order theory of mind, and second-order theory of mind). In both the computer-based and non-computer-based tasks, dyslexic adults performed worse than non-dyslexic adults in the false belief tasks. However, when given the ToM30Q questionnaire, which makes fewer demands on language and memory, dyslexic and non-dyslexic adults showed no difference in theory of mind. The authors suggest that dyslexic adults, and possibly some other atypical groups, may fail in theory of mind tasks, not because of deficits in theory of mind as such but because of performance limitations caused by weaknesses in language and memory.

Németh et al. assess the executive functions and mentalizing abilities of patients with borderline personality disorder (BPD). Eighteen such patients and 18 healthy controls were tested on IQ, theory of mind (the Reading the Mind in the Eyes Test, and Faux Pas tests), mentalizing about their own emotional states (an alexithymia test), and several domains of executive function. Patients with BPD were impaired compared with controls on the alexithymia measure and the Faux Pas test, but having a BPD diagnosis was a positive predictor of performance in the Reading the Mind in the Eyes Test. Executive functions and IQ predicted performance in the Faux Pas test but were not associated with performance in the Reading the Mind in the Eyes Test or the alexithymia test.

The findings reported in this Research Topic converge in indicating that there are important and quite complex relationships between theory of mind and a wide variety of cognitive characteristics at all ages, in both typically developing individuals and in several developmental and psychiatric disorders. We hope that the findings will inspire yet further research on how such relationships may persist or change with age in both typical and atypical development, the direction of these relationships longitudinally, how they may vary between different disorders, and the extent to which different aspects of theory of mind may show different relationships with other cognitive characteristics. We hope that future studies will provide further insights into whether these relationships differ between typical samples and those with disorders and perhaps thus increase our understanding of whether different disorders should be seen as sharply distinct from typical functioning or as falling on the extreme end of a continuum. We also hope that the findings in this Research Topic, and in future studies that they inspire, may have an impact on the education of typically developing individuals and the treatment of disorders.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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frontiers in Psychology

BRIEF RESEARCH REPORT
published: 14 July 2020
doi: 10.3389/fpsyg.2020.01583

Examining the Relationship Between Executive Functions and Mentalizing Abilities of Patients With Borderline Personality Disorder

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OPEN ACCESS

Edited by:
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University of Pennsylvania,
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Reviewed by:
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University of Turin, Italy
Brian Kavanaugh,
Brown University, United States*

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Specialty section:
*This article was submitted to
Cognitive Science,
a section of the journal
Frontiers in Psychology*

Received: *10 January 2020*
Accepted: *12 June 2020*
Published: *14 July 2020*

Citation:
Németh N, Péterfalvi Á, Czéh B, Tényi T and Simon M (2020) Examining the Relationship Between Executive Functions and Mentalizing Abilities of Patients With Borderline Personality Disorder. Front. Psychol. 11:1583. doi: 10.3389/fpsyg.2020.01583

Patients with borderline personality disorder (BPD) experience interpersonal dysfunctions; therefore, it is important to understand their social functioning and the confounding factors. We aimed to investigate the mentalizing abilities and executive functioning (EF) of BPD patients and healthy subjects and to determine the relative importance of BPD diagnosis and EF in predicting mentalizing abilities while controlling for general IQ and comorbid symptom severity. Self-oriented mentalizing (operationalized as emotional self-awareness/alexithymia), other-oriented mentalizing [defined as theory of mind (ToM)], and several EF domains were examined in 18 patients with BPD and 18 healthy individuals. Decoding and reasoning subprocesses of ToM were assessed by standard tasks (Reading the Mind in the Eyes Test and Faux Pas Test, respectively). Relative to controls, BPD patients exhibited significant impairments in emotional self-awareness and ToM reasoning; however, their ToM decoding did not differ. Multivariate regression analyses revealed that comorbid psychiatric symptoms were negative predictors of alexithymia and ToM decoding. Remarkably, the diagnosis of BPD was a positive predictor of ToM decoding but negatively influenced reasoning. Moreover, EF had no impact on alexithymia, while better IQ, and EF predicted superior ToM reasoning. Despite the small sample size, our results provide evidence that there is a dissociation between mental state decoding and reasoning in BPD. Comorbid psychiatric symptoms could be considered as significant negative confounds of self-awareness and ToM decoding in BPD patients. Conversely, the impairment of ToM reasoning was closely related to the diagnosis of BPD itself but not to the severity of the psychopathology.

Keywords: borderline personality disorder, mentalization, alexithymia, theory of mind, Reading the Mind in the Eyes Test, Faux Pas Test, executive functioning, symptom severity

INTRODUCTION

Borderline personality disorder (BPD) is a psychiatric condition characterized by three symptom clusters including affective dysregulation, impulsivity, and disturbed relatedness (Sanislow et al., 2002). According to the mentalization-based model of BPD (Sharp and Kalpakci, 2015; Fonagy and Luyten, 2016), these features of BPD can be viewed as a consequence of impairments in the capacity to mentalize, i.e., to understand behavior in terms of underlying mental states. According to this theory, mentalization is defined as a multidimensional construct involving several dimensions and abilities. One of these dimensions relates to the objects of mentalizing: it can be directed either toward the mental states of the self or toward the mental states of others.

Impairment of self-oriented mentalizing can be manifested as low levels of emotional self-awareness or alexithymia (Choi-Kain and Gunderson, 2008). Alexithymia is a clinical condition characterized by an inability to identify and describe one's own affective experiences (Taylor et al., 1997). Studies have found that borderline patients are more alexithymic than healthy controls (for a meta-analysis, see Derks et al., 2017) and reported relationships between BPD individuals' alexithymic traits and the severity of their symptoms (e.g., Gaher et al., 2013; McMain et al., 2013). However, to date, no attention has been paid to the potential neurocognitive underpinnings of alexithymia in BPD.

Other-oriented mentalizing can be operationalized as theory of mind (ToM) (Choi-Kain and Gunderson, 2008), a social cognitive function by which we can attribute mental states, such as beliefs, intentions, and emotions, to others (Baron-Cohen et al., 1985). ToM is a multidimensional construct and consists of several subprocesses (Tager-Flusberg and Sullivan, 2000; Sabbagh, 2004). Mental state decoding is the social–perceptual aspect of ToM, which involves the ability to detect and discriminate others' mental states based on their observable social behavior. Mental state reasoning implies the social–cognitive subcomponent, involving causal inferences and predictions about others' mental states based on additional information sources including context and general social knowledge.

Findings on ToM performance in BPD indicate that the decoding and reasoning subprocesses of ToM may be unequally affected by the disorder. Several studies have found that BPD patients exhibited intact or even enhanced ability to decode others' mental states based on facial expressions (Fertuck et al., 2009; Frick et al., 2012; Zabihzadeh et al., 2017). By contrast, other studies have shown that borderline patients perform worse than healthy controls on ToM reasoning tasks (Harari et al., 2010; Brüne et al., 2016), but the severity of their deficit is task dependent (Petersen et al., 2016). It has been suggested that BPD patients' ToM impairment becomes apparent in more complex tasks that require contextual processing and the integration of multiple mental state perspectives (Baez et al., 2015; Petersen et al., 2016). This raises the possibility that the difficulties of BPD patients in ToM reasoning are not due to deficits in their basic ToM abilities but rather to deficits in neurocognitive skills, mainly in executive functioning.

Executive functioning (EF) refers to capabilities that enable flexible and goal-directed responses in novel or complex situations. Through the higher-order monitoring and regulation of cognitive subprocesses, EF plays an important role in the operation of many cognitive functions (Chan et al., 2008). The role of EF in mentalizing abilities is a widely investigated topic in both clinical and non-clinical samples. Regarding emotional awareness, it has been hypothesized that the cognitive systems that are responsible for the higher-level elaboration of emotional experiences are not specialized for emotional processing but rather implement domain-general executive functions (LeDoux, 2000; Lane and Garfield, 2005). This notion implies that executive dysfunction may cause disturbances in emotional self-awareness. Supporting this idea, several studies have found a relationship between poor performance on EF tasks and alexithymic symptoms (e.g., Henry et al., 2006; Santorelli and Ready, 2015).

Concerning the EF–ToM relationship, it has been suggested that these two abilities are implemented by two separate but interacting cognitive systems (Stone and Gerrans, 2006; Aboulafia-Brakha et al., 2011; Wade et al., 2018). According to this view, there are cognitive mechanisms specifically involved in the representation of mental states, but domain-general executive processes are required to efficiently manage and properly apply those representations in complex circumstances. In line with this assumption, many behavioral studies have demonstrated that performance on EF tests shows association with ToM performance, mainly in the case of those complex ToM tasks that have high cognitive load and contextual demands (Aboulafia-Brakha et al., 2011; Ahmed and Stephen Miller, 2011). These results suggest that EF is more strongly related to the reasoning aspect of ToM than to the decoding component.

There is a lack of research on the relationship between mentalizing abilities and EF in BPD. This limitation is particularly striking in studies that have demonstrated structural and functional abnormalities in frontal executive brain areas and impaired behavioral performance on executive tasks in borderline patients (Krause-Utz et al., 2014; McClure et al., 2016). Given this gap in the literature, the present study addressed two objectives. The first aim was to analyze simultaneously the mentalizing and executive profiles of BPD patients by comparing their performance to healthy individuals on tasks assessing different subdomains of mentalization and EF. Our second aim was to perform multivariate analyses to determine the relative importance of BPD diagnosis and EF in predicting alexithymia, as well as ToM performance while considering the potential effects of psychiatric symptom severity and general intelligence.

METHODS

Participants

BPD patients (N = 18) were recruited from the Affective Disorder Unit of the Department of Psychiatry and Psychotherapy, University of Pécs. All patients fulfilled the Diagnostic and Statistical Manual of Mental Disorders, 5th edition (DSM-5) diagnostic criteria for BPD (American Psychiatric Association [APA], 2013). Exclusion criteria for the patient group were any other personality disorder, psychotic disorders, bipolar disorder, posttraumatic stress disorder, current substance use disorder, a history of head injury, neurological diseases, and intellectual disability. Healthy controls (HC, N = 18) were recruited through online advertisements. Exclusion criteria for controls included any mental disorder, a history of substance abuse, a history of neurological disorders, and head injury with loss of consciousness for more than 30 min, an IQ < 85, and any learning difficulties.

All participants lived in the urban and suburban area of Pécs, were Caucasian, and native Hungarian speakers.

The diagnoses were established with structured clinical interviews (SCID-5-CV: First et al., 2016; SCID-5-PD: First et al., 2018). The severity of psychiatric symptoms was assessed with the Symptom Check List-90-Revised (SCL-90-R) questionnaire (Derogatis, 1977; Unoka et al., 2004), and the overall level of intelligence (IQ) was estimated with a four-subtest version of the Wechsler Adult Intelligence Scale-Revised (Kaufman et al., 1991). At the time of the investigations, 17 of the 18 patients were on psychotropic medication. Healthy controls were matched pairwise to the patients for sex, age (±4 years), education (±2 years), and IQ (±5 points). None of the healthy individuals took psychotropic medication. The clinical and demographic data are presented in **Table 1**.

All subjects gave written informed consent, and the study was approved by the Research Ethics Committee of the Faculty of Humanities, University of Pécs (Ethical Approval No.: 2015/1).

Instruments

Executive Function Tasks

Four subdomains of executive functioning (EF) were measured: (1) mental set shifting [with Wisconsin Card Sorting Test (WCST); Berg, 1948]; (2) working memory updating [with Listening Span Task (LST); Daneman and Blennerhassett, 1984; Janacsek et al., 2009]; (3) prepotent response inhibition [with Eriksen Flanker Task (FT); Eriksen and Schultz, 1979]; and (4) long-term memory access [with the Letter Fluency Task (LFT); see Strauss et al., 2006; Tánczos et al., 2014]. The WCST and the FT were computerized tasks taken from the Psychology Experiment Building Language (PEBL) test battery (Mueller and Piper, 2014). The EF variables of interest were the number of perseverative errors on the WCST, the number of words remembered in the LST, the interference time on the FT, and the number of words generated in the LFT. To get a global measure of executive functioning, we calculated an average z score from these four EF variables, which was converted into a t score (= composite EF score).

Mentalizing Tests

The level of emotional self-awareness/alexithymia was surveyed using the total scores of the 20-item self-report Toronto Alexithymia Scale (TAS-20; Bagby et al., 1994; Cserjési et al., 2007).

ToM capacities were examined with two standard ToM tasks. To measure ToM decoding ability, we used the Reading the Mind in the Eyes Test (RMET, Baron-Cohen et al., 2001; Ivády et al., 2007). This task is composed of 36 black-and-white photographs depicting the eye region. For each photograph, four mental state words were displayed, and the participants' task was to decide which one best described what the person in the picture was feeling or thinking. As the RMET requires recognition of others' mental states based on static and socially decontextualized perceptual stimuli, it does not necessitate contextual processing and complex inferences about mental states. Thus, the RMET is regarded as a prototypical task to measure the social–perceptual, decoding aspect of ToM (Sabbagh, 2004; Bora et al., 2006; Richman and Unoka, 2015).

TABLE 1 | Demographic and clinical characteristics of the study samples.

	BPD (n = 18)		HC (n = 18)		t-value	P-value
Demographics						
Gender ratio (female/male)	17/1		17/1			
Age in years (mean ± SD)	34.72 ± 8.02		34.11 ± 9.39		0.210	0.835
Education level in years (mean ± SD)	12.78 ± 3.30		12.89 ± 2.78		−0.240	0.812
IQ estimate (mean ± SD)	109.79 ± 8.22		112.99 ± 8.60		−1.139	0.262
Psychiatric symptom severity						
SCL-90-R GSI (mean ± SD)	2.06 ± 0.66		0.40 ± 0.28		9.769	**<0.001**
SCL-90-R PST (mean ± SD)	66.94 ± 12.24		23.22 ± 12.42		10.639	**<0.001**
SCL-90-R PSDI (mean ± SD)	2.71 ± 0.47		1.48 ± 0.54		7.210	**<0.001**
	n	**%**	***n***	**%**	**Chi square**	***P*-value**
Current comorbid disorders						
Depressive disorders	10	55.5	0	0	13.85	**<0.001**
Anxiety disorders	6	33.3	0	0	7.2	**<0.01**
Substance use disorders	5	27.7	0	0	5.81	**0.016**
Eating disorders	1	5.5	0	0	1.014	**0.31**
Medications						
Antidepressants	11	61.1				
Benzodiazepines	13	72.2				
Mood stabilizers	9	50				
Antipsychotics	16	88.8				

Statistically significant P-values are written in bold. BPD, borderline personality disorder; HC, healthy controls; IQ, intelligence quotient; SCL-90-R, Symptom Check List-90-Revised; GSI, Global Severity Index; PST, Positive Symptom Total; PSDI, Positive Symptom Distress Index; SD, standard deviation.

ToM reasoning was assessed with the Faux Pas Test (FPT, Stone et al., 1998; Gál et al., 2011, 2014). This task consists of 20 short stories about different interpersonal situations that may or may not contain a social faux pas. After each story, participants were asked whether any of the story characters said something awkward. If participants said yes, further questions were raised regarding the characters' cognitive and affective mental states. As a story-based verbal task, the FPT does not involve perceptual processing and requires causal inferences about the characters' mental states on the basis of information provided by the contextual scenes and general social knowledge. Based on these features, the FPT is regarded as an appropriate task to investigate the social–cognitive, reasoning aspect of ToM (Wang et al., 2008; Thoma et al., 2013; Faiśca et al., 2016). (Detailed information about tests used in the study is reported in the **Supplementary Material**).

Statistical Analysis

Between-group differences in demographic, clinical, neuropsychological, alexithymia, and ToM variables were analyzed using independent-samples *t* tests. For EF and mentalizing measures, we calculated Cohen's *d* effect sizes. After the between-group comparisons, assumptions were tested, and multiple linear regression analyses were run in the whole sample. In the regression models, the total scores of TAS-20, RMET, and FPT were separately taken as dependent variables. BPD diagnosis (coded as a dummy variable: 0 = absence of the diagnosis, 1 = presence of diagnosis), SCL-90-R Global Severity Index (GSI), estimated IQ, as well as the composite EF scores were used as predictors in all models. To estimate the effect sizes of the predictors, Cohen's f^2 values were calculated. *P*-values (two-tailed) $\leq$ 0.05 were considered statistically significant.

RESULTS

Between-Group Comparisons

The demographic and clinical features of BPD and HC groups are shown in **Table 1**. The groups were matched in terms of gender, age, education level, and estimated IQ. On the SCL-90-R questionnaire, the BPD group had significantly higher depression, anxiety, and global severity scores than the controls.

Group means and results of between-group comparisons for EF and mentalizing performances are presented in **Table 2**. There were no significant between-group differences in any EF domains. (We found a medium effect size for the composite EF and Inhibition scores, with a trend level significance of between-group difference for the latter one).

Mentalizing Abilities

The BPD group had a significantly higher alexithymia score on the TAS-20 relative to the HC group ($P < 0.001$, Cohen's $d = 1.31$). In our sample, ToM decoding (RMET) performances in the two groups did not significantly differ. However, the BDP group showed a significant impairment in ToM reasoning ($P = 0.026$, Cohen's $d = -0.78$), as demonstrated by their lower mental state inference score on the FPT.

Regression Analyses in the Whole Sample

Alexithymia

The multiple regression model predicting alexithymia was significant, explaining 56.9% of the variance in the TAS-20 scores. The diagnosis of BPD, the estimated IQ, and the composite EF score were non-significant predictors with small-to-medium effect sizes. General psychiatric symptom severity was the only significant predictor in the model ($P = 0.002$, Cohen's $f^2 = 0.36$) (**Table 3**).

ToM Decoding

The multiple regression model predicting ToM decoding accuracy was significant, accounting for 29.2% of the variance in the RMET scores. In this model, BPD diagnosis predicted significantly better performance on the RMET ($P = 0.05$, Cohen's $f^2 = 0.14$). However, greater psychiatric symptom severity was related to significantly worse performance ($P = 0.021$; Cohen's $f^2 = -0.19$). The cognitive variables and IQ were non-significant predictors with small effects (**Table 3**).

ToM Reasoning

The multiple regression model predicting ToM reasoning ability was significant, with 49.8% of the variance in the FPT scores accounted for by the predictors. BPD diagnosis was a significant negative predictor of FPT performance ($P = 0.032$, Cohen's $f^2 = -0.16$). Higher estimated IQ and composite EF scores predicted significantly better performance on the FP ($P = 0.015$, Cohen's $f^2 = 0.21$, and $P = 0.007$, $f^2 = 0.27$, respectively). Only the general symptom severity was a non-significant predictor in this model (**Table 3**).

DISCUSSION

This is the first study to examine the relationship between EF, alexithymia, and ToM in BPD while simultaneously considering the confounding effects of psychiatric symptom severity and general IQ. Our results strengthen the notion that BPD patients' mentalizing subdomains are dissociated: their self-awareness and ToM reasoning were impaired, while their ToM decoding was comparable with those of healthy controls. In a series of multiple regression models, we tested the relative predictive value of EF, IQ, the comorbid clinical symptoms, and the diagnosis of BPD on mentalizing capacities. Comorbid psychiatric symptoms had significantly negative relative importance while predicting self-awareness/alexithymia and ToM decoding. However, the diagnosis of BPD was proved to be a significant negative predictor of ToM reasoning but a positive predictor of decoding. EF and IQ positively influenced BPD patients' ToM reasoning.

The Executive and Mentalizing Profile of BPD

For assessing EF, we adopted theories about the fractionation of EF into different subcomponents (Miyake et al., 2000; Fisk and Sharp, 2004). There were no statistically significant between-group differences in any EF measures. However, BPD patients

TABLE 2 | Executive functions and mentalizing abilities in patients with borderline personality disorder (BPD) and healthy control (HC).

	BPD (*n* = 18)		HC (*n* = 18)		*t*-value	*P*-value	Cohen's *d*
	Mean	SD	Mean	SD			
Executive functions							
Shifting (WCST perseverative errors)[a]	10.61	5.20	8.78	4.91	1.088	0.284	0.36
Updating (LST working memory span)	3.37	0.68	3.65	0.89	−1.046	0.303	−0.35
Inhibition (FT interference time)[a]	43.85	23.74	29.17	25.17	1.800	0.081	0.60
Access (LFT total words)	50.39	15.21	51.78	16.44	−0.263	0.794	−0.09
Composite executive function score	46.62	6.76	50.00	5.65	−1.629	0.113	−0.54
Mentalizing							
Alexithymia (TAS-20 total score)[a]	59.00	12.78	43.67	10.48	3.936	<**0.001***	**1.31**
ToM decoding (RMET total score)	24.67	4.17	25.56	2.77	−0.753	0.457	−0.25
ToM reasoning (FPT total score)	27.78	5.94	31.89	4.55	−2.332	**0.026**	**−0.78**

*Group means and between-group comparisons. BPD, borderline personality disorder; HC, healthy controls; WCST, Wisconsin Card Sorting Test; LST, Listening Span Task; FT, Flanker Task; LFT, Letter Fluency Task; TAS-20, Toronto Alexithymia Scale-20 items; RMET, Reading the Mind in the Eyes Test; FPT; Faux Pas Test; SD, standard deviation.[a]Higher scores indicate worse functioning. Statistically significant results are presented in bold. *Significant after Bonferroni correction. Cohen's d values of 0.2, 0.5, and 0.8 represent small, medium, and large effect sizes, respectively.*

TABLE 3 | Multiple regression models for mentalizing abilities.

Variables	*B*	Std. Error	Beta	*t*-value	*P*-value	Cohen's f^2
Alexithymia[a]						
Constant	73.288	26.942		2.720	0.011	
BPD diagnosis	−5.479	6.694	−0.200	−0.818	0.419	−0.02
Symptom severity	12.797	3.805	0.904	3.363	**0.002**	**0.36**
IQ estimate	−0.308	0.233	−0.187	−1.322	0.196	−0.06
Executive functioning	4.271	3.098	0.196	1.379	0.178	0.06
Theory of Mind decoding[b]						
Constant	25.170	8.749		2.877	0.007	
BPD diagnosis	4.440	2.174	0.640	2.043	**0.050**	**0.14**
Symptom severity	−3.015	1.236	−0.841	−2.440	**0.021**	**−0.19**
IQ estimate	0.014	0.076	0.034	0.187	0.853	0.00
Executive functioning	0.805	1.006	0.146	0.800	0.430	0.02
Theory of Mind reasoning[c]						
Constant	1.224	11.743		0.104	0.918	
BPD diagnosis	−6.559	2.918	−0.592	−2.248	**0.032**	**−0.16**
Symptom severity	2.767	1.658	0.484	1.669	0.105	0.09
IQ estimate	0.262	0.101	0.394	2.577	**0.015**	**0.21**
Executive functioning	3.895	1.350	0.442	2.885	**0.007**	**0.27**

Predictors of mentalizing abilities in the whole sample (n = 36). Cohen's f^2 values of 0.02, 0.15, and 0.35 represent small, medium and large effect sizes, respectively. Statistically significant results are presented in bold. BPD, borderline personality disorder; IQ, intelligence quotient. [a]$F(4,31) = 10.24$, $P < 0.001$. [b]$F(4,31) = 3.19$, $P < 0.026$. [c]$F(4,31) = 7.70$, $P < 0.001$.

performed worse in the inhibition component of EF at a trend level significance ($P = 0.081$, with a medium effect size: Cohen's $d = 0.6$). This trend-level between-group difference is in harmony with prior studies suggesting that deficits in response inhibition may be of central importance in BPD (Posner et al., 2002; Rentrop et al., 2008; Ruocco et al., 2012; van Dijk et al., 2014; Unoka and Richman, 2016). We can presume that the lack of significance was due to the low statistical power resulting from our small sample size.

Similarly to previous studies (for a review, see Derks et al., 2017), we found that BPD patients were significantly impaired relative to controls in their ability to mentalize (recognize and describe) their emotional states. Other-oriented mentalizing was operationalized in our study as ToM. The decoding and reasoning subcomponents of ToM were examined by prototypical tasks, the Reading the Mind in the Eyes Test, and the Faux Pas Test, respectively. Our results indicated that BPD patients' ability to decode others' mental states was preserved. By contrast, patients with BPD were impaired in their ability to reason about the mental states of others, evidenced by a large between-group difference in the number of correct mental state attributions on the Faux Pas Test. These findings replicated the results of several preceding studies and our recent meta-analysis that found similar performance on the RMET but substantially poorer performance on the Faux Pas Test in borderline patients compared to healthy controls (Baez et al., 2015; Petersen et al., 2016; Zabihzadeh et al., 2017; Németh et al., 2018). Our results endorse findings suggesting that the mentalizing profile in BPD is characterized by a dissociation between the decoding and the reasoning subprocesses of ToM.

Factors Influencing Mentalizing Abilities

In our multiple regression model, neither general IQ nor global executive functioning was a significant predictor of alexithymia. Interestingly, not the diagnosis of BPD, but greater severity of comorbid psychiatric symptoms has been proven to be a relative predictor of a higher TAS-20 score. These findings are in line with prior studies (e.g., Loas et al., 2012; Pluta et al., 2018) demonstrating that borderline individuals are more alexithymic than healthy controls; however, this difference can mainly be explained by their comorbid clinical symptoms, especially by depression and anxiety. Although previous research has demonstrated a relationship between executive functioning and alexithymia in various clinical and non-clinical samples (Henry et al., 2006; Bogdanova et al., 2010; Koven and Thomas, 2010; Santorelli and Ready, 2015), our results suggest no relationship between these two abilities in BPD. Nevertheless, our study is the first that investigated this relationship in BPD; thus, further research with an extended number of cases is needed on this topic.

Remarkably, the multiple regression analysis predicting ToM decoding ability demonstrated opposing effects of BPD diagnosis and the severity of psychiatric symptoms. While BPD diagnosis predicted better performance on RMET, greater severity of coexisting psychiatric symptoms was associated with worse response accuracy. Previous studies using the RMET in borderline patients yielded inconsistent results, reporting reduced accuracy (Unoka et al., 2015; Van Heel et al., 2019), enhanced accuracy (Fertuck et al., 2009; Zabihzadeh et al., 2017), or no significant difference (Schilling et al., 2012; Baez et al., 2015) compared to healthy controls. Our findings suggest that the inconsistency of prior studies may be at least partly due to the confounding effect of the severity of psychiatric symptoms.

We found that BPD diagnosis was independently related to worse reasoning performance on the FPT, while psychiatric symptom severity was not a significant predictor in the model. However, both higher general IQ and better global EF were independently related to higher FPT scores. Contrary to our RMET results, here, we found that better EF was related to improved FPT performance. These findings suggest that these two ToM tasks may rely on different mechanisms. With its decontextualized stimuli, the RMET does not require contextual processing and complex reasoning processes. The FPT is a verbal task and requires causal inferences about mental states based on short stories in real-life social contexts. In the FPT, adequate mental state attribution depends not only on the ability to extract relevant information from the context but also on the ability to integrate representations of the characters' mental states. Moreover, FPT also involves linguistic processing and other non-social cognitive skills and imposes additional cognitive load relative to the RMET. Our results suggest that this additional load uses up mainly executive function resources. These findings are in line with previous studies that examined the relationship between EF and ToM using RMET and FPT (e.g., Ahmed and Stephen Miller, 2011; Thoma et al., 2013; Baez et al., 2015; Torralva et al., 2015) and support the notion that the higher-order, reasoning aspect of ToM is more closely linked to domain-general cognitive abilities and prefrontal functioning than the lower-order, decoding component (Tager-Flusberg and Sullivan, 2000).

BPD diagnosis was also independently related to FPT performance in the multiple regression analysis. This negative effect of BPD remained significant in the model even after adjusting for general IQ, global EF, and psychiatric symptom severity. This suggests that mental state reasoning deficit might be a stable characteristic of the BPD. To date, only one study has examined the relationship between EF and ToM in BPD (Baez et al., 2015). Using similar ToM tasks, this research group found deficits both in EF and mental state reasoning in borderline patients. In their multivariate analysis, EF was significantly related to ToM reasoning performance, but BPD diagnosis was not a significant predictor of this ability, suggesting that mental state reasoning deficit is not a core feature of BPD, but is rather a consequence of executive dysfunction. Nevertheless, the small sample size is a major limitation for both studies; the contradictory relationship between EF and ToM in BPD deserves further examination.

Limitations

The main limitation of our study was the low statistical power due to the small sample size. Thus, all of our findings must be treated as preliminary and should be replicated in larger samples. We should very carefully interpret our results especially those with EF. Executive dysfunction was suggested to play an important role in the pathomechanisms of BPD (Fertuck et al., 2006; Sebastian et al., 2014). A recent meta-analysis on neuropsychological functioning in BPD (Unoka and Richman, 2016) found a moderate effect size (Cohen's d = -0.54) for EF impairment, which is the same as that on our composite EF scores. We can assume that our non-significant result in the between-group comparison of EF scores (P = 0.113) is largely due to the low number of cases.

Moreover, no clinical comparison group was included in the study; therefore, we did not investigate whether the detected mentalizing profile and its confounders are specific for BPD. BPD patients were recruited from the acute clinical setting. We did not examine demographic variables such as marital status and employment and did not follow-up on the sample to test how mentalizing abilities, cognitive functions, and comorbid clinical symptoms correlated with the demographic variables related to the functional outcome. Due to the high variability of comorbid psychiatric disorders and the psychotropic medications taken by BPD patients, it was not possible to form homogeneous subgroups to test the effect of these factors. Although a large proportion of our patients were on psychotropic medication (mainly on low-dose atypical antipsychotics), the impact of psychoactive drugs was not examined here. Finally, we only considered the severity of comorbid psychiatric symptoms measured by SCL-90; no other clinical questionnaires were applied.

CONCLUSION

Acknowledging the limitations, the present study provides some important clues for therapy and future research on mentalizing abilities in patients with BPD. Our study presents further evidence that there is a dissociation between ToM decoding and reasoning abilities in BPD. Our results fit well to the theory of Fonagy and Bateman (2008): BPD patients who grow up in a non-reflecting, non-validating, and often abusing family environment develop an increased emotional vigilance to social stimuli, especially to those with negative emotional content. Nevertheless, BPD patients' ToM abilities are just partially developed, since their reflexive awareness is low, and their mental state reasoning abilities are significantly impaired.

Based on our limited results, clinicians should carefully monitor BPD patients' comorbid psychiatric symptoms and consider that comorbid symptoms can negatively impact the patients' self-awareness and mental state decoding abilities. Conversely, impairment in mental state reasoning appears to be a core feature of BPD, but better IQ and EF can positively influence this deficit. However, regarding the low number of cases in our present study, further research is necessary to test our data in a larger sample.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Research Ethics Committee of the Faculty of Humanities, University of Pécs. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

NN and TT conceived the study and designed the experiments. NN collected and analyzed the data and drafted the manuscript. ÁP helped with the interpretation of data and writing of the manuscript. MS selected the patients, made the diagnosis, and revised the manuscript for publication. MS and BC raised funding and provided supervision and had helpful comments on the interpretation of the data. All authors contributed to the writing of the manuscript and/or revising it critically for important intellectual content. All authors approved the final version to be published and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

FUNDING

This work was financially supported by the following grant agencies: Hungarian Brain Research Program (2017-1.2.1-NKP-2017-00002) and EU Social Fund (EFOP-3.6.3-VEKOP-16-2017-00009). Further financial support was received from the Medical School of the University of Pécs. These grant agencies had no influence on study design; on the collection, analysis, and interpretation of data; on the writing of the report; and on the decision to submit the article for publication.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2020.01583/full#supplementary-material

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

ORIGINAL RESEARCH
published: 17 September 2020
doi: 10.3389/fpsyg.2020.567401

Theory of Mind Profiles in Children With Autism Spectrum Disorder: Adaptive/Social Skills and Pragmatic Competence

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Theory of Mind (ToM) is one of the most relevant concepts in the field of social cognition, particularly in the case of Autism Spectrum Disorders (ASD). Literature showing that individuals with ASD display deficits in ToM is extensive and robust. However, some related issues deserve more research: the heterogeneous profile of ToM abilities in children with ASD and the association between different levels of ToM development and social, pragmatic, and adaptive behaviors in everyday life. The first objective of this study was to identify profiles of children with ASD without intellectual disability (ID), based on explicit and applied ToM knowledge, and compare these profiles with a group of children with typical development (TD). A second objective was to determine differences in symptom severity, adaptive/social behavior, and pragmatic abilities between the profiles identified. Fifty-two children with a clinical diagnosis of ASD without ID and 37 children with TD performed neuropsychological ToM tasks and two vocabulary and memory tests. In addition, all of their mothers completed different questionnaires about applied ToM abilities, severity of ASD symptoms, adaptive/social skills, and pragmatic competence. Two subgroups were identified in the cluster analysis carried out with explicit and applied ToM indicators. The "Lower ToM abilities" profile obtained significantly lower scores than the "Higher ToM abilities" profile on all the ToM measures. Furthermore, the analysis of covariance, controlling for vocabulary and working memory (ANCOVAs), showed statistically significant differences in applied ToM abilities between the two groups of children with ASD without ID and the group with TD. However, only the group with "Higher ToM abilities" achieved similar performance to the TD group on the verbal task of explicit ToM knowledge. Finally, the "Lower ToM abilities" cluster obtained significantly higher scores on autism symptoms (social and communication domains) and lower scores on adaptive behavior and pragmatic skills than the cluster with "Higher ToM abilities." Taken together, these findings have implications for understanding the heterogeneity in ToM skills in children with ASD without ID, and their differential impact on social, communicative, and adaptive behaviors.

Keywords: autism, adaptative skills, theory of mind, social, pragmatic competence

OPEN ACCESS

Edited by:
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Osaka Shoin Women's University, Japan

Reviewed by:
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University of Turin, Italy
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Specialty section:
This article was submitted to Cognitive Science, a section of the journal Frontiers in Psychology

Received: *29 May 2020*
Accepted: *20 August 2020*
Published: *17 September 2020*

Citation:
Rosello B, Berenguer C, Baixauli I, García R and Miranda A (2020) Theory of Mind Profiles in Children With Autism Spectrum Disorder: Adaptive/Social Skills and Pragmatic Competence. Front. Psychol. 11:567401. doi: 10.3389/fpsyg.2020.567401

INTRODUCTION

The Theory of Mind (ToM) is a broad, complex, and multifaceted construct, defined as the ability to attribute mental states (beliefs, desires, intentions) to oneself and to others, making it possible to explain and predict behavior (Premack and Woodruff, 1978). For decades, authors have argued that ToM deficits are prevalent in Autism Spectrum Disorder (ASD) (Baron-Cohen et al., 1985), a neurodevelopmental condition characterized by persistent communication and social interaction difficulties, restricted interests, and the presence of repetitive behaviors (American Psychiatric Association, 2013). Robust empirical findings confirm these ToM impairments in ASD (Kimhi, 2014), based on inferior performance on assessment tasks.

Autism Spectrum Disorders has a very heterogeneous range of symptoms with varying degrees of severity. Similarly, performance on tests assessing ToM skills is not uniform either. A key factor influencing this variability has to do with the ToM component being assessed and the type of task used for this purpose. Research currently supports the subdivision of ToM into implicit and explicit components that describe different aspects of social stimulus processing (Frith and Frith, 2012). On the one hand, explicit ToM skills refer to a conceptual, logical, and controlled ToM knowledge, which is distinguished by sequential and conscious processing (Satpute and Liberman, 2006; Frith and Frith, 2012). Tasks with clear instructions such as classic first- and second-order false beliefs would be paradigmatic examples of procedures for evaluating this explicit component. On the other hand, the implicit component of the ToM acts quickly, spontaneously, and unconsciously. It allows the correct anticipation of behavior without a deliberate reflection on the mental state of the other. In this regard, the tasks involving the categorization of facial expressions according to the emotion expressed are methods for evaluating implicit competence.

Explicit and Applied Theory of Mind in ASD

In general, research has found that people with ASD without intellectual disabilities (ID) tend to perform better on explicit ToM tasks (Happé, 1995; Senju, 2012, 2013). This has been demonstrated through the use of standard first- and second-order false belief tests (Dahlgren and Trillingsgaard, 1996; Baron-Cohen, 2001; Cantio et al., 2018), and even with complex, advanced-level tasks (e.g., Director Task), where adolescents with ASD have been found to perform on par with the typically developing (TD) group (Barendse et al., 2018). In contrast, performance was significantly lower on tasks of an implicit nature, such as those based on facial emotion perception and categorization without the aid of contextual cues (Harms et al., 2010; Uljarevic and Hamilton, 2013; Lozier et al., 2014; Schaller and Rauh, 2017), free verbal judgments about social situations (Callenmark et al., 2014), or gaze patterns, assessed by eye-tracking, which reflect spontaneous attributions of false beliefs (Zhou et al., 2019).

A question that has been widely discussed in research is whether, regardless of the type of task and the ToM component assessed, there is a clear discrepancy between the performance of people with ASD on 'laboratory' measurements and their application of ToM in natural everyday environments (Senju et al., 2009; Scheeren et al., 2013). Hutchins et al. (2016, p. 98) defined applied ToM as "the ability to deploy ToM knowledge to successfully address ToM dilemmas as they are presented in real-world samples of behavior." It has been observed, for example, that people with ASD can succeed on false belief tasks, but they fail when they have to act spontaneously based on this knowledge, i.e., when they have to demonstrate applied ToM (Senju, 2012; Livingston and Happé, 2017).

There could be several reasons for this discrepancy in the results. Undoubtedly, real-life situations are more complex and dynamic in terms of information processing. As Hutchins et al. (2016, p. 98) highlighted, "applied ToM competence is ostensibly affected by a variety of endogenous (e.g., executive functioning, motivation, and sensitivity) and exogenous (e.g., physical setting) factors." Clearly, during everyday social interactions, people with ASD are exposed to a continuous stream of ToM challenges with varying demands. The social cues are more unpredictable and ambiguous, and they take place under time pressure with limited information and cognitive resources. The large number of verbal and non-verbal contextual cues make them difficult to process automatically, causing congestion that acts as a bottleneck in the processing of social stimuli. This problem is compounded by social patterns that have not been adequately developed (Schaller and Rauh, 2017). These difficulties with applied ToM are consistent with findings showing that training in the attribution of mental states in formal situations does not necessarily guarantee better social adaptation of people with ASD (Begeer et al., 2011; Senju, 2013). For this reason, procedures for the assessment of mental skills have been designed with greater ecological validity, attempting to capture the application of ToM to the real world in everyday life. Questionnaires such as the "Theory of Mind Inventory" (ToMI) (Hutchins et al., 2011) have made it possible to identify disorders in children with ASD with larger effect sizes than those obtained from the administration of explicit proficiency tests (Berenguer et al., 2018).

Another reason for the inconsistent findings may be the use of measures that have been designed to assess a broad spectrum of ToM skills, ranging from understanding basic mental states to skills at a more advanced level of development (Steele et al., 2003). The controlled condition where the assessment is conducted would also influence the results. Thus, the use of simple structured tasks with explicit instructions and limited options decreases the social cognition demands, which would favor successful results. Other possible sources of variability in ToM results in ASD would be cognitive ability, given that ToM is a meta-representational skill dependent on general domain cognitive skills (Pellicano, 2010; Pruett et al., 2015), or even other deficient processes in ASD, such as executive functions (Miranda et al., 2017; Demetriou et al., 2018). It has also been documented that ToM task performance is closely related to language skills, particularly receptive vocabulary and complementation syntax (Tager-Flusberg, 2001). Language proficiency would act as a compensatory mechanism to facilitate task achievement, but it would not imply the mastery of genuine and mature ToM.

ToM and Adaptive/Social Skills

In general, ToM skills, the ability to share feelings, exchange ideas, and anticipate others' behavior, are essential for social life (Zhou et al., 2019). Successful social functioning requires an understanding of other people's emotions, intentions, beliefs, and knowledge. However, although deficits in mind-reading skills may reasonably explain, at least in part, the social difficulties experienced by people with ASD, research findings are inconsistent.

Pioneering studies such as the one by Fombonne et al. (1994) sought precisely to describe the associations between adaptive social skills, assessed by parental reports on a subset of items from the Vineland Adaptive Behavior Scales (Sparrow et al., 1984), and performance on false belief tasks. Specifically, in the study by Fombonne et al. (1994), participants who succeeded in overcoming social cognition tasks were older, showed higher intellectual ability, and performed better on social and adaptive behaviors involving understanding minds. However, when their verbal ability was taken into account, these specific differences were no longer significant.

Later, other studies using measures of social understanding (false belief understanding, affective perspective-taking) and measures of social responsiveness and social interaction (level of engagement with peers on the playground and prosocial behavior in a structured laboratory task) found that, in children with autism, initiating joint attention and empathy were strongly related to both measures of social interaction competence (Travis et al., 2001). Similar results were obtained when using teachers' ratings of peer interaction skills, which showed a significant correlation with the scores obtained on false belief tasks by children with ASD (Peterson et al., 2007).

To the same end, Tager-Flusberg (2001) applied a battery of various ToM tasks (including symbolic play, moral judgment, and false belief) to a large sample of participants with ASD, and they found a significant association between ToM skills and social competence, again assessed with the Vineland social scale (Sparrow et al., 1984). More recently, Bishop-Fitzpatrick et al. (2017), in a cross-sectional study, showed that better performance on second-order false belief tasks was associated with better socio-adaptive behavior and fewer social problems. Mazza et al. (2017), using mediation analysis, warned that ToM plays a key role in the development of social skills, and that the lack of ToM competence in children with autism alters their competent social behavior. Thus, they concluded that the ability to understand emotions and beliefs is necessary in order to display appropriate social behavior. Finally, Altschuler et al. (2018) reported a positive relationship between affective ToM (ability to infer other people's emotions) and social symptoms characteristic of ASD. In other words, affective ToM predicted the severity of social symptoms, but not social functioning in a broad sense. In the same study, no type or level of ToM (basic or advanced) was able to predict the social behavior described by the parents.

Not all research has identified this positive association between ToM and social competence. For example, Prior et al. (1990) could not find a relationship between performance on false belief tasks and caregivers' estimates of the social skills of their children with autism. Similarly, although in Joseph and Tager-Flusberg's (2004) study, ToM and executive functions could explain significant variance on the Communication section of the ADOS-G (Lord et al., 2000), this effect did not occur in the Social Interaction section. That is, the executive functions and the ToM were more strongly associated with communicative functioning than with social functioning. Moreover, it has been possible to identify a subgroup or profile of individuals with ASD who, in spite of manifesting continuous difficulties in understanding the mind of the other, exhibited few social affectation symptoms (Livingston et al., 2019). This subgroup, called "high compensators," presented characteristics such as a higher verbal intelligence quotient (IQ) and better executive functioning skills, among other features.

In addition, in longitudinal studies like the one by Bennett et al. (2013), although language, non-verbal IQ, and ToM predicted a relatively small but significant amount of variance in adaptive functioning, ToM was not uniquely predictive of variance in adaptive socialization in early adolescence after controlling for IQ. Nor was this predictive power of ToM found in the study by Peterson et al. (2016), who noticed that neither language ability nor ToM directly predicted peer social skills.

The inconsistency in the results seems to indicate that ToM is necessary but not sufficient to explain social competence. Therefore, an attempt has been made to identify other factors that, along with ToM skills, can better justify social functioning deficits in ASD. Thus, studies have shown that ToM competence combined with pragmatic language skills can predict and directly and indirectly influence the socialization of children with ASD without intellectual disabilities (Berenguer et al., 2018). These relationships are to be expected, given the profile of vulnerability that children with ASD present in the pragmatic area, a universal deficit in the disorder (Lam, 2014).

ToM and Pragmatic Ability in ASD

Theory of Mind and the pragmatic dimension of language are closely intertwined, and several findings from different approaches support this relationship. From a developmental perspective, it has been raised that ToM and pragmatics are co-evolved functions (Westra and Carruthers, 2017). From a psycholinguistic framework, no account can be given of key pragmatic notions like indirect speech acts, deictic expressions, presuppositions, pronoun reference or irony, in the absence of the involvement of ToM (Cummings, 2013). Finally, from a neurobiological point of view, a significant overlap has been found between the neural basis of ToM and that of narrative comprehension (Mar, 2011), which is directly related to pragmatic skill (Botting, 2002). All these arguments have led to conclude that "ToM and pragmatic aspects of language are so fused that they cannot be separable" (Kobayashi, 2018, p. 118). In this regard, O'Neill (2012) established a pragmatic taxonomy in which "mindful pragmatics" was considered, that is, the uses of language that require adopting the perspective of the listener, such as engaging in a conversation or elaborating a speech. In both situations, the information needs of the receiver must be monitored and adapted to his/her perspective. Ultimately, the correct interpretation of the intentions and beliefs of the interlocutor in relation to the context is absolutely essential for good development of pragmatic communication.

Although still scarce, most studies on the subject demonstrate a significant association between mind-reading skills and pragmatic competence. Thus, correlations have been found in children with autism – but not in children with developmental delay – between performance on ToM tasks and the ability to respond to a conversational partner with new, relevant, and contingent information (Capps et al., 1998). The same significant association has been found between understanding of first-order false belief tasks and various narrative properties, such as the use of evaluative statements (Capps et al., 2000) and referential cohesion (Kuijper et al., 2015). Specifically, in relation to discourse, longitudinal studies have found that ToM contributed unique variance in discourse skills beyond the contribution of language competence (Hale and Tager-Flusberg, 2005). Furthermore, a mediating role of ToM has been identified in the association between language ability at the age of 6–8 years and adaptive communication measured 6 years later, which suggests that "structural language (grammar and vocabulary), ToM and later adaptive communication are related over the course of development in children with ASD" (Bennett et al., 2013, p. 17).

Symptom Severity and ToM

Research has shown an association between greater ToM deficits and ASD symptom severity in terms of social communication difficulties and restricted and repetitive behaviors. A study by Shimoni et al. (2012) found that clinical assessment of autistic symptoms in children with Asperger Syndrome/High Functioning Autism was negatively correlated with ToM measures, obtained through The Social Attribution task (SAT) (Klin, 2000). Statistically significant correlations were found for the Pertinence and Salience indices, and for measures of the ADI-R (Rutter et al., 2006). In other words, more autistic symptoms were related to more non-pertinent propositions and fewer social elements identified.

Subsequently, Hoogenhout and Malcolm-Smith (2017), using hierarchical cluster analysis, determined that ToM skills were capable of reliably discriminating ASD severity levels, and the three clusters they identified (severe, moderate, and mild ASD) were strongly associated with the level of support required, as indicated by the type of school environment. These results agree with those reported by Aljunied and Frederikson (2011), who found that a ToM index, combined with IQ measures, contributed significantly to the categorization of children with ASD in three types of educational support. Particularly, for children with less severe needs, those who did not need any additional support were differentiated from those who did by ToM measures.

Finally, using structural equation modeling, and accounting for ToM and executive functions (EF) in one model, Jones et al. (2018) established that mind-reading difficulties were associated with more severe social communication symptoms and restrictive and repetitive behaviors, in adolescents with ASD. It is noteworthy that the strength of associations between social communication and ToM and between restrictive and repetitive behaviors and ToM were similar. This last finding contrasts with the results of other studies that did not find any significant correlation between ToM and restrictive and repetitive behaviors (Joseph and Tager-Flusberg, 2004; Cantio et al., 2016). These inconsistencies are explained according to the procedure used to evaluate the behavior symptomatology, mainly through observation or parent-interview. In contrast, Jones et al. (2018) used a targeted questionnaire designed to gather information about the breath of restricted and repetitive behaviors observed in ASD. It is concluded that "a bewildering social world due to impoverished mentalizing abilities could lead to that kind of behaviors that lessen anxiety and reduce confusion" (Jones et al., 2018, p. 103). Consequently, impairments in understanding the social world could promote the emergence of idiosyncratic and unusually intense interests and repetitive behaviors.

In summary, ToM is a complex construct that has not been used consistently in research, which has led to considerable variability in the evaluation tasks and mixed literature results. It is likely that the divergent results at least partly depend on the assessment demands and the cognitive level of the individuals being assessed. Therefore, measures of explicit ToM competence and applied ToM competence, along with different levels of ToM skills and cognitive levels, should be taken into account to identify more homogeneous profiles. A cluster analysis may be an appropriate methodology to establish different profiles of mind-reading skills within ASD when attempting to analyze the relationships between ToM and other common difficulties in this disorder, such as pragmatic difficulties or social adjustment problems.

Consequently, the first objective of this study was to identify profiles of children with ASD without intellectual disability (ID), based on explicit and applied ToM knowledge, comparing these profiles with a group of children with typical development (TD). We hypothesize that the profiles identified in children with ASD will differ on ToM skills of different types (explicit and applied), and that these children, even the best performing profile, will have a lower level of development than the TD group. A second objective was to examine differences in ASD symptom severity, social and adaptive behavior, and pragmatic abilities among the identified profiles. We expect that, based on the central role of ToM deficits in ASD, the profile with lower ToM abilities will show more severe symptoms and lower socio-adaptive and pragmatic skills.

MATERIALS AND METHODS

Participants

This study included 52 children with ASD without intellectual disability (ID) and 37 children with typical development (TD). The two groups of children were between 7 and 11 years old, and they had an intellectual functioning within the limits of normality on the K-BIT (Kaufman and Kaufman, 2000).

The group of children with ASD had received a clinical diagnosis of an autism spectrum condition in hospitals and medical centers by Psychiatry and Child Neurology services in the Valencian community at ages ranging between 2 years and 11 months and 6 years old. According to the protocol for the ASD diagnosis, the Diagnostic and Statistical Manual of Mental Disorders criteria for ASD from the fourth edition (DSM-IV; American Psychiatric Association, 1994), the Autistic Diagnostic Interview—Revised (ADI-R; Rutter et al., 2006), and/or the Autism Diagnostic Observation Schedule-WPS (ADOS-WPS; Lord et al., 1999) were administered by a multidisciplinary team. In order to confirm the ASD diagnosis for the present study, the Social Communication Questionnaire (SCQ; Rutter et al., 2003) and the Autism Diagnostic Interview-revised (ADI-R; Rutter et al., 2006) were administered, taking into account the recommended cut-off points. These two instruments were administered to the parents by a clinical psychologist from the research team who had been accredited in their application. Likewise, all the children met the strict diagnostic criteria for ASD from the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association, 2013), based on information reported by teachers and parents. Both informants, through interviews with a clinical psychologist, rated the severity of the criteria in the two ASD dimensions on scales ranging from 0 to 3 points (0 represents "almost never," 1 "sometimes," 2 "often," and 3 "many times").

Regarding the school modality, three children with ASD (5.8%) were attending school in regular classrooms full time without educational support; 29 children (55.7%) attended regular classrooms but received educational support for their specific needs in the school; and finally, 20 children (38.5%) were placed in the Communication and Language classroom modality. In other words, according to the DSM-5 (American Psychiatric Association, 2013), the support required by the participants corresponded to level 1 severity. Furthermore, 32.7% of the children with ASD were taking antipsychotic medication (mostly risperidone) for behavioral problems and irritability symptoms.

The typically developing children were in the same schools as the clinical sample in the study. They had no history of psychopathology or referral to pediatric mental health units (USMI), according to the information found in the school records, and they did not meet DSM-5 criteria for ASD on the screening carried out before beginning the evaluation. None of them was taking any psychoactive medication.

The exclusion criteria for the children who participated in this study were evaluated through an extensive anamnesis carried out with the families. They included neurological or genetic diseases, brain lesions, sensory, auditory, or motor deficits, and an IQ below 80.

Both groups of children, with ASD and with TD, were matched on age [$t(89) = -0.15$, $p = 0.88$], IQ [$t(89) = -0.28$, $p = 0.78$], and their level on a Vocabulary subtest from the WISC-IV (Wechsler, 2003) [$t(89) = -1.04$, $p = 0.30$].

Measures

The selection of the measures used was primarily based on the following criteria: utility and relevance according to the objectives of this study, translation and adaptation to Spanish and good psychometric properties.

Explicit and Applied ToM Knowledge

The subtests of Affect Recognition and Theory of Mind, which are included in the Social Perception domain of the NEPSY–II (A Developmental Neuropsychological Assessment Battery, Korkman et al., 2007), were administered to all the children to assess their explicit ToM knowledge. The first subtest, Affect Recognition (AR), aims to evaluate the ability to identify emotions (happy, sad, anger, fear, disgust, and neutral emotion) through photographs of children's faces. The second subtest, Theory of Mind, contains two parts. The first part (verbal task) includes 15 items that assess the subject's ability to understand beliefs, intentions, thoughts, and feelings that are different from their own. The child is read various scenarios or shown pictures, and s/he is then asked to correctly answer questions that require knowledge about another individual's point of view. The second part (contextual task) includes 5 items that assess the subject's ability to put him/herself in the place of one of the characters and think about what s/he is feeling in a situation represented in a drawing. The child is shown a picture depicting a social context and asked to select one photograph from four options that depicts the appropriate affect of one of the people in the picture. Higher scores on both Nepsy-II tests indicate greater development of theory of mind skills. Many studies have reported reliability data for all the scales, and there is also evidence of convergent and discriminant validity of the NEPSY battery (Korkman et al., 2007).

To evaluate the application of ToM skills, the parents completed the Theory of Mind Inventory (ToMI; Hutchins et al., 2014; Spanish adaptation by Pujals et al., 2016). It comprises 42 items distributed in three scales, and each item is scored from 0 to 20 points, with 5 response alternatives ranging from "definitely not" to "definitely." The early subscale assesses skills for understanding basic emotions. The basic subscale includes understanding mental terms and the distinction between physical and mental representations. Finally, the advanced subscale, which was used in this study, assesses second-order beliefs (i.e., "My child understands that people can be wrong about what other people want") and competence in understanding inferences and complex social judgments (i.e., "My child understands the difference between a friend teasing in a nice way and a bully making fun of someone in a mean way"). High scores indicate good perception in the development of theory of mind skills. The ToMI has adequate validity, good internal consistency, and test-retest reliability. It has also shown excellent sensitivity (0.90) and specificity (0.90) (Hutchins et al., 2011; Pujals et al., 2016).

Psychological and Behavioral Adjustment

The SDQ questionnaire (SDQ-Cas-Goodman, 1997; adapted to Spanish by Rodríguez-Hernández et al., 2012) was filled out by the parents to assess a broad range of mental health symptoms. It contains a total of 25 items grouped in five subscales (emotional symptoms, behavioral problems, hyperactivity/attention problems, peer relationship problems, and prosocial behavior problems). Specifically, four of the five subscales are scored in a similar way, with higher scores indicating a greater likelihood of significant problems, whereas the prosocial subscale provides a reverse score where higher scores indicate more prosocial behaviors or strengths. In this study, we used the subscale of peer relationship problems, which contains 5 items (i.e., "Rather solitary, tends to play alone), and the subscale of prosocial behavior, which also has 5 items (i.e., "Helpful if someone is hurt, upset, or feeling ill").

The SDQ has shown good statistical and psychometric properties, with Cronbach's alpha values above 0.70 (Goodman, 2001), confirmed in the Spanish population (0.76) (Rodríguez-Hernández et al., 2012). It also obtained acceptable to high internal consistency in the current study (Cronbach's α = 0.74–0.80 between subscales).

Adaptive/Social Skills

The Vineland Adaptive Behavior Scale (VABS-II ed; Sparrow et al., 2005) was filled out by parents to evaluate the adaptive capacity of their children. It includes four fundamental domains: communication, daily living skills, socialization, and motor skills. It has another domain that extracts an index of maladaptive behavior. For this study, the scores in two domains were used, daily living skills and socialization skills. Daily living skills describe personal (e.g., eating, dressing, and hygiene), domestic (e.g., household tasks performed), and community (e.g., using money, answering the phone) tasks, and the socialization scale also includes three subscales that describe interpersonal relationships, play and leisure time, and coping skills.

The Vineland-II scale has been widely used in people with ASD to evaluate social maturity. It has solid psychometric properties, with high test-retest reliability (α = 0.98) (Sparrow et al., 2005).

Pragmatic Abilities/Pragmatic Competence

The Children's Communication Checklist (CCC-2; Bishop, 2003) provides information about communication characteristics in subjects from 4 to 11 years old. The frequency of the behaviors described in each item included in the CCC-2 is rated on a 4-point scale; a high score indicates greater communication problems. In addition, the 70 items included in the CCC-2 are grouped in 10 subscales that measure different communicative aspects. The first block assesses the structural aspects of language and has four subscales (*speech*, *syntax*, *semantics*, and *coherence*). The second block evaluates the pragmatic aspects of language and also has four subscales (*inappropriate initiation*, *stereotyped language*, *use of context*, and *non-verbal communication*). Finally, the last block contains two subscales designed to evaluate the typical features of ASD (*social relationships and interests*). In the present study, we used the pragmatic composite index (PCI), which is obtained by adding together the scores on the coherence, inappropriate initiation, stereotyped language, use of context, and non-verbal communication subscales. This specific grouping, although not contemplated in the CCC-2, has been used in other previous studies (Helland, 2014). The CCC-2, which in this study was filled out by the parents, presents good internal consistency that ranges between 0.66 and 0.80 (Bishop, 2003).

Severity of ASD Symptoms

The severity of ASD symptoms was assessed with the Social Communication Questionnaire (SCQ; Rutter et al., 2003), which is based on a semi-structured parent interview used for the diagnostic evaluation of children with suspected ASD. It provides information about three domains of autistic symptoms: reciprocal social interaction (i.e., "Does your son/daughter have specific friends or a close friend?"); communication (i.e., "Can you have a conversation with him/her that flows both ways and requires taking turns speaking or elaborating on what was said before?"); and restricted/repetitive behaviors (i.e., "Has s/he ever shown more interest in the parts of a toy or object [for example, turning the wheels on a car] than in using the toy itself?"). The SCQ has good psychometric properties (Cronbach's alpha of 0.84–0.93 across age groups and a Cronbach's alpha of 0.81–0.92 across diagnostic groups) (Rutter et al., 2003). In this study, the Cronbach's alpha for the questionnaire was 0.78, which is similar to what Rutter et al. (2003) reported.

Procedure

This research was performed in accordance with the ethical standards of the Research Ethics Committee of the University of Valencia, which is regulated by Ethical Principles for Medical Research Involving Human Subjects (Declaration of Helsinki 1964, World Medical Association, 2013). Likewise, it received authorization from the Board of Education of the Valencian Government to access the schools and locate the participants.

The evaluation was carried out in the schools where the children were enrolled, in specially prepared spaces that met optimal conditions for psychoeducational assessment. The informed oral and written consent of the parents of all the participants was also obtained after informing them about the research proposal. The children were evaluated during school hours, without interfering with the basic curricular activities. The intelligence test and the two tests from the social perception domain were administered to all the children individually by trained examiners. The parents (mostly mothers) provided information about their children's ToM skills in daily life contexts, ASD symptoms, and adaptive/social skills. The teachers-tutors filled out the questionnaire selected to assess EF.

Data Analyses

The statistical analyses were performed with the statistical program for the Social Sciences [SPSS v 24.0 (SPSS)]. Preliminary analyses checked all data for multicollinearity and multivariate outliers. The asymmetry and kurtosis data indicate that most of the variables followed a normal distribution (all values between −1 and 1). Variables that did not show a normal distribution were transformed using square-root transformation.

To examine distinct profiles (i.e., subgroups) of Theory of Mind abilities in ASD, we performed hierarchical cluster analysis. The input for this analysis included three variables from the social perception domain of the NEPSY-II battery: Emotion recognition, Verbal task of ToM, and Contextual task of ToM; and three variables from the Theory of Mind Inventory (ToMI): Early scale, Basic scale, and Advanced scale. Moreover, the variables were standardized to z-scores.

We evaluated hierarchical clustering using multiple internal validity measures. Specifically, we varied the number of clusters from two to three, and the optimal N-cluster solution was determined on the basis of visual inspection of the dendrogram figure and the agglomeration coefficients.

Additionally, we also carried out the same procedure with non-hierarchical clustering, namely, *K*-means, because this procedure allows us to specify the number of clusters in advance. Lastly, in order to fit the optimal cluster analysis solution, we used the variance ratio criterion (VRC) for each selected cluster. The VRC refers to the ratio of the 'within variance' (variance explained by the typology) and 'between variance,' corrected for the number of clusters and responses. The two-cluster solution seemed to be optimal in the hierarchical cluster analysis, based on Ward's method, and the VRC showed a lower score for two solutions (Cohen-Addad et al., 2019).

After analyzing the resulting dendrogram and data, the decision was made to group the children in two clusters, controlling for vocabulary and working memory (ANCOVAs). We labeled each of the ASD subgroups based on the patterns of functioning across domains of ToM abilities. Then we checked the possible differences between the Clusters obtained and a control group with TD.

Finally, one-way analyses of variance (ANOVAs) were conducted to determine the differences between the children in the cluster groups on the following measures: the Strengths and Difficulties Questionnaire- SDQ (Peers problems and Prosocial scale); the Vineland Adaptive Behavior Scales-VABS-II (Daily life skills and Socialization domains); the Children's Communication Checklist -CCC-2 (Pragmatic Index); and the Social Communication Questionnaire-SCQ (Social, Communication, and Stereotyped behavior scales). For the ANOVAs, the level of significance was set at $p < 0.004$, after applying the Bonferroni correction. The proportion of total variance accounted for by the independent variables was calculated using partial eta squared [according to Cohen (1988): eta squared, 0.06 = small; 0.06–0.14 = medium, 0.14 = large].

RESULTS

Profiles of Children With ASD Without Intellectual Disability (ID) Comparison of Profiles With Children With Typical Development (TD)

The first goal of the analysis was to examine whether children with ASD were more likely to cluster into a single group or multiple groups on the basis of measures of ToM skills.

Results from the hierarchical cluster analysis with the children's ToM abilities determined an optimal number of clusters in two groupings, distinguished by the tendency of their scores on the variables included in the analysis: TOM explicit knowledge (emotion recognition, verbal, and contextual ToM) and applied knowledge (Early, Basic, and Advanced ToMI). Cluster 1 (n = 22; 42.30%) presented higher scores on all the variables of theory of mind skills, on both applied ToM abilities and explicit ToM abilities. By contrast, Cluster 2 (n = 30; 57.69%) showed lower scores than Cluster 1 on all the ToM skills measured.

Analyses of covariance, controlling for vocabulary and working memory (ANCOVAs), were then conducted to determine the significant differences between the two clusters in the theory of mind skills considered. After applying Bonferroni correction, children classified in Cluster 1 obtained scores that were statistically different from Cluster 2 on most of the measured variables, with the comparisons showing moderate to large effect sizes on Verbal ToM and Early, Basic, and Advanced ToMI: Verbal-ToM, $F_{1,50} = 50.39$, $p < 0.001$, $\eta_p^2 = 0.50$; 001; Early-ToMI, $F_{1,50} = 19.25$, $p < 0.001$, $\eta_p^2 = 0.28$; Basic-ToMI, $F_{1,50} = 44.11$, $p < 0.001$, $\eta_p^2 = 0.47$; Advanced-ToMI, $F_{1,50} = 9.99$, $p < 0.001$, $\eta_p^2 = 0.16$. The differences between the two groups did not reach statistical significance after applying the Bonferroni correction on the effect sizes for Emotion Recognition ($\eta_p^2 = 0.09$) and the contextual ToM task ($\eta_p^2 = 0.11$).

Based on the described patterns of functioning across domains of ToM abilities, Cluster 1 was labeled "Higher ToM skills," and Cluster 2 was called the "Lower ToM skills" group (see **Table 1** and **Figure 1**).

Additionally, the results of the Bartlett sphericity test indicate that the variables were sufficiently intercorrelated [$\chi^2(15) = 78.25$; $p < 0.001$], which is an important requirement for subsequent multivariate analysis.

Multivariate Analysis of Variance (MANOVA) was conducted to analyze differences between Cluster 1 "Higher ToM abilities," Cluster 2 "Lower ToM abilities," and the TD group on the Emotion recognition and social perception subscales of the NEPSY-II (explicit ToM knowledge) and the ToMI inventory scales (applied knowledge). The MANOVA conducted to assess the main group effect among the three groups was statistically significant [Wilk's Lambda (Λ) = 0.07, $F_{(12,162)} = 37.23$, $p < 0.001$, $\eta_p^2 = 0.73$]. ANOVAs showed significant differences on the NEPSY subscales: Emotion recognition, $F_{2,86} = 22.46$, $p < 0.001$, $\eta_p^2 = 0.34$; Verbal-ToM, $F_{2,86} = 52.81$, $p < 0.001$, $\eta_p^2 = 0.55$; Contextual-ToM, $F_{2,86} = 9.43$, $p < 0.001$, $\eta_p^2 = 0.18$. Statistically significant differences were also found on the applied ToM tasks (ToMI): Early-ToMI, $F_{2,86} = 54.36$, $p < 0.001$, $\eta_p^2 = 0.55$; Basic-ToMI, $F_{2,86} = 132.51$, $p < 0.001$,

TABLE 1 | Means, standard deviations (SD) of TOM skills for the two clusters obtained, and statistically significant differences between the two clusters (Higher TOM skills and Lower TOM skills).

Measure	Cluster 1 Higher TOM skills (n = 22) *M (SD)*	Cluster 2 Lower TOM skills (n = 30) *M (SD)*	$F_{(1,50)}$	p	η_p^2
Emotion Re	25.18 (3.14)	22.70 (4.43)	5.02	0.029	0.09
Verbal TOM	17.00 (2.74)	11.83 (2.47)	50.39	0.000*	0.50
Contextual TOM	4.54 (0.80)	3.51 (1.85)	5.95	0.018	0.11
Early ToMI	16.58 (3.19)	13.00 (2.67)	19.25	0.000*	0.28
Basic ToMI	15.57 (2.24)	10.98 (2.60)	44.11	0.000*	0.47
Advanced ToMI	9.43 (2.84)	6.99 (2.73)	9.79	0.003*	0.16

*Emotion Re, emotion recognition; Verbal TOM, theory of mind-Verbal; Contextual TOM, theory of mind- contextual; ToMI, theory of mind inventory. *p < 0.008 (Bonferroni correction).*

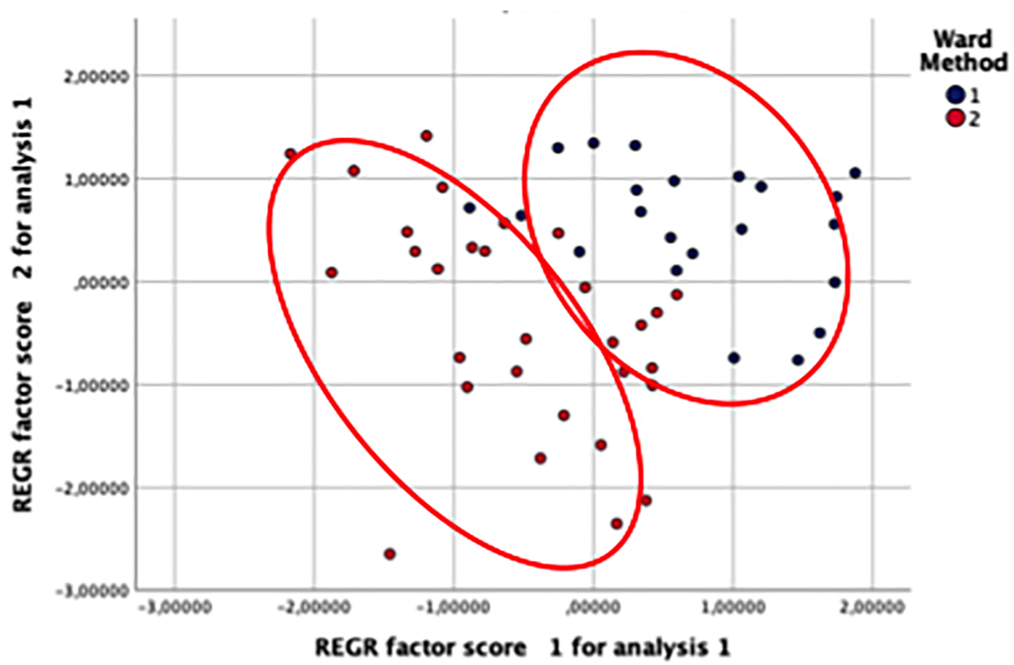

FIGURE 1 | Scatterplot of pairwise comparisons between clusters on each TOM subscale.

η_p^2 = 0.75; Advanced-ToMI, $F_{2,86}$ = 139.89, p < 0.001, η_p^2 = 0.76.

Bonferroni *post hoc* analyses showed statistically significant differences on the Verbal TOM task between Cluster 2 "Lower ToM abilities" and both Cluster 1 "Higher ToM abilities" and the TD group, whereas there were no significant differences between Cluster 1 "Higher ToM abilities" and the TD group. A similar pattern was observed on the Contextual ToM task, where there were no significant differences between Cluster 1 ("Higher ToM abilities") and the TD group, but there were statistically significant differences between Cluster 2 "Lower ToM abilities" and both Cluster 1 "Higher ToM abilities" and the TD group. Finally, there were statistically significant differences between the TD group and both Cluster 1 and Cluster 2 on Early-ToMI, Basic-ToMI, and Advanced-ToMI (p < 0.001), with significant differences between the two Clusters of ASD children ("Higher" and "Lower ToM abilities"). Consequently, Cluster 1, in the comparison with the TD group, showed a profile of generalized deficits affecting both explicit and applied ToM skills. In contrast, the deficit of Cluster 2, in comparison with the TD group, was found in the application of ToM skills.

Figure 2 shows the comparisons of the mean scores of the two ASD clusters and the TD group.

Differences in Severity of Symptoms, Social-Adaptive Behavior, and Pragmatic Abilities Across the Profiles of Children With ASD

Table 2 presents the comparison of two Clusters of ASD, 'Lower ToM abilities" and 'Higher ToM abilities," on social-adaptive behavior, pragmatic abilities, and severity of symptoms. The analysis of variance revealed statistically significant differences between the two clusters in Daily life skills (VABS) $F_{1,50}$ = 11.07, p = 0.002, η_p^2 = 0.18; Social domain (VABS) $F_{1,50}$ = 15.27, p < 0.001, η_p^2 = 0.23; Pragmatic index (CCC) $F_{1,50}$ = 16.48, p < 0.001, η_p^2 = 0.25; the Social symptoms domain (SCQ) $F_{1,50}$ = 9.97, p = 0.003, η_p^2 = 0.17; and the Communication symptoms domain (SCQ) $F_{1,50}$ = 14.61, p < 0.001, η_p^2 = 0.323. After applying the Bonferroni correction (p < 0.004), the variables that remained significant were the same: Daily life skills (VABS), Socialization skills (VABS), Pragmatic index (CCC), Social symptoms domain (SCQ), and Communication symptoms domain (SCQ).

DISCUSSION

A critical target in ASD research is to identify homogenous subgroups to better understand neurodevelopmental patterns and design meaningful intervention strategies. In the past decade, several studies have used the methodological resource of cluster analysis to empirically derive ASD subtypes that share common cognitive and behavioral characteristics (Baeza-Velasco et al., 2014; Campbell et al., 2014; Hoogenhout and Malcolm-Smith, 2017). Following this approach, the first aim of the present study was to identify profiles of children with ASD without ID, based on measures of explicit and applied ToM knowledge. The cluster analysis carried out using different ToM measures made it possible to identify two profiles of children with ASD. One group, made up of 42.30% of the participants, showed better performance than the other group on all the variables of

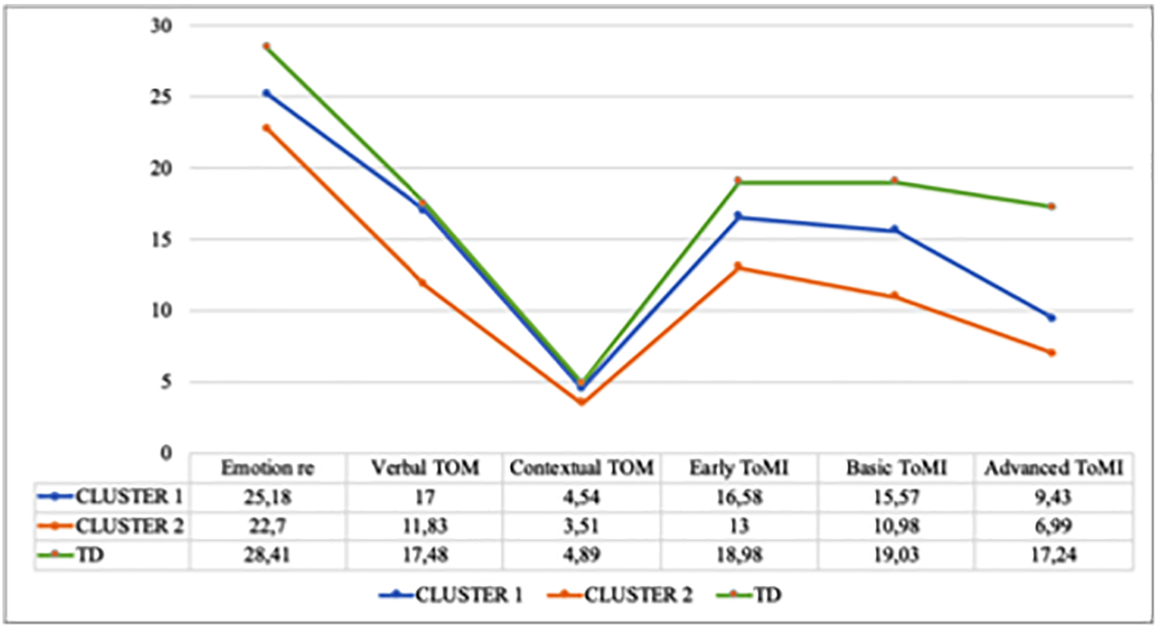

FIGURE 2 | Means of Clusters 1, 2, and the typically developing group (TD) on the TOM children's variables.

TABLE 2 | Means, standard deviations (SD) of social, adaptive behavior, and autism severity for the two clusters obtained (Higher TOM skills and Lower TOM skills), and statistically significant differences between them.

	Cluster 1 Higher TOM skills (*n* = 22)		Cluster 2 Lower TOM skills (*n* = 30)				
Measures	***M***	***SD***	***M***	***SD***	$F_{(1,50)}$	***p***	η_p^2
SDQ_Peers	5.77	2.09	5.77	2.19	0.00	0.992	0.00
SDQ_Prosocial	6.46	2.69	5.23	1.94	3.63	0.061	0.07
VABS_Daily L	82.77	9.18	74.37	8.86	11.07	0.002*	0.18
VABS_Social	81.00	10.0	71.43	7.58	15.27	0.000*	0.23
CCC_Pragmatic I	23.77	8.62	15.20	6.61	16.48	0.000*	0.25
SCQ_Social	7.86	3.31	11.03	3.77	9.97	0.003*	0.17
SCQ_Communica	6.20	2.35	8.47	1.93	14.61	0.000*	0.23
SCQ_Stereotyp	4.65	2.06	4.93	1.93	0.25	0.617	0.01

SDQ Peers, strengths and difficulties questionnaire peers problems scale; VABS_Daily L, vineland adaptive behavior scales_daily life skills; CCC_Pragmatic I, children's communication checklist_pragmatic index; SCQ_Communica, social communication questionnaire_communication; SCQ_Stereotyp, stereotyped behavior scale. **p* < *0.004 (Bonferroni correction).*

ToM abilities, and so it was labeled the "Higher ToM abilities" group. The other group had the lowest ToM performance and consisted of 57.69% of the children with ASD, and so it was called the "Lower ToM abilities" group. Moreover, both clusters differed significantly on the explicit verbal ToM task and on three levels of applied ToM abilities, early, basic, and advanced. These differences persisted even after controlling variables that have been shown to play an essential role in ToM development in children with ASD, such as the language level (Steele et al., 2003) or working memory (Kouklari et al., 2019).

Additional important information stemmed from comparing the two ASD groups and the TD group on ToM skills. This analysis helped to determine the specific types of deficits in children with ASD. Thus, applied ToM skills distinguished between the children with ASD and their typically developing peers. Statistically significant differences between the TD group and the two groups of children with ASD, both those in the "Lower" group and those with "Higher ToM abilities," were found on all three ToMI subscales (Early, Basic, and Advanced). Therefore, parents perceived that the two groups with ASD had more difficulties than the TD group in understanding basic emotions, distinguishing between the physical and mental, making second-order inferences, or making complex social judgments. In addition, the group with ASD and "Lower ToM abilities" showed worse competence than the TD group on understanding first- and second-order false beliefs, double deception, and figurative language, all of which are assessed on the ToM verbal subtest. This group with ASD and "Lower ToM abilities" also presented difficulties on the contextual task, obtaining significantly worse results than the ASD group with

"Higher ToM abilities." By contrast, on the two measures that assess the explicit component of ToM, the verbal and contextual tasks on the NEPSY, the ASD group with "Higher ToM abilities" had similar performance to the TD group.

Clearly, two profiles of children with ASD without ID have been differentiated, namely "Higher" and "Lower" ToM abilities, based on explicit and applied ToM knowledge. However, the effect sizes (see **Table 1**) show the greater weight of the verbal task (understanding the other's point of view) and the Basic ToMI subscale (understanding mental terms of feelings and actions) in differentiating the two groups. Furthermore, when comparing the two ASD groups and the TD group, the verbal task also discriminates the ASD group with worse ToM skills from the other two groups.

In sum, of the two Clusters of children with ASD, Cluster 2 ("Lower ToM abilities") showed generalized explicit and applied ToM impairments, whereas the impairment of Cluster 1 ("Higher ToM abilities") was more specific. In general, children in the latter group performed well on explicit ToM tasks where they had time to process the information and were given clear instructions and even options to select the correct answer (Barendse et al., 2018). Their failures focused on effectively applying the conceptual knowledge to real life interactions, which could be due, at least in part, to difficulties in developing appropriate strategies in an often unpredictable and changing context. Therefore, the initial hypothesis was fulfilled: the profiles identified in children with ASD differed in the level of development of different ToM skills and the application of the skills to daily life, which, even in the best performing profile, showed a weaker development than in the group with TD.

A second aim of the study was to examine whether the identified clusters could be differentiated by testing external variables such as symptom severity, social/adaptive behavior, and pragmatic abilities. As expected, the profile that had the greatest problems with ToM abilities showed greater ASD symptom severity and worse socio-adaptive and pragmatic skills. In fact, the group with "Lower ToM abilities" was characterized by more severe ASD symptoms and poorer pragmatic skills, in terms of inappropriate communicative beginnings and deficits in coherence and interpretation of language depending on the context, among other indicators. This group also showed significantly less mastery of daily living skills and poorer adaptive skills than the "Higher ToM abilities" profile, which showed less widespread impairment. Our results corroborate previous findings that have linked the prevalence of ToM in ASD to the degree of autistic symptoms (Lerner et al., 2011; Hoogenhout and Malcolm-Smith, 2017) or to pragmatic and social competence (Tager-Flusberg, 2001; Mazza et al., 2017; Baixauli et al., 2019).

On measures of Peer problems and Prosocial behavior, the means of both the Cluster with "Lower ToM abilities" and the Cluster with "Higher ToM abilities" are in the borderline/abnormal range. These impairments include behaviors such as inappropriate affect, social isolation, and failure to initiate interactions with peers, cooperate, share, make friends, express empathy, or provide emotional support. However, the two Clusters of children with ASD without ID were not significantly differentiated by the behaviors rated on these two scales. Thus, our results suggest that the difficulties of children with ASD-ID with prosocial behavior or relations with peers cannot be explained solely by differences in ToM ability. Previous studies concluded that, although performance on ToM tasks is associated with different subtypes of prosocial behavior (helping, cooperating, and comforting), the magnitude of the association is relatively weak (Imuta et al., 2016). Moreover, no ToM types have predicted parent reported social functioning of their children with ASD (Altschuler et al., 2018), and no simple or direct relationship has been found between behavioral indices of ToM ability and everyday social interactions, as in friendships described by children with high-functioning ASD (Calder et al., 2013).

Limitations and Future Directions

This research has some limitations that should be considered, and so the findings should be interpreted with caution. On the one hand, the implicit component of the ToM was not evaluated, which would have allowed a more complete profile of the mind-reading skills of the participants to be outlined. We are aware that the best information collection strategy would have been to involve different sources by using a variety of assessment measures (multi-method assessment). However, parents of children with ASD are a reliable source of information about their children's ToM because they have the opportunity to observe them during real world social interactions (Hutchins et al., 2011; Lerner et al., 2011). Even more, the ToM Inventory filled out by parents in our study has shown to provide a broad view the child's theory of mind abilities, which can help to identify different profiles and potential targets within and across domains (early, basic, and advanced) (Greenslade and Coggins, 2016). Moreover, observational measures of pragmatic and social competence were not used either, as they were only assessed through parental estimates. Given the dependence and contextual variability characterizing these skills, it would have been desirable to have information from other informants (teachers, for example) in other significant settings in the child's life.

Similarly, the small sample size and the predominance of males are two aspects that restrict the generalization of the results to the population of girls with ASD. It is possible that, in general, girls show a better profile. In fact, whereas social impairments and mentalizing language are linked in boys with ASD, this link seems to be weaker in girls (Boorse et al., 2019). Therefore, studies with larger samples that include girls with ASD are needed in order to find out how ToM deficits are manifested in this population. Moreover, ToM is a dynamic construct influenced by individual experiences, for what it should also be analyzed the specific role of contextual factors that have an impact on the developmental trajectories of explicit and applied ToM skills: maternal mind-mindedness (Laranjo et al., 2010), quality of relationships with siblings (Prime et al., 2016), or peer interactions (Slaughter et al., 2015). Longitudinal studies may also be an avenue for future research that can provide a more complete and dynamic understanding of the interaction between ToM and other indicators of the functioning of people with ASD, for example, in terms of predictors and social outcomes.

Implications

The findings of the present study raise several clinical considerations regarding the diagnosis and assessment of autism spectrum disorders. First, this study confirms that children with ASD without ID vary in their development of ToM abilities. It is reinforced the idea that ToM is a multifaceted range of skills that are not always impaired to the same grade in children wit ASD. One group of children could show a more severe profile, characterized by deficits in cognitive understanding of other people's mental states and in applied behavioral aspects of ToM skills, whereas the impairments in the other group could be related to their competence in applying ToM skills. In any case, even the subgroup with better ToM abilities, whose performance on explicit ToM is equal to that of TD, does not seem to successfully deal with social interactions in daily life. In these situations, it is necessary to respond spontaneously to a variety of events, which requires more resources than when performing tasks in contexts with greater stimulus control. Hence, it is important to complement the assessment using ToM performance tasks with procedures that evaluate how children cope with real-world social interactions and capture different levels, that is, early, basic, and advanced ToM. In conclusion, we think the data provided in this study are valuable because they emphasize the usefulness of incorporating applied and observational measures of ToM abilities into diagnostic processes in ASD clinical practice.

Second, this research provides information about the dynamic relationship of ToM with other important social functioning domains, as suggested by neuro-constructivist approaches (Bennett et al., 2013). The ASD group with "Higher ToM abilities" presents better adaptive skills related to daily life and socialization, such as money management and pragmatic skills, and less ASD symptomatology. However, both groups (Lower and Higher ToM) continue to show problems with peers and deficits in prosocial behavior, suggesting that deficits in social awareness are not the only explanation for social behavior problems. Other factors such as low social motivation or lack of opportunities for interaction or specific interference responses (i.e., reduction in social behaviors) may be involved. In this regard, a comprehensive assessment will help to clarify whether social problems are due to a lack of social cognition or social performance or both, in order to tailor interventions accordingly.

Together, the profiles identified suggest that ToM is appropriately conceptualized as a continuum of skills as well as an ASD severity indicator of individual differences in social outcomes. Therefore, information about ToM profiles has both clinical and practical importance in the evaluation and design of interventions that fit the profiles of difficulties and potential of people with ASD. On the one hand, it evidences the need to use batteries that include a wide range of measures and task demands in order to capture individual differences. The objective will be to identify the map of lower mind skills, as well as more advanced abilities, in children with ASD. On the other hand, closely related to the above, ToM profiles highlight the need to design specific treatment targets that fit an individual's particular profile in a highly complex domain. Even though each child with ASD may have a different social functioning level, active participation in mentalization tasks related to understanding the mental states of others may improve his/her social awareness. Improvements in the conceptual understanding of ToM, however, are not sustained or generalized to real-life social settings and interactions (Fletcher-Watson et al., 2014). Consequently, as Bennett et al. (2013) highlighted, social cognition-based interventions should be developmentally sensitive and ecologically valid, incorporating naturalistic settings and engaging parents, teachers, and peers as facilitators (Kasari et al., 2010). Although ToM can impact social skills, social experiences themselves, especially support from peer relationships, can provide richer opportunities for everyday social interaction in school-aged children with ASD (Rodda and Estes, 2018).

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation, to any qualified researcher.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee of University of Valencia. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

AM, CB, and BR designed the research. CB, RG, and BR performed the evaluations. CB analyzed the data. IB, BR, and CB contributed to the final writing of the manuscript. All authors revised the manuscript.

FUNDING

This research was financed by the Spanish Ministry of Economy and Competitiveness (PSI2016-78109; AEI/FEDER, UE) and the pre-doctoral grant from the University of Valencia, UV-INV-PREDOC15-265889.

ACKNOWLEDGMENTS

We would like to thank the children, parents, and teachers who participated in this study.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

ORIGINAL RESEARCH
published: 04 November 2020
doi: 10.3389/fpsyg.2020.581117

The Path to Fully Representational Theory of Mind: Conceptual, Executive, and Pragmatic Challenges

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Although an explicit Theory of Mind (ToM) has been found to develop around 4 years of age in Western societies, recent work showing that 4- and 5-year-olds fail modified versions of False Belief tasks as well as seemingly easier True Belief tasks calls into question the robustness of preschoolers' belief understanding. Some have argued these findings illustrate children's conceptual limitations in their understanding of belief that are masked by standard False Belief tasks. However, others claim these examples of children's failure can be explained by pragmatics of the testing situation, rather than conceptual limitations. Given the documented relation between ToM and executive function, an unexamined possibility is that children's failure can be explained by certain executive demands. In the current study, we examined the relation between typically developing 4- (n = 43) and 5-year-olds' (n = 42) performance on traditional and modified False Belief tasks, True Belief tasks, and one component of executive functioning - working memory. We found that children performed worse on modified False Belief tasks and True Belief tasks compared to standard 2-option False Belief tasks, and that working memory was related to modified 3-option contents False Belief performance. These results suggest that a fully representational ToM, one that is stable in the context of increased conceptual, executive, and pragmatic demands, may develop later than traditional accounts have assumed.

Keywords: theory of mind, executive function, working memory, cognitive development, false belief

OPEN ACCESS

Edited by:
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Specialty section:
This article was submitted to
Cognitive Science,
a section of the journal
Frontiers in Psychology

Received: *07 July 2020*
Accepted: *13 October 2020*
Published: *04 November 2020*

Citation:
Pesch A, Semenov AD and Carlson SM (2020) The Path to Fully Representational Theory of Mind: Conceptual, Executive, and Pragmatic Challenges. Front. Psychol. 11:581117. doi: 10.3389/fpsyg.2020.581117

INTRODUCTION

Theory of Mind (ToM) is a social cognitive skill that refers to the ability to understand and reason about other people's mental states, including beliefs. Achieving ToM understanding allows children to succeed in social environments, such as school, and therefore understanding the developmental timeline of ToM is informative to various intervention programs and curricula (*for review*, Carlson et al., 2013). A representational ToM refers to the view that beliefs and desires are representations of the real world and that these representations mediate our actions in the world. Our beliefs about the world can be either true or false and our intentions and desires can be either fulfilled or unfulfilled. We act to fulfill our desires in light of our beliefs and therefore if we know somebody's beliefs and desires we can predict how they will act in a certain situation (Perner, 1991). According to this view, if somebody performs a misguided action then this is either because they have a false belief or an unaligned desire.

However, the traditional tools used to measure ToM understanding may not be telling the whole story. Indeed, facets of the tasks such as how the scenario is presented or whether there are additional attentional demands on the child may change how a child responds to a ToM task. Therefore, understanding the underlying demands of traditional ToM tasks can help researchers better trace the development of ToM skills and provide insight into future intervention programs.

Standard Theory of Mind Measures

Traditionally, children's attainment of ToM is measured by a False Belief task in which a child must answer in accordance with what a character believes, even if that belief contradicts the reality of the situation (Wimmer and Perner, 1983). In the False Belief Contents task (Hogrefe et al., 1986), children witness a container (e.g., an M&M box) and are shown that it contains an unexpected object (e.g., key). The child is asked what someone else, who has never seen inside this box before, would think is in the container. If children are reasoning about another person's belief, they have to ignore the reality (that the key is in the box) and respond that another person would think M&Ms are in the M&M container. Similarly, in the Location variant of the task (Wimmer and Perner, 1983), children witness a scenario in which a protagonist places an object into one of two locations (Location A), then the protagonist leaves the room and another character moves the object to another location (Location B) and the child is asked where will the protagonist look for the object upon returning to the room. For children to reason about belief, they have to ignore the reality that the object is in Location B and say that the character would look for the object in Location A. Although performance on False Belief tasks can vary by age depending on the type of questions being asked and the scenarios presented (Wellman and Liu, 2004), typically, 4 to 4.5-year-olds pass the standard False Belief task, whereas younger children fail (Wellman et al., 2001). It should be noted, however, that there is evidence to suggest false belief understanding and its precursors as early as infancy using other dependent measures such as eye gaze (*for review*, Clements and Perner, 1994; Carlson et al., 2013).

Role of Executive Function

Performance on ToM tasks is robustly linked with individual differences in children's executive function (EF) skills (for a meta-analysis, see Devine and Hughes, 2014). EF refers to neurocognitive skills involved in goal-directed control of behavior and thoughts; these skills include inhibitory control, cognitive flexibility and working memory (Miyake et al., 2000; Zelazo et al., 2016). According to one account of these results, EF skills allow children to *express* their knowledge of ToM. For example, a 3-year-old child might be reasoning about a character's belief that the object is in Location A, but the most recent move to Location B created a strong representation that they are unable to inhibit. Over time, as inhibitory control develops, children can more accurately express their existing ToM knowledge (Carlson et al., 1998). Alternatively, EF skills might make it possible for children to first suppress their own salient thoughts and beliefs, a *sine qua non-for* reasoning about the beliefs of others. On this account, EF skills facilitate the *emergence* of ToM (Carlson and Moses, 2001; Moses, 2001).

Perceptual Access Reasoning

Both expression and emergence accounts highlight the contributions of EF skills to ToM, but they rely on successes and failures on the standard False Belief task, a task whose utility has come into question as being the primary indicator of explicit ToM attainment (Fabricius et al., 2010). A critique of this task suggests that passing the False Belief task can be achieved by reasoning about a protagonists' perceptual access to a set of events, rather than the protagonists' beliefs (Fabricius and Khalil, 2003). According to the Perceptual Access Reasoning (PAR) hypothesis, children reason that agents with perceptual access have knowledge, whereas agents who lack perceptual access do not have knowledge. Crucially, this type of reasoning process does not involve attributions of mental states (intentions, desires, and beliefs) to agents. For example, if a protagonist places an object in Location A and then someone moves the object to Location B while the protagonist is watching, then the child reasons that the protagonist did not lose perceptual access, knows where the object is, and will therefore search correctly at Location B. However, if the protagonist was absent from the room when the object was moved, then the child reasons that the protagonist does not know where the object is and will search incorrectly at Location A, not because the child is drawing on a representational understanding of mental states, but because the protagonist's perceptual access to the event was broken. This reasoning strategy results in passing standard 2-option False Belief tasks. According to the PAR hypothesis, the traditional 2-option False Belief task is limited in terms of disentangling the traditional perspective on ToM and the PAR account because the incorrect choice and the belief choice are one and the same.

Support for the PAR account emerges from two primary findings. The first piece of evidence for the PAR account comes from a modified False Belief task that includes an additional incorrect response option, thereby disambiguating a PAR generic incorrect response from a traditional ToM reality-based incorrect response (Fabricius and Khalil, 2003). In the Location task, Location C is added such that it is present in the room alongside Location A and Location B, but is neither the original hiding location (belief response) nor final hiding place (reality response). According to the PAR hypothesis, a child who witnesses a protagonist lose the chain of perceptual access will reason the protagonist will not know where the object is and will thus be wrong when searching for the object. Given the presence of two incorrect options (belief and irrelevant), the child should arbitrarily select one of them. Indeed, Fabricius and Khalil (2003) found that a modified 3-option False Belief task showed higher failure rates for 5-year-olds (65%) than on the traditional 2-option False Belief task (36%).

The second source of support for the PAR account involves children's performance on True Belief tasks. True Belief tasks originally were used with 3-year-olds to demonstrate that False Belief failure is not accounted for by incidental task demands because they were able to pass the True Belief tasks but failed the False Belief tasks (Wellman et al., 2001). True Belief tasks are not typically administered to 4-year-olds because they are able to pass the presumably more difficult False Belief version. Structurally, True Belief and False Belief tasks are similar: the child observes as a protagonist hides an object in Location A, leaves the room, and another character moves the object to Location B. However, then the character moves the object *back* to Location A. The child is asked where the protagonist will look for the object upon returning to the room. In this task, the reality and the belief option are the same and moving the toy was inconsequential, so the child should say the protagonist will look in Location A. Yet, for 4-year-olds who typically pass the False Belief task, a large proportion of them fail the True Belief variant (Fabricius and Khalil, 2003; Fabricius et al., 2010). On the PAR account, children reason that seeing/not seeing → knowing/not knowing and that knowing/not knowing → getting it right/getting it wrong (Hedger and Fabricius, 2011). Therefore, they would expect the protagonist to search incorrectly (getting it wrong) on this task by virtue of having been absent during the hiding events (not seeing), even though the object is, in fact, right where they last saw it. Hence, the very same heuristic that led to an apparently correct response on the standard False Belief task would lead 4-year-olds to respond incorrectly on the True Belief task. Based on 4- and 5-year-olds' performance on modified False Belief tasks and True Belief tasks, the PAR hypothesis argues that children do not attain a fully representational ToM until closer to age 6.

Pragmatics

Although 4- and 5-year-olds' failure on modified 3-option False Belief tasks and True Belief tasks supports the PAR hypothesis, other work suggests that performance may be influenced by pragmatic demands, which would preserve children's conceptual understanding of belief. For example, a replication study conducted by Perner and Horn (2003) found that children performed well on both standard 2-option and modified 3-option False Belief tasks. The authors argued that the poor performance reported by Fabricius and Khalil (2003) could be attributed to the use of three yes-no test questions (which might confuse children), instead of an open ended test question. Similar arguments have been made in response to children's counterintuitive True Belief performance. Oktay-Gür and Rakoczy (2017) argued that a sufficiently modified True Belief task in which the critical change of location occurs in the presence of the character prior to them leaving the room (and breaking their perceptual access) is associated with improved performances for 4- and 6-year olds. Rakoczy and Oktay-Gür (2020) systematically examined how the communicative pragmatics of True Belief tasks might lead 4-year-olds to fail whereas 3-year-olds pass. In particular, they found that when True Belief tasks were administered first and False Belief tasks second, performance on True Belief was much better than if the order was reversed. The authors interpreted these findings to suggest that the perceived ease of the True Belief questions made children think there was some trick or that the examiner wanted a non-obvious response when the question came after the False Belief question. Furthermore, if children were given context about the task, explaining that some questions were easier and were designed for younger kids, then performance on True Belief tasks also increased.

Working Memory

Yet another explanation for the evidence concerning the modified False Belief task remains unexamined. Specifically, the inclusion of a third option might increase the strain on children's working memory, making performance on the task lower than the traditional 2-option task. Similarly, when considering 2nd order False Belief tasks where a child must reason about another person's false belief about the protagonist's false belief, the added level increases the executive function demands and performance declines (Happé, 1994; Miller, 2009). If working memory demands are increased by adding a third option to the traditional task, then one would expect that performance will continue to decrease with additional options. Therefore, it is possible that pragmatic demands of the True Belief task being administered to older children, along with increased working memory demands placed by the modified 3-option task, suggest alternatives to be considered alongside the PAR hypothesis.

Present Study

The present study sought to address the conceptual, pragmatic, and executive issues that constrain children's performance on modified multi-option False Belief tasks. The *conceptual* account suggests that children do not yet have a fully representational ToM by 4 years of age and that their apparent success on the 2-option False Belief tasks is due to a confound in task design. The PAR hypothesis suggests the relatively poor performance on 3-option versions (where they are just as likely to choose the irrelevant response as the belief response) reveals that young children are using a simpler heuristic akin to, "Did the protagonist see the turn of events?" as opposed to representing the protagonist's mental state of belief. Alternatively, the *executive* account explains differences between performance on 2- and 3-option False Belief tasks through the added demands on executive function, specifically working memory. Given the robust association between EF and ToM (Devine and Hughes, 2014), it might be the case that additional options pose a challenge to children's under-developed working memory capacity, thus impeding their ability to express their ToM.

To arbitrate these competing arguments, we tested the role of working memory in performance on multi-option False Belief tasks in multiple ways. First, we added a 4-option task to the 2- and 3-option versions. This addition allowed us to test for the contributions of working memory to modified False Belief task performance, such that performance on the 4-option task would be poorer than the 3-option task which in turn is poorer than the 2-option task. The second way we examined this issue was to administer independent tests of working memory to explore associations between working memory and ToM performance. Third, we tested for pragmatics with our use of open-ended test questions in standard and modified False Belief tasks and inclusion of task order in our analyses. On the PAR hypothesis, 4- and 5-year-olds' performance should reflect patterns reported in prior investigations. Specifically, children should pass standard 2-option False Belief tasks but fail the True Belief tasks and modified

3- and 4-option False Belief tasks, and this pattern should not be associated with working memory. On the other hand, if working memory is associated with performance on multi-option False Belief tasks or True Belief tasks, then this would offer support for an executive account. Finally, support for a pragmatics account would be reflected by children passing standard and modified 3-option False Belief tasks (due to the use of an open-ended test question), as well as a significant effect of task order on True Belief task performance.

Next, our study was positioned to address disparate findings between the Contents and Location variants of the ToM tasks. In particular, studies have found that 4-year-olds perform worse on the Contents variant than the Locations variant (Fabricius et al., under review; Fabricius and Khalil, 2003; Perner and Horn, 2003). It is possible that these findings could be explained by differing working memory demands inherent in Contents or Location variants. In the Contents task, greater working memory may be required to hold in mind the various contents and select the correct response among them.

Finally, our study presented an opportunity to explore the anomalous findings of 4-year-old children failing True Belief tasks while passing False Belief tasks. The *pragmatics limitation* account suggests that there are aspects of task administration that make it difficult for older children to pass the True Belief tasks, specifically due to the pragmatics of the task. For instance, presenting such an "easy" question to a child might make them confused and second guess their answer, especially if it followed a false belief question (Oktay-Gür and Rakoczy, 2017; Rakoczy and Oktay-Gür, 2020).

MATERIALS AND METHODS

Participants

Eighty-five children participated in the study [47 female, $M_{\text{age(months)}}$ = 60.50; *SD* = 7.00, range = 49.60–71.80 months], including 43 4-year-olds [28 female, $M_{\text{age(months)}}$ = 54.45; *SD* = 2.96, range = 49.60–59.40 months] and 42 5-year-olds [19 female, $M_{\text{age(months)}}$ = 66.68; *SD* = 3.73, range = 60.60–71.80 months]. This sample size was based on having 80% power to detect a moderate effect size of $f = 0.36$. Five participants were excluded from analyses, due to examiner error ($n = 2$), child refusal ($n = 2$), and one child was discovered to be the twin of a previous participant after data were already collected. Participants were selected from a university-maintained database of children living near a large Midwestern city. Children from this database are primarily White, native English speakers from middle to high socioeconomic status (SES) households. Upon concluding the visit, children selected a plastic toy prize (valued < $1) and were given a lab T-shirt. Parents were also given a $10 gift card.

Procedure

All children were tested individually in a single 30-min videotaped session by one of two graduate research assistants. The measures included a ToM battery and a working memory battery. Tasks were administered in three blocks, each consisting of two ToM tasks (a Contents and a Location variant) followed by a working memory task. Task order was counterbalanced using a Latin square design that preserved ToM tasks of the same number of options (e.g., 3-option False Belief task) within the same block while counterbalancing the order in which the blocks and the working memory tasks appeared. As a result, there were 8 task orders, 2 task orders presented the 2-option True Belief tasks first ($n = 20$) and 6 task orders presented some variant of the False Belief task first ($n = 65$).

Measures

Working Memory Measures

Corsi Blocks (Corsi, 1972)

Children were asked to point to a series of wooden blocks arranged on a physical board in an irregular order. The first block of trials, forward span, required children to repeat a pattern of tapping blocks exactly as E demonstrated. Children started with a practice span of 1 and then 2 taps and then continued to test spans of 2 blocks up to a potential span of 9 blocks. If a child failed a certain span length then they would be administered an additional pattern at the same span length. If a child failed two patterns at the same span length then the administration concluded. After the forward span block, children proceeded to the backward span block where children they were required to tap blocks in the reverse order as E. As with the forward span block, children who failed on a given pattern were given one more pattern at the same span, and two failed patterns of a given span concluded the task.

Word Span (Carlson et al., 2002)

Children were asked to repeat a list of words back to E (forward span) and in reverse order (backward span). The forward span block was always given before the backward span block. Children were introduced to the task with a puppet (Ernie) who demonstrated saying words forward (e.g., E said "*bear*, *hat*" and Ernie replied "*bear*, *hat*") or backward (e.g., E said "*book*, *cup*" and Ernie replied "*cup*, *book*"). Children received a practice trial for each span direction and were corrected if necessary. Test trials started with a span length of 2 and increased to a max span of 5. If children correctly repeated the words without errors, then E would proceed to next span length. If a child failed at a given span length, they would then be given up to two more word sets at the same span length before terminating the task.

Count and Label (Gordon and Olson, 1998)

In this measure of dual-task performance, children were asked to count and label objects presented to them. E presented the child with three objects (key, comb, and toy dog), naming and pointing to each. Next, E counted as they pointed to each object (one, two, and three). Finally, E pointed, counted, and named each object in turn: "*One is a key*, *two is a comb*, *three is a dog*." Children were given their own set of items (doll, shoe, and block) and were asked to repeat the steps E took (first label the items, then count the items, then count and label the items). Children repeated the counting and labeling of the same items twice and scores were given for the number of trials (out of two) they completed correctly.

Theory of Mind Measures

True Belief

There were two True Belief tasks, a Contents version and a Location version. The tasks were modeled after previous work investigating the PAR hypothesis (Fabricius et al., 2010).

Contents. In the True Belief Contents task, children were shown an M&Ms candy box and asked what they thought was inside. Children were corrected with a series of prompts if they did not state M&Ms or candy (e.g., *"What kinds of things come in a box like this?"*). Children were then shown the contents of the box (a key) and allowed to touch it before E placed it next to the box on the table. E then produced a cup filled with M&Ms and poured into the box while stating, "*Here, let's put some candy inside.*" Children were then asked two control questions: "*What is inside the box now?*" and "*What was inside the box when I first showed it to you?*" Incorrect responses were corrected and re-asked. The empty cup and key were then removed from the table. E asked the test question, *"Let's pretend I have a friend named John waiting right outside the door. He's never seen inside this box. When he first looks at the box, before he opens it, will he think there is a candy or a key* [counterbalanced] *inside?"* Children were then asked an open ended justification question, *"Why will he think there is a candy/key inside?"*

Location. In the True Belief Location task, a red and blue box were placed on the table and children were introduced to Sarah, who wanted to save her toy for later. Sarah placed her toy in the red box and then sat in between the two boxes. Sarah's dad entered and was described as cleaning Sarah's room. Dad moved the toy from the red box to the blue box, stating *"Watch Sarah, I'm moving your toy."* Then Sarah and her dad were removed from the table. Children were asked three control questions: *"Remember when Sarah was here, where did Sarah put the toy away?"*, *"Did Sarah watch him move her toy?"*, and *"Where did Sarah's dad move the toy to?"* Children who failed a control question were retold the story and the question was repeated. Children were then asked the test question, *"Look, Sarah comes back to get her toy and stands right here* [between the cupboards], *where does she think her toy is?"*

False Belief

The False Belief battery included standard and modified versions of Contents and Location tasks. There were 6 tasks: two 2-option False Belief (standard Contents and Location), two 3-option False Belief (modified Contents and Location), and two 4-option False Belief (modified Contents and Location). The modified 3- and 4-option False Belief tasks were modeled after prior work investigating the PAR hypothesis (Fabricius and Khalil, 2003; Fabricius et al., under review). Responses to standard versions of the task included two options: reality and belief. Responses to modified versions of the task included three options: reality, irrelevant, and belief. The tasks are described in detail below.

Contents. In all three versions (2-option, 3-option, and 4-option) of the False Belief Contents task, children were shown a familiar box (Crayon box, Band-Aid box, or Cookie box) and asked what they thought was inside. Children were corrected with a series of prompts if they did not state the contents displayed on the box (e.g., "*What kinds of things come in a box like this?*"). Children were then shown the contents of the box and depending on the version of the task, a series of objects were revealed and placed back in the box.

In the 2-option version, a pencil [reality] was removed from the box and then placed back inside. Children were asked two control questions: *"What kind of box is this?"* and *"What is inside the box now?"* E asked the test question: *"Let's pretend I have a friend named Sam waiting right outside the door. He's never seen inside this box. When he first looks at the box, before he opens it, will he think there is a pencil or crayons* [counterbalanced] *inside?"* Children were then asked an open-ended justification question, *"Why will he think there is a pencil/crayons inside?"*

In the 3-option version, a toy car [irrelevant] was removed from the Band-Aid box. E then produced a spoon [reality] and placed the spoon inside the box. Children were asked two control questions: *"What was in the Band-Aid box in the beginning?"* and *"What is in the box now?"* E removed the toy car from the table, produced a toy doll, and asked the test question (*"Here comes Kate. Kate has never seen inside this box. What does Kate think is in the box?"*) and the memory control question (*"Did Kate see inside this box?"*).

In the 4-option version, a coin [irrelevant] was removed from the Cookie box. E then produced a rock [irrelevant] and placed the rock [irrelevant] inside the Cookie box. E then produced a block [reality]. E removed the rock from the box and replaced it with the block. Children were asked three control questions: *"What was in the Cookie box in the beginning?"*, *"What did we put in the box next?"*, and *"What is in the box now?"* E removed the coin and rock from the table, produced a toy doll, and asked the test question (*"Here comes Mark. Mark has never seen inside this box. What does Mark think is in the box?"*) and the memory control question (*"Did Mark see inside this box?"*).

Location. In all three versions (2-option, 3-option, and 4-option) of the False Belief Location task, boxes were produced and children were told a story about a set of characters.

In the 2-option version, a green and white box were placed on the table and children were introduced to Spot, a dog who wanted to save his favorite treat for later. Spot placed his treat in the white box [belief] and then went outside to play. Spot's friend Fluffy the cat entered and moved the treat to the green box [reality] and then left as well. Children were asked four control questions: *"Where is the treat now? [reality]"*, *"Where was the treat in the beginning? [belief]"*, *"Who moved it to the green box?"*, and *"Could Spot see that?"* Children who failed a control question were retold the story and the question was repeated. Children were then asked the test question, *"Now Spot comes back to get his treat. Where will Spot first look for his treat?"*

In the 3-option version, a red, blue, and white box were placed on the table and children were introduced to Anna and her dad. Dad brought Anna a chocolate bar and, while she watched, placed it in the blue box [irrelevant]. Dad decided to move the chocolate from the blue box to the red box [belief]. Then Anna left the room, and Dad moved the chocolate to the white box [reality] and left as well. Children were asked four control questions: *"Where did Anna watch Dad put the chocolate first? [irrelevant]"*, *"Where* *did Anna watch Dad put the chocolate next? [belief]"*, *"Then Anna left, and where did Dad put it when she was gone? [reality]"*, and *"Did Anna see her dad move it to the white box?"* Children who failed a control question were retold the story and the question was repeated. Children were then asked the test question, *"When Anna comes back to get her chocolate, where will she first look for her chocolate?"*

In the 4-option version, red, white, blue, and green boxes were placed on the table and children were introduced to Sam and his mom. Mom brought Sam a chocolate bar and, while he watched, placed it in the blue box [irrelevant]. Mom decided to move the chocolate from the blue box to the white box [irrelevant]. Mom then decided to move the chocolate from the white box to the green box [belief]. Then Sam left the room, and Mom moved the chocolate to the red box [reality] and left as well. Children were asked five control questions: *"Where did Sam watch Mom put the chocolate first? [irrelevant],"* *"Where did Sam watch Mom put the chocolate next? [irrelevant],"* *"Where did Sam watch Mom put the chocolate after that? [belief],"* *"Then Sam left, and where did Mom put it when she was gone? [reality],"* and *"Did Sam see his mom move it to the red box?"* Children who failed a control question were retold the story and the question was repeated. Children were then asked the test question, *"When Sam comes back to get his chocolate, where will he first look for his chocolate?"*

RESULTS

Working Memory Assessments

Children's performance on working memory tasks can be seen in **Table 1**. As shown in **Table 2**, Both Corsi Block and Word Span tasks were correlated with each other, even after controlling for age, whereas Count and Label was correlated with Backward Word Span but not with Corsi Block or with age. Both 4-year-olds and 5-year-olds performed at ceiling for Count and Label. Given the ceiling effect and the lack of consistent correlations with other working memory measures, Count and Label task was excluded from further analyses. Thus, we created a Working Memory Composite by averaging *z*-scores of highest level passed on Backward Corsi and Backward Word Span. There were age-related differences in working memory such that 5-year-olds had higher working memory composites than 4-year-olds, $t(71.24) = -3.85$, $p < 0.001$. There were no differences in working memory related to gender.

TABLE 1 | Working memory task performance by age group.

	4-year-olds			5-year-olds		
Task	**Min**	**Max**	**Mean (*sd*)**	**Min**	**Max**	**Mean (*sd*)**
Corsi block	1	4	2.35 (*0.95*)	1	5	3.19 (*1.15*)
Backward word span	1	3	2.05 (*0.87*)	1	4	2.50 (*0.80*)
Count and label	0	2	1.16 (*0.81*)	0	2	1.45 (*0.71*)

Italicized values are indicated to be (SD)-standard deviation.

True Belief Task Performance

Although the primary aim of this study was to examine the contributions of working memory to modified false belief task performance, we also examined children's performance on 2-option True Belief tasks given recent work suggesting some children perform worse on such tasks compared to standard (2-option) False Belief tasks. We first examined the correlations between working memory and True Belief task performance. Inspection of the raw and partial correlations (controlling for age) revealed non-significant correlations (see **Table 2**).

Next, we compared performance across True Belief and standard (2-option) False Belief tasks. A logistic mixed effects model was conducted to predict score (1: Pass, 0: Fail) from the fixed effects of task order, age (months), task type (True Belief vs. False Belief), task version (Contents vs. Location), the interaction between task type and task version, and the random effects (intercept) of participants. The analysis revealed a significant effect of age ($\beta = 0.05$, $p = 0.01$). There was also a significant effect of task version ($\beta = 1.13$, $p = 0.01$), with better performance on Location versions of the task compared to Contents versions. In addition, there was a significant interaction between task version and task type ($\beta = -1.77$, $p = 0.002$). While children's performance on Contents versions of the True Belief and False Belief tasks was similar, they performed significantly better on the Location version of the False Belief task compared to the Location version of the True Belief task (see **Figure 1**). Task order was not significant.

Both age groups performed significantly above chance on Contents and Location versions of the standard 2-option False Belief tasks [4-year-olds Contents FB: $t(42) = 2.41$, $p < 0.05$; 4-year-olds Location FB: $t(41) = 7.531$, $p < 0.0001$; 5-year-olds Contents FB: $t(41) = 7.53$, $p < 0.0001$; 5-year-olds Location FB: $t(40) = 13.25$, $p < 0.0001$]. In contrast, on True Belief tasks, 5-year-olds performed significantly above chance on both versions of the task [5-year-old Contents TB: $t(39) = 4.68$, $p < 0.0001$; 5-year-old Location TB: $t(39) = 1.96$, $p < 0.05$], whereas 4-year-olds' performance did not differ from chance on either version of the task [4-year-olds Contents TB: $t(40) = 1.76$, $p = 0.08$; 4-year-olds Location TB: $t(42) = 0.15$, $p = 0.88$].

False Belief Task Performance

Children's average performance across the set of control questions was uniformly high, ranging from 96 to 100% [True Belief Contents: 98%; True Belief Location: 99%; standard (2-option) False Belief Contents: 100%; standard (2-option) False Belief Location: 99%; 3-option False Belief Contents: 100%; 3-option False Belief Location: 99%; 4-option False Belief Contents: 99%; 4-option False Belief Location: 97%]. Children who answered a control question incorrectly were not given credit for passing.

Given recent work suggesting that pragmatic demands can impede children's performance on true belief tasks (e.g., Rakoczy and Oktay-Gür, 2020), we included task order in all models described below. Task order indicates which ToM task children received *first*: Order 1: True Belief, Order 2: standard False

TABLE 2 | Correlations among study variables.

	1	2	3	4	5	6	7	8	9	10	11	12
(1) Backward Corsi Span		0.10	0.40***	0.83***	−0.20†	−0.12	0.01	−0.09	0.13	0.10	0.11	0.05
(2) Count and label	0.18		0.43***	**0.32*** **	0.00	−0.01	0.01	−0.02	0.05	0.05	0.01	0.02
(3) Backward word span	**0.47*** **	**0.46*** **		0.85***	−0.20†	−0.19†	0.14	0.17	0.18†	0.14	0.13	−0.04
(4) WM composite	**0.86*** **	**0.37*** **	**0.86*** **		**−0.24***	−0.18	0.09	0.05	0.19†	0.15	0.15	0.00
(5) TB contents	−0.12	0.03	−0.15	−0.15		**0.26***	−0.09	−0.14	−0.11	−0.11	−0.13	−0.16
(6) TB location	−0.09	0.00	−0.17	−0.16	**0.26***		−0.19	−0.09†	−0.20	−0.10†	**−0.33*** **	−0.06
(7) FB 2 contents	0.11	0.07	0.20†	0.18†	−0.05	−0.17		−0.20†	**0.41*** **	0.15	**0.26***	0.12
(8) FB 2 locations	−0.02	0.01	0.20†	0.11	−0.11	−0.08	−0.16		0.02	0.13	**0.24***	0.21†
(9) FB 3 contents	**0.28** **	0.13	**0.27***	**0.33*** **	−0.04	−0.17	**0.47*** **	0.08		**0.31** **	**0.62*** **	**0.25***
(10) FB 3 locations	**0.24***	0.12	**0.23***	**0.28***	−0.05	−0.08	**0.23***	0.17	**0.41*** **		**0.30***	**0.42*** **
(11) FB 4 contents	0.21†	0.06	0.20†	0.24*	−0.09	**−0.31** **	**0.31*** **	**0.27***	**0.65*** **	**0.36*** **		0.18
(12) FB 4 locations	0.19†	0.09	0.06	0.14	−0.10	−0.05	0.20†	**0.24***	**0.36*** **	**0.49*** **	**0.25***	
(13) Age (months)	**0.43*** **	0.21†	0.28**	**0.41*** **	0.15	0.03	**0.25***	0.14	**0.40*** **	**0.37*** **	**0.26***	**0.34*** **

*Below diagonal are bivariate correlations. Above diagonal are partial correlations controlling for age. Computed correlation used Pearson method with pairwise deletion (FB, false belief; TB, true belief). *p < 0.05, **p < 0.01, ***p < 0.001, †p < 0.10. Bold values indicate statistically significant correlations.*

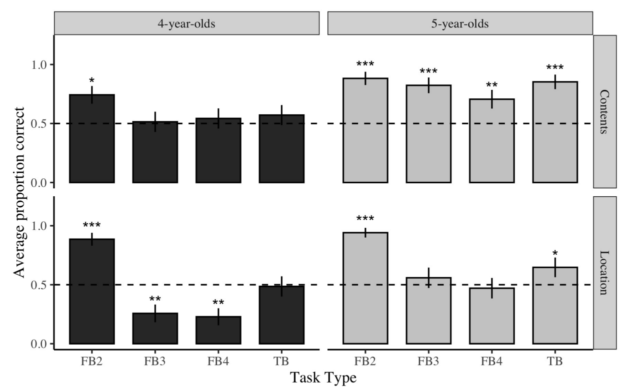

FIGURE 1 | Average performance on each ToM tak as a function of task version and age. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. Dashed line represents chance performance on task.

response) or fail (providing either the irrelevant or reality response). Inspection of **Figure 1** reveals two things. First, whereas children across both age groups performed better on Location versions than Contents versions of standard (2-option) False Belief tasks, they performed better on Contents versions of modified 3- and 4-option False Belief tasks and True Belief tasks. Second, modified 3- and 4-option False Belief tasks were more difficult for children, especially for 4-year-olds compared to 5-year-olds. Specifically, whereas 4-year-olds' performance on Contents and Location versions of standard (2-option) False

TABLE 3 | Results of mixed logistic regression model predicting odds of choosing belief by age, task order, task type, and task version.

Predictor	Odds ratios	Conf. Int (95%)	*P*-value
Intercept	0.03	0.00–0.31	0.003
Task order	0.79	0.62–1.01	0.062
Age (months)	1.10	1.06–1.14	**<0.001**
Task (modified 3-options FB)	0.42	0.18–0.97	**0.042**
Task (modified 4-option FB)	0.34	0.15–0.77	**0.010**
Task (true belief)	0.53	0.23–1.24	0.143
Task version (location)	2.69	0.92–7.87	0.071
Task (modified 3-option FB) * Version (location)	0.10	0.03–0.39	**0.001**
Task (modified 4-option FB) * Version (location)	0.10	0.03–0.36	**0.001**
Task (true belief) * Version (location)	0.18	0.05–0.66	**0.010**
Random effects			
$\int^2$	3.29		
|00 subject	0.37		
ICC	0.10		
N subject	69		
Observations	552		
Marginal R^2/conditional R^2	0.303/0.373		

The reference group for Task was 2-option FB. The reference group for Task Version was Contents. Bold values are statistically significant values.

Belief, Order 3: 3-option modified False Belief, Order 4: 4-option modified False Belief.

To begin, we compared performance across standard and modified tasks. To maintain consistency across the set of tasks, reality and irrelevant responses were both coded as 0 to indicate an incorrect response on modified 3- and 4-option False Belief tasks. A logistic mixed effects model was conducted to predict score (1: Pass, 0: Fail) from the fixed effects of task order, age (months), task type (True Belief, standard (2-option) False Belief, 3-option False Belief, 4-option False Belief), task version (Contents vs. Location), the interaction between task type and task version, and the random effects (intercept) of participants.

The analysis revealed a significant main effect of age, as well as several two-way interactions between task type and task version (see **Table 3**). To better understand the pattern of performance across the battery of ToM tasks, the proportional scores were compared with chance, as shown in **Figure 1**. Here, chance was defined as a 50/50 pass (providing the belief

Belief tasks was high, they were at or below chance on all other ToM assessments. Five-year-olds performed well across contents versions of both standard and modified False Belief tasks, but their performance dropped to chance on Location versions of the modified False Belief tasks.

To better understand poor performance on the modified False Belief tasks, we examined the proportion of children choosing the reality versus irrelevant option, as these responses reflect different ways of "getting it wrong." In 3-option False Belief tasks, choice of the third "irrelevant" option suggests children's use of perceptual access reasoning because the irrelevant option is one that the protagonist in the narrative is ignorant of or lacking perceptual access to. According to the PAR view, children who lack a fully developed ToM should choose between the belief and irrelevant options but avoid choosing the reality option.

To explore this, we examined children's choices for each option on the modified False Belief tasks. **Table 4** shows the number of children who chose each option for both Location and Contents versions of the modified 3- and 4-option False Belief tasks. Descriptively, both 4- and 5-year-olds showed low rates of choosing the reality option (Range: 7–41%), although it should be noted that choice of the reality option was higher on Contents versions of the tasks compared to Location versions among 4-year-olds ($ps < 0.01$). This task effect replicates prior work showing that 4-year-olds are more likely to choose the reality option on Contents versions of modified tasks compared to Location versions (Fabricius and Khalil, 2003; Fabricius et al., under review).

Looking only at children who avoided the reality option, selection of the belief or irrelevant options varied. Binomial tests were conducted to test whether children's choice of the belief option (when they avoided the irrelevant option) was greater than chance. Among 4-year-olds, rates of choosing the belief option across *Location* versions of the modified tasks were significantly below chance ($ps < 0.05$), whereas choice of the belief option was significantly higher than chance on *Contents* versions of the modified tasks ($ps < 0.01$). For 5-year-olds, selection of the belief option did not differ from chance on *Location* versions of the tasks, but was significantly above chance on *Contents* versions of the tasks ($ps < 0.001$). Thus, for children who avoided the reality option, there was greater selection of the irrelevant option on *Location* versions of the modified 3- and 4-option False Belief tasks, whereas they were generally correct in their selection of the belief option on *Contents* versions of the modified 3- and 4-option False Belief tasks.

TABLE 4 | Percent (Number) of 4- and 5-year-olds choosing each option by task type and version.

	3-option false belief			4-option false belief		
	Belief	**Irrelevant**	**Reality**	**Belief**	**Irrelevant**	**Reality**
4-year-olds						
Location	0.29 (12)	0.63 (26)	0.07 (3)	0.23 (9)	0.68 (26)	0.07 (3)
Contents	0.44 (19)	0.13 (6)	0.41 (18)	0.50 (20)	0.17 (7)	0.32 (13)
5-year-olds						
Location	0.57 (24)	0.33 (14)	0.09 (4)	0.52 (21)	0.42 (17)	0.05 (2)
Contents	0.78 (33)	0.04 (2)	0.16 (7)	0.72 (29)	0.10 (4)	0.17 (7)

Relation Between Working Memory and Theory of Mind

Although these findings offer initial support in favor of a conceptual limitation account, driven by children's performance on Location versions of the modified tasks, an alternative possibility is that modifying false belief tasks to include additional options might tax children's working memory. Indeed, at test, children are tasked with reconstructing the sequence of events to correctly recall which location or object the protagonist has a false belief about. Thus, we examined contributions of working memory to children's performance on False Belief tasks, which would lend support to executive accounts of ToM.

First, as shown in **Table 2**, we found significant correlations between the Working Memory Composite and performance on the modified 3-option False Belief Contents $r(85) = 0.33$, $p < 0.01$, and 3-option False Belief Location task $r(85) = 0.28$, $p < 0.05$. The Working Memory Composite was also correlated with the 4-option False Belief Contents $r(85) = 0.24$, $p < 0.05$ but not the 4-option False Belief Locations task. Working memory was not correlated with performance on True Belief or the standard 2-option False Belief tasks. When controlling for age, however, only the relation between Working Memory and the 3-option modified Contents False Belief task remained marginally significant ($r = 0.19$, $p < 0.10$).

Next, we examined whether working memory would predict success on the false belief tasks using logistic regression. As in the above analyses, for the modified tasks, we collapsed the two incorrect responses (irrelevant and reality) into one response category, yielding a score of 1 (belief) or 0 (irrelevant or reality). A logistic mixed effects model was conducted to predict score (1: Pass, 0: Fail) from the fixed effects of task order, age (months), task type (2-, 3, or 4-option False Belief), task version (Contents vs. Location), Working Memory Composite score, the interaction between task type and Working Memory, and the random effects (intercept) of participants. The analysis revealed significant main effects of task order, age, task type, and task version (see **Table 5**). Consistent with the analysis above, performance increased with age, was lower on modified 3- and 4-option versions of the False Belief task compared to the 2-option standard False Belief task, and was lower on Location versions of the modified False Belief tasks compared to Contents versions. Working memory was not related to performance.

This was followed up with ordinal logistic regression analysis (OLR) to preserve the three ordered response categories (belief, irrelevant, and reality). Separate OLRs were run for each version of the modified 3- and 4-option False Belief tasks. In all models, response was predicted by task order, age (months), and Working Memory Composite score. The results are shown in **Tables 6**, **7**. The analyses revealed significant contributions of age to performance across both Location and Contents versions of the modified 3-option False Belief tasks ($ps < 0.05$) as well as on the Location version of the modified 4-option False Belief task ($p < 0.01$). The Working Memory Composite score was associated with performance on the Contents version of the 3-option False Belief task ($p < 0.05$). Task order was not associated with performance.

DISCUSSION

In light of recent work suggesting that preschool-aged children might lack a representational ToM, this study sought to determine how the addition of irrelevant response options influences performance, and whether individual differences in working memory relate to 4- and 5-year-olds' performance on the modified False Belief tasks. In line with previous research, preschoolers performed worse on modified 3- and 4-option False Belief tasks and True Belief tasks compared to standard (2-option) False Belief tasks. We found that working memory was related to performance on the 3-option Contents but not Location version, and that age was the strongest predictor of passing modified False Belief tasks and True Belief tasks. These findings suggest that conceptual and executive limitations may play a role in the development of ToM.

Performance on Modified False Belief Tasks

In the current study, preschoolers performed worse on modified False Belief tasks compared to standard False Belief tasks. This finding replicates and offers important extensions to previous reports. First, the pattern of responses found here are consistent with findings reported in a study by Fabricius and Khalil (2003). More specifically, children's responses on modified False Belief tasks were largely constrained to the belief and irrelevant options, suggesting that their selections were not arbitrary. Fabricius and Khalil (2003) argue that children who use PAR attribute ignorance to agents and with two "wrong" options in the narrative (belief and irrelevant), thus selection of the two choices should fluctuate. In addition to task performance, we replicate an anomalous task version effect reported in two prior studies (Fabricius and Khalil, 2003; Perner and Horn, 2003) in which choice of the reality option was higher on Contents versions of the tasks compared to Location versions. According to the PAR hypothesis, preschoolers perform worse on Contents tasks because it is difficult to think of a "wrong" option when the options are not perceptually salient. Here, we found this pattern on both 3- and 4-option modified False Belief tasks for children in our 4-year-old age group. However, despite greater selection of the reality option amongst 4-year-olds on the Contents tasks, both 4- and 5-year-olds performed better (i.e., were more likely to provide the belief response) on Contents versions of the tasks compared to Location versions. This may be due to the use of boxes with familiar items depicted on the cover (Band-Aids and Cookies), serving as a salient reminder of the belief option when asked the test question on Contents tasks.

TABLE 5 | Results of mixed logistic regression model predicting odds of choosing belief by age, task order, task type, task version, and WM Composite.

Predictor	Odds ratios	Conf. int (95%)	*P*-value
Intercept	0.02	0.00–1.47	0.075
Task order	0.62	0.41–0.96	0.030
Age (months)	1.15	1.07–1.23	**<0.001**
Task (modified 3-options FB)	0.08	0.03–0.17	**<0.001**
Task (modified 4-option FB)	0.06	0.03–0.13	**<0.001**
Task version (location)	0.34	0.19–0.59	**<0.001**
WM composite	0.64	0.25–1.60	0.336
Task (modified 3-option FB) * WM composite	2.24	0.84–5.98	0.109
Task (modified 4-option FB) * WM composite	1.52	0.58–3.96	0.394
Random effects			
∫^{2}	3.29		
|00 subject	1.85		
ICC	0.36		
N subject	69		
Observations	414		
Marginal R^2/Conditional R^2	0.373/0.599		

The reference group for Task was 2-option FB. The reference group for Task Version was Contents. Bold values are statistically significant values.

TABLE 6 | Ordinal logistic regression models for 3-option false belief tasks.

Variable	б (*SE*)	*Z*	Odds ratio	95% CI for *OR* Lower	Upper
Location version					
Task order	−0.37 (0.21)	−1.76	0.68	0.44	1.03
Age (months)	0.08 (0.03)*	0.03	1.09	1.02	1.17
WM composite	0.18 (0.29)	0.29	1.20	0.67	2.18
Contents version					
Task order	−0.25 (0.22)	−1.15	0.77	0.50	1.19
Age (months)	0.09 (0.03)*	2.40	1.09	1.01	1.19
WM composite	0.70 (0.32)*	0.32	2.02	1.09	3.87

*CI, confidence interval; OR, odds ratio. *p < 0.05.*

TABLE 7 | Ordinal logistic regression models for 4-option false belief tasks.

Variable	б (*SE*)	*Z*	Odds ratio	95% CI for *OR* Lower	Upper
Location version					
Task order	−0.24 (0.23)	−1.04	0.78	0.49	1.22
Age (months)	0.10 (0.03)**	2.63	1.10	1.02	1.19
WM composite	−0.07 (0.31)	−0.24	0.92	0.49	1.71
Contents version					
Task order	−0.21 (0.21)	−1.03	0.80	0.52	1.21
Age (months)	0.06 (0.03)	1.77	1.06	0.99	1.15
WM composite	0.47 (0.31)	1.48	1.60	0.86	3.02

*CI, confidence interval; OR, odds ratio. **p < 0.01.*

Second, our findings extend beyond the previous reports by including a 4-option False Belief task. To our knowledge, this is the first study to test for the contribution of adding more options to standard (2-option) False Belief tasks in a linear fashion. Although modified 3- and 4-option False Belief tasks were more difficult compared to standard 2-option False Belief tasks, the modified tasks did not differ from each other in difficulty. Control question performance was excellent across both 3- and 4-option versions of the tasks, suggesting that children accurately recalled the sequence of movements of the objects/locations described in the narrative. Moreover, children were not more likely to arbitrarily select among the four options in the 4-option tasks compared to the 3-option tasks, offering additional support that they may have utilized a reasoning strategy like PAR. Finally, we found the same task effect in the 4-option tasks, such that there were higher rates of selecting the reality option on Contents compared to Location, but that selection of the belief response (among those who avoided reality) was higher. Again, this may be attributed to the fact that the familiar contents on the box served as a reminder of the belief option when asked the test question. Future work could explore for differences in task version by asking the test question without the box present at test. Given the similar pattern of responses across the set of modified tasks administered here, it is plausible that a similar cognitive process is functioning on false belief tasks regardless of the number of options.

Contributions of Working Memory to False Belief Performance

One possible explanation, which we investigated here, was that the addition of objects/locations to the narrative would impose greater executive demands. Whereas previous work argues that conceptual limitations, driven by preschoolers' use of PAR, account for their performance on modified 3-option False Belief tasks, we investigated this from a different lens. Specifically, we focused on how the neurocognitive processes involved in executive function might explain performance on modified False Belief tasks. Due to an expectation that working memory would be particularly taxed by the demands of the modified False Belief tasks, we focused on this component of executive function in the present work.

We found weak associations between working memory and children's performance on modified False Belief tasks. After controlling for age, significant positive correlations between working memory and performance on modified 3- and 4-option False Belief tasks disappeared. This also held for standard 2-option False Belief tasks. Further, ordinal logistic regression analyses found that the Working Memory Composite score was only associated with performance on the modified 3-option Contents False Belief task. This suggests that working memory alone cannot explain performance on False Belief tasks, extending to both task type (2-, 3-, and 4-option) and task version (Contents and Location). These results were unexpected given previous reports on the relation between working memory and false belief performance (Devine and Hughes, 2014). Despite this, it is important to note that we did not include measures of inhibitory control or cognitive flexibility, both of which have been found to relate to performance on standard (2-option) False Belief tasks (Carlson et al., 2002). Thus, it remains possible that the neurocognitive processes involving executive function contribute to children's false belief understanding.

True Belief Performance

We included True Belief tasks in response to work reporting poor performance on these tasks at this age (Fabricius et al., 2010). Like others (Oktay-Gür and Rakoczy, 2017; Rakoczy and Oktay-Gür, 2020), we found that children performed worse on True Belief tasks compared to standard 2-option False Belief tasks. Specifically, whereas 5-year-olds selected the belief option at above chance levels, 4-year-olds were at chance on both Contents and Location versions despite performing well on standard False Belief tasks. This pattern has been argued to support the PAR hypothesis; that is, children at this age who reason that an agent who does not have current perceptual access will "get it wrong" should provide the belief response on standard 2-option False Belief tasks and the reality response on 2-option True Belief tasks (Hedger and Fabricius, 2011). Another explanation, recently offered by Rakoczy and Oktay-Gür, suggests that poor performance on True Belief tasks is due to the confusing pragmatics involved, which can be remedied by administering True Belief before False Belief or by changing the test question wording. Yet another possibility is that True Belief tasks impose executive demands we have failed to take into consideration. Indeed, research on EF and ToM has focused on standard False Belief task performance, leaving uninvestigated the role for EF on reasoning about false beliefs *and* true beliefs. Though we failed to find evidence of a positive relationship between working memory and true belief performance in the present study, it remains possible that other components of EF may play a role in true belief reasoning.

Conceptual, Pragmatic, and Executive Limitations

Our results speak to growing debate in the literature surrounding children's ToM development. The disparate performance on these tasks suggests to some scholars conceptual limitations to children's belief understanding, whereas others point to pragmatic limitations masking children's conceptual abilities.

On the PAR hypothesis, conceptual limitations are evident in children's attributions of ignorance to agents. Our results offer support for this view, specifically among 4-year-olds. As predicted by the PAR hypothesis, 4-year-olds performed worse on modified 3- and 4-option False Belief tasks compared to 2-option False Belief tasks. Specifically, their pattern of responding aligns with the PAR prediction that there should be few selections of the reality response and more equal selection of the belief and irrelevant responses. In addition, 4-year-olds' performance across standard 2-option False Belief tasks and True Belief tasks supports the PAR prediction that children who are reasoning about ignorance should pass standard False

Belief tasks but fail True Belief tasks. Previous investigations of the PAR hypothesis have demonstrated these predicted patterns of responses, but used these tasks across different studies, administering modified False Belief tasks (Fabricius and Khalil, 2003) or standard 2-option False Belief vs. True Belief (Fabricius et al., 2010). The current study offers a unique contribution to this body of evidence by administering all of these tasks in the same within-participant design, and finding the predicted pattern across the battery of ToM tasks. If conceptual limitations are responsible for children's pattern of responding, we would expect to find that a reasoning strategy (like PAR) functions across a set of tasks for children using that heuristic, which we report here. This suggests that 4-year-olds may lack a fully representational ToM despite passing the standard False Belief tasks.

These findings offer minimal support for a pragmatic limitation account. Support for a pragmatics account is drawn from findings that children can pass modified True Belief tasks, for example if characters are present for the critical location change (Oktay-Gür and Rakoczy, 2017) or if children are told questions might be trivial because they are intended for younger children (Rakoczy and Oktay-Gür, 2020). While the present study did not systematically test for pragmatic differences across our ToM battery, recent work has found that manipulating various aspects of modified 3-option False Belief tasks (e.g., manipulations to the narrative, movements of the object, which movements the protagonist witnessed) did not affect performance in any predictable fashion (Fabricius et al., under review). Thus, to date, there is scant evidence supporting the predictions made by pragmatic accounts, suggesting there may be a deeper reason for children's failures.

In a large literature, facets of EF have been shown to relate to children's ToM development, leading scientists to wonder whether EF allows for the conceptual understanding involved in belief reasoning (emergence accounts) or is a constraint on the expression of an already-developed conceptual understanding of belief (expression accounts) (Moses, 2001). While this debate was not at the center of the work conducted here, our findings suggest that EF might play a role in performance on modified False Belief (specifically, 3-option Contents False Belief), though it remains unclear whether this relation supports an emergence or expression account. On the one hand, although we had predicted that additional options would tax working memory, children's working memory scores were not a strong predictor of passing modified 3- and 4-option False Belief tasks. This suggests that the working memory demands of the additional task events were minimal. On the other hand, it may be that EF plays a role in the conceptual understanding involved in reasoning on modified tasks, in ways that we failed to test for here. More robust exploration of the relation between EF (including working memory, inhibitory control, and cognitive flexibility) has the potential to reveal more about our understanding of ToM development in the preschool years. For instance, finding that EF relates to performance on more than standard False Belief tasks would suggest that EF is critical to belief reasoning across a range of tasks.

Limitations

This study has a number of limitations. First, as just discussed, while we expected working memory to be particularly taxed by the addition of irrelevant options on modified False Belief tasks, it might have been prudent to also assess other components of EF. This would have allowed us to better determine the impact that specific components of EF have on performance across modified False Belief tasks (as well as True Belief tasks, though this was not the primary aim of the current study). Thus, in future work, it will be important to include a larger EF battery to examine the contributions of EF on ToM. Second, while we situate our results within the debate surrounding conceptual, pragmatic, and executive demands, we did not systematically manipulate pragmatics of the tasks. To this end, we cannot rule out the possibility that pragmatic demands might have accounted for our findings, in ways recently proposed by Oktay-Gür and Rakoczy (2017) and Rakoczy and Oktay-Gür (2020). Third, our sample was predominantly White and from high socioeconomic households, limiting our ability to generalize these findings and conclusions to other populations.

CONCLUSION

Although standard False Belief tasks have acquired tenure as a marker of ToM understanding, recent empirical work suggests there may be limitations to preschoolers' understanding of belief. The work presented here is one of the first to take into consideration varied accounts of ToM development by administering standard and modified False Belief tasks, True Belief tasks, and measures of working memory in the same within-participant design. We sought to determine whether previous reports using these tasks would replicate when administered in the same testing session, including the addition of 4-option task versions, and whether individual differences in working memory would explain children's performance on this unique ToM battery. Our findings speak to a rising debate within the literature about how to interpret children's responses to different types of ToM tasks. We found evidence in favor of a conceptual limitation account, given children's poor performance on both modified False Belief tasks and True Belief tasks (despite their strong performance on standard 2-option False Belief tasks). In addition, we found preliminary evidence in favor of an executive account given the association between working memory and performance on the modified 3-option Contents False Belief task. Finally, we found little evidence supporting a pragmatics account given the lack of an association between task order and task performance. While we cannot settle the debate here, the growing body of work examining preschoolers' performance on different ToM tasks suggests that more research is needed to better understand preschoolers' development of belief reasoning. We add to the current debate the possibility that executive demands play a role in children's performance on these modified tasks in addition to the possibility of conceptual and pragmatic limitations. It is important to consider the implications of these findings, given the robust use of standard False Belief tasks to assess ToM in developmental research.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Institutional Review Board at the University of Minnesota. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

AS, AP, and SC conceptualized the study. AS and AP collected, analyzed, and interpreted the data. AS and AP drafted the manuscript. SC critically reviewed the manuscript. All authors gave their final approval of the manuscript.

FUNDING

This work was supported by a small grant from the University of Minnesota Institute of Child Development awarded to AS and AP. The grant amount was for $1,000 and went to stimulus creation and participant payments.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

ORIGINAL RESEARCH
published: 23 November 2020
doi: 10.3389/fpsyg.2020.593807

Pragmatics in the False-Belief Task: Let the Robot Ask the Question!

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The poor performances of typically developing children younger than 4 in the first-order false-belief task "Maxi and the chocolate" is analyzed from the perspective of conversational pragmatics. An ambiguous question asked by an adult experimenter (perceived as a teacher) can receive different interpretations based on a search for relevance, by which children according to their age attribute different intentions to the questioner, within the limits of their own meta-cognitive knowledge. The adult experimenter tells the child the following story of object-transfer: "Maxi puts his chocolate into the green cupboard before going out to play. In his absence, his mother moves the chocolate from the green cupboard to the blue one." The child must then predict where Maxi will pick up the chocolate when he returns. To the child, the question from an adult (a knowledgeable person) may seem surprising and can be understood as a question of his own knowledge of the world, rather than on Maxi's mental representations. In our study, without any modification of the initial task, we disambiguate the context of the question by (1) replacing the adult experimenter with a humanoid robot presented as "ignorant" and "slow" but trying to learn and (2) placing the child in the role of a "mentor" (the knowledgeable person). Sixty-two typical children of 3 years-old completed the first-order false belief task "Maxi and the chocolate," either with a human or with a robot. Results revealed a significantly higher success rate in the robot condition than in the human condition. Thus, young children seem to fail because of the pragmatic difficulty of the first-order task, which causes a difference of interpretation between the young child and the experimenter.

Keywords: theory of mind, preschool children, pragmatics, humanoid robot, mentor-child context, ignorant robot, human robot interaction, first-order false belief task

OPEN ACCESS

Edited by:
Hiromi Tsuji,
Osaka Shoin Women's University, Japan

Reviewed by:
Federico Manzi,
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Specialty section:
This article was submitted to Cognitive Science, a section of the journal Frontiers in Psychology

Received: *11 August 2020*
Accepted: *28 October 2020*
Published: *23 November 2020*

Citation:
Baratgin J, Dubois-Sage M, Jacquet B, Stilgenbauer J-L and Jamet F (2020) Pragmatics in the False-Belief Task: Let the Robot Ask the Question! Front. Psychol. 11:593807. doi: 10.3389/fpsyg.2020.593807

1. INTRODUCTION

For almost 40 years, the explicit question in false belief tasks (FBT) of Wimmer and Perner (1983), in which the child must express the false belief of a character on the state of the world, has been the commonly accepted task to study the Theory of Mind (ToM). Understanding the false beliefs of others is of considerable importance for the cognitive and social development of children. It is required to grasp that others have mental states, subjective representations conditioned to specific knowledge and experiences, distinct from ours. Thus, understanding that beliefs can be different from one person to another (Perner, 1991). Sabbagh and Bowman (2018) highlight that explicit FBT are a simple test paradigm perfectly representative of this understanding. In these tasks, children must recognize that someone else will behave in a way that does not correspond to how they understand the state of the world.

Explicit FBT require a direct verbal answer to an explicit question of the experimenter. The expected answer seems to be very intuitive and is traditionally considered to be a reliable indicator of the understanding of false beliefs. The explicit FBT of Wimmer and Perner (1983) is the following task: The experimenter tells the child participant a story of object transfer through the use of clips[1]: Before going out to play, the child Maxi puts his chocolate into the green cupboard. While he is outside, his mother moves the chocolate and puts it into the blue cupboard. Maxi then comes back to get his chocolate (see **Figure 1**)[2].

The child must predict which cupboard Maxi will open to try to get his chocolate. To get the child's answer, the experimenter asks the following test question (ToM question): "Where will Maxi look for the chocolate?" In this question, children are invited to indicate that Maxi will look for the chocolate where he believes it is (i.e., where he left it) instead of where the children know it really is. To answer correctly (green cupboard), the child must activate in their mind the false belief of the character Maxi, who doesn't know the chocolate has been moved, while inhibiting their own knowledge of the world (the chocolate is in the blue cupboard). A control question is then asked by the experimenter following the ToM question to make sure the child understood the story. If the child answers correctly to the ToM question, a "reality question" is then asked regarding the true location of the chocolate at the end of the story: "Where is the chocolate really?" If the child instead fails to answer the ToM question, the next question is then a "memory question" to see if they remember where the chocolate was at the beginning of the story: "Do you remember where Maxi put the chocolate in the beginning?" Results of numerous studies done with neuro-typical children of various cultures (Callaghan et al., 2005) indicate that the majority of 4 years-old children answer the blue cupboard to the ToM question (where the chocolate actually is). It is necessary to wait 4–5 years to see children answering correctly that Maxi will look into the green cupboard (Wimmer and Perner, 1983; Baron-Cohen et al., 1985; Wellman et al., 2001; Sabbagh and Bowman, 2018). The explanation being that children between 3 and 5 learn conceptual knowledge necessary to make explicit decisions about the representative mental state of others[3].

Yet, these results seem to be in contradiction with behavior observed in 3 years-old children requiring first order abilities, such as the game of Hide and Seek. In this game, the child must go somewhere they will not be seen by others. To succeed the child must understand the difference between their knowledge and what others will perceive. Children younger than 4 are able to evaluate what can be perceived by others, and thus to adopt a point of view different from their own (Shatz et al., 1983; Reddy, 1991, 2007, 2008; Bartsch and Wellman, 1995). The first order ToM then seems to be an ability acquired before the age of 4 (Baillargeon et al., 2010; Westra and Carruthers, 2017). Hala et al. (1991) show that children who failed an explicit FBT, in an ecological situation, can understand and use the false beliefs to explain the mental state of the protagonist of the story. The reasons of the systematic failure of 3 years-old children would be, for these authors, due to the specificity of the explicit FBT. The child must give conscious and declarative answers to the questions of the experimenter. Explicit tasks with verbal answers would require important cognitive resources. These tasks would greatly involve executive functions; such as the ability of the child to inhibit their own point of view to consider that of others. These executive functions would still be immature at the age of 4 (Leslie, 2005; Baillargeon et al., 2010; Westra and Carruthers, 2017; Oktay-Gür et al., 2018, for a discussion). In implicit FBT, in which the answers of children are deduced from actions or gazes and not from explicit pointing or linguistic replies, a much more precocious success (starting from 15 months old) is observed (Onishi and Baillargeon, 2005; Southgate et al., 2007; Surian et al., 2007; Baillargeon et al., 2010; Scott et al., 2010; Heyes, 2014).

In consequence, there is a "developmental paradox of the understanding of false beliefs" (De Bruin and Newen, 2012; Newen and Wolf, in press): toddlers succeed in implicit FBT using behavioral responses but kids below the age of 4 generally fail the explicit FBT in which they must explicitly answer the experimenter's question. Some following a "nativist" approach argue in favor of an early ability to detect false beliefs (based on an innate module) allowing toddlers to succeed in implicit FBT (Leslie et al., 2004). Others following a more "empiricist" approach argue that the ability to understand false beliefs is due to the development of cognitive abilities. It is that development which is responsible for the change of performance in explicit FBT at the age of 4 (see Newen and Wolf, in press, for a recent review). Newen and Wolf (in press) point out a distinction dividing both nativists and empiricists into those who give a cognitive explanation and those who give a situational explanation to the failure of children. For the former, explicit FBT would be difficult because the correct answer would require cognitive resources not yet developed for children between 3 and 4. For the latter, the failure in explicit FBT would actually be the result of the procedure itself; which would be a source of the misunderstanding of the question for these children. Our study focuses on this situational explanation (and in particular the pragmatic explanation) of the

[1]The situation is more or less complex depending on the level of false belief evaluated. Three levels of representation (three gradual orders of difficulty) obtained at different ages can be distinguished (Duval et al., 2011). Order zero is automatically acquired. It corresponds to what we are currently thinking about. First order corresponds to the inference of the mental state of someone else and would only be acquired at the age of 4. The second order refers to the inference of the mental state of another person about another person and should be acquired between 6 and 7. This paper is mainly interested in the age at which children acquire the first order ToM. For the sake of simplicity, we will omit to specify "first order" when we refer to "explicit FBT" in the rest of this paper.

[2]In Wimmer and Perner (1983) Maxi would put the chocolate in the "blue" cupboard and his mother would move it to the "green" cupboard. We've interchanged the colors in this article to match the clips used in our experiment that were taken from Duval et al. (2011, p. 45).

[3]See for a recent argument in favor of this hypothesis (Doherty and Perner, 2020).

FIGURE 1 | The story "Maxi and Chocolate" of Wimmer and Perner (1983) in clips (taken from Duval et al., 2011, p. 45). Left clip : Maxi comes home from shopping with his mother, and puts the chocolate into the green cupboard before going outside to play. Middle clip: While Maxi is gone, Maxi's mother takes the chocolate from the green cupboard to make a cake and puts it back into the blue cupboard. Right clip: Maxi comes home for a snack. He still remembers where he put the chocolate.

failure of toddlers in explicit FBT. We suggest a new procedure able to cancel out situational factors without modifying the structure of explicit FBT themselves. Still, we believe that the situational explanation is profoundly cognitive as well as the Relevance Theory (Sperber and Wilson, 1986) we use to explain the influence of the situation is a fundamentally cognitive theory.

Helming et al. (2014, 2016), Westra (2017), and Westra and Carruthers (2017) all consider the failure of children younger than 4 to be caused by a defective understanding of the expectations of the experimenter in the question. The correct interpretation of the ToM question would require a cognitive effort too great for children of that age. Furthermore, since discussions on beliefs are not common, children would systematically interpret the expectations of the experimenter to be about testing the child's knowledge about the state of the world (i.e., indicating where the chocolate really is) compared to the beliefs of a fictive character. This incorrect interpretation of the ToM question would be caused by the conversational context: the attribution of the status of teacher to the experimenter, and their own status of pupil. We suggest transforming this context (1) By switching the roles and specific statuses of the experimenter and of the child participant and (2) By replacing the experimenter with an "ignorant and slow entity." This context, we call "mentor-child," disambiguates the ToM question asked by the ignorant entity by making it clear that it expects to understand the false belief of Maxi. To do this, we replace the experimenter with a humanoid robot NAO. This work will be organized in the following way: After recalling the obligation to consider the pragmatic implicatures in all acts of communication, we will expose those driving the child to produce an incorrect answer in the explicit FBT. We will then explain a new procedure to diminish the ambiguity of the questions. After describing the results, we will discuss them and conclude with the suggestion of future areas of research.

2. THE AMBIGUITY OF THE TOM QUESTION

Sperber and Wilson (1986, 2002) have shown that all communication is inevitably of a pragmatic nature. A communicator performs in a way, such as producing a speech act or a gesture, and the receiving audience must understand the intent hidden beneath the surface. It is especially important to understand that most of the experimental paradigms in cognition, social cognition and developmental cognition correspond to an act of communication between an experimenter and participants. There are many examples in the psychological literature that answers given, considered to be incorrect by the experimenter, by adult participants are actually the result of the participants' misunderstanding of the intentions of the experimenter. The utterances used and the context of the experimental task trigger implicatures in the participants that can induce answers that are different from those expected by the experimenter (see Dulany and Hilton, 1991; Sperber et al., 1995; Baratgin and Noveck, 2000; Macchi, 2000; Politzer and Macchi, 2000; Baratgin, 2002, 2009; Bagassi and Macchi, 2006; Baratgin and Politzer, 2006, 2007, 2010; Macchi and Bagassi, 2012; Macchi et al., 2019, 2020, for examples). Many developmental studies also give pieces of evidence for the ability of children, given their age, to recognize the intentions of the communicator (see Braine and Shanks, 1965a,b; McGarrigle and Donaldson, 1974; Rose and Blank, 1974; Markman and Wachtel, 1988; Politzer, 1993, 2004, 2016; Gelman and Bloom, 2000; Diesendruck and Markson, 2001; Bagassi et al., 2020, for examples).

Sperber (1994) suggests that the child uses the simplest procedure of interpretation which consists in inferring from the communicative stimulus the most relevant intention in relation to their own point of view. However, what is relevant for the child may be different from what the experimenter actually intends to communicate. Thus, by analyzing the experimental task of Piaget and Szeminska (1941) on the class inclusion question, Politzer (1993, 2004, 2016) has shown that the performances of children in relation to their age could be explained by the differences of their interpretation of the question. The experimenter showed five asters and three tulips. The child was then asked whether "there are more asters or more flowers." The typical answer of children under 8 is "There are more asters." Politzer demonstrates that the question can be characterized by an ambiguity at the root of the response of the youngest children. While the question of class inclusion is enunciated, according to the relevance principle (Sperber and Wilson, 1986), children will try to infer the expectations of the experimenter and to adapt their answer so that it feels relevant to them. Questions are relevant when they make the person to whom they are asked answer in a relevant way (i.e., questions that require the least cognitive cost for the most contextual effect). These assumptions depend on the representational attributions of the child for the experimenter which are a function of their development (Hayes, 1972). According to Politzer, young children do not make mistakes of class inclusion. They simply have a different representation of the question, making them give an incorrect answer.

> "This is a fundamental insight. Once this view is adopted, the disambiguation of the question must be envisaged in relation to the child's development. From the notion that the children attempt to render the question optimally relevant it follows that the way they do so will vary with their cognitive development. In other words, the interpretation chosen by the children is constrained by their level of development. Therefore, the interpretation can be predicted based on what is likely to be the children's estimation of the relevance of the question" (Politzer, 2016, p. 3).

Politzer observed that when he disambiguated the question of class inclusion the success of participants was significantly improved and came earlier: between 5 and 6 years-old (see also Jamet et al., 2018).

It is then legitimate to wonder if, like with the question of class inclusion, the incorrect reply given by young children in explicit FBT could also be the result of a different interpretation of the ToM question which would be caused by an incorrect inference of the experimenter's expectations. With the years, and with the acquisition of the pragmatic skills of the child, the ambiguity of the question would later decrease. This pragmatic hypothesis could explain the early success in implicit FBT, which are simplifications of explicit FBT in which the ToM question is not explicitly asked. To succeed in these tests, the child does not need to correctly interpret the question or to correctly infer the intention of the experimenter. They only need to understand the false beliefs. For Siegal and Beattie (1991), Westra (2017), Westra and Carruthers (2017), since the beginning of their development, young children can create representations of others' beliefs and understand the false beliefs. However, 3 years-old children do not expect beliefs to be a likely topic of conversation (Westra, 2017). It is difficult for them to induce that facts relative to someone's beliefs can be a relevant topic in the conversation with the experimenter and that this is what the question is about. Despite the fact that young children constantly attribute propositional attitudes to other agents, understanding when these pre-linguistic concepts play a part in the conversation is not only a question of acquisition of the adequate vocabulary but would also be a question of the development of pragmatic skills (Westra and Carruthers, 2017). The child must be exposed to conversations for these social stimuli to play a crucial part in the strengthening of their linguistic and pragmatic skills (Astington and Olson, 1995; Carpendale and Lewis, 2004; Antonietti et al., 2006; Westra, 2017)[4].

This lack of pragmatic skill is even more salient in explicit FBT as the conversational interaction happens between the child and a stranger (the experimenter). At the age of 3, even if the young child has had numerous interactions with their parents and family, interactions with adults are generally limited, except for the teacher which is for most still a recent interaction (3 is usually the age at which children start school). The teacher is certainly an important reference for the young child during the experiment. After 2 months of class, preschool children have integrated the didactic contract wanted by the teacher. The teacher explicitly invites the pupils to work well, to show everything they know. Each time the child returns to class, after completing an activity, the teacher will ask them if they worked well. As Westra and Carruthers (2017) explained, children are readily able to consider that the interaction with the experimenter has an educational intention. Indeed, educational clues are almost always present in an explicit FBT. The experimenter, for the child, is in a social position much superior to theirs and, just like their teacher, has the encyclopedic knowledge. The experimenter-child relationship reinforces this impression of superiority since the experimenter is introduced to the child as an authority figure to whom they must obey. This attribution of teacher is facilitated even more by the fact that the experiments most often happen at school, during school time. This supposition of an educational intention in the task implies, for the child, that an educational behavior is expected of them, as it is usually the case in this context. Therefore, they are in a position of pupil during the experiment. How uncommon the situation is, an adult replacing the teacher for an educational exercise, can strengthen the idea that this exercise is really important and that this new teacher may be special and knows more than the usual teacher. This attribution is all the easier since the experimenter is often presented as a researcher, a specialist. Preschool children indeed seem to be already sensitive to the knowledge of the informant in educational activities (Jeong and Frye, 2018b).

[4]Clues exist seeming to indicate that the late success in explicit FBT may indeed be the result of learning from repeated social experiences (Wang and Su, 2009). Studies show that a correlation exists between the number of brothers and sisters of a similar age and the comprehension of false beliefs (Perner et al., 1994; Ruffman et al., 2012; Jenkins and Astington, 2014). From the age of 3 the child can use language from a meta-cognitive point of view to lie (Lewis and Saarni, 1993) and start to be able to use contextual information (Salomo et al., 2013). It is necessary to wait the age of 4 to see children able to adapt their discourse by taking into account the age of the listener, their status and their gender; and can adapt their discourse to younger people. They can also ask a conversation partner to reformulate an utterance if they did not understand it (Clark and Amaral, 2010).

When teaching a new concept in an example or a story, the teacher later checks the child understood correctly through simple and direct questions linked to what was just told. These questions are very rarely ambiguous. The correct answer expected by the teacher is usually meant to prove that they understood the story correctly. Thus, to the child, the same can be expected of the questions asked by the experimenter. The main difficulty in explicit FBT is the fact that they involve four different elements of knowledge: (1) Where Maxi initially put the chocolate, (2) The change of location done by Maxi's mother, (3) The fact that this change of location happened in Maxi's absence, and (4) The fact that Maxi is looking for his chocolate, probably in the wrong place. For the child, there are multiple possible interpretations of the experimenter's expectations when they ask the ToM question. They can be: trying to assess whether the child understood the change of location of the chocolate (steps 1 and 2), or assess whether the child understood the fact that Maxi was not there during the change of location, and that in consequence he will look for the chocolate in the wrong place: the initial location (steps 3 and 4). Along these interpretations, the one which concerns the attribution of beliefs to someone else has a greater cognitive cost for young children. They are generally not experienced enough in interacting with adults to grasp the relevance of this expectation. Children of 3 years-old will instead use the more familiar interpretation: they will think that the experimenter expects the reply to be about the child's understanding of the change of location (Siegal and Beattie, 1991; Hansen, 2010; Lewis et al., 2012; Westra, 2017).

Helming et al. (2014, 2016) offer a more elaborate pragmatic explanation of young children's answer. For them, explicit FBT force the children to adopt two points of views at the same time. One is more detached: "spectating" in the third person the action of the main character of the story, in particular focusing on the character's beliefs; and the other is more communicative: interacting with the experimenter in the second person. This first point of view being disrupted by the second. The ToM question then generates two biases: one "referential" and one "cooperative." Children have the possibility of mentally representing the real location of the chocolate or where Maxi wrongly believes it is. Using the word chocolate in the question can bias children toward answering with the real location (referential bias). The interaction with the experimenter would bring the child to focus on the knowledge they share (i.e., the real location of the item). This would then disrupt the ability of the child to track the false belief of the main character from the third person point of view. In essence: when the experimenter refers to the target item, they direct the attention toward the real location. The cooperative bias is the result of the tendency of toddlers to want to make themselves useful by spontaneously helping others (even adult strangers) to reach their goals, even if it requires a greater effort and if they are busy with a task of their own (see Warneken and Tomasello, 2007, 2009, 2013; Liszkowski et al., 2008; Buttelmann et al., 2009, 2014; Warneken, 2015). This helpfulness seems to be mainly motivated by an intrinsic care for the other and not for any personal reward (Hepach et al., 2012, 2016). This tendency to help others made it possible to create implicit FBT. The task given to toddlers consisted in helping an adult reach their goal. Yet to infer this goal, the toddlers needed to consider what the adult believed. This tendency would drive children to adopt a second person point of view toward the main character of the story, rather than a spectating point of view in the third person, this in turn driving them to incorrectly interpret the expectations of the experimenter. Children understand that the main character needs help, because he has false beliefs, to avoid picking the wrong location. They spontaneously want to help him by telling him the correct location and can readily expect to be invited to do so. This, for the child, would strengthen the interpretation of the ToM question "Where will Maxi look for his chocolate?" as an invitation to help the main character find the item. This means interpreting the question as a normative question "Where should he look for his chocolate?" or even "Can you tell Maxi where to find his chocolate?" As Newen and Wolf (in press) point out, this pragmatic explanation is not in contradiction with the cognitive explanation (in terms of "mental files" by Recanati, 2012) suggested by Perner et al. (2015), Perner and Leahy (2016), and Huemer et al. (2018). These mental files, or mental representations, include the "information management tools about an object in the world" and the links between the different files which make it possible to share information between them. In "Maxi and the chocolate," the child has two mental files of the situation: one "regular" file with the information that the chocolate is in the blue cupboard, and one "indirect by proxy" file indexed on Maxi with the information that the chocolate is in the green cupboard. According to Perner and Leahy (2016), when children below the age of 4 are faced with the ToM question, they are not yet able to switch between the indirect mental file and the regular mental file in a controlled and systematic way. It is only once the mental files are linked that the child can access the information about Maxi's beliefs. The pragmatic explanation, through the Relevance Theory, allows us to understand which mental file will be activated. In a traditional context, the mental file which has the least cognitive cost and the greatest contextual effect is the regular mental file which answers what the child believes to be the experimenter's expectation.

Thus, as Westra and Carruthers (2017) pointed out, there are two interpretations at stake in addition to the correct interpretation of the ToM question for a total of three possible interpretations: (1) The "helpfulness-interpretation" where the question corresponds to an invitation to help the character, (2) The "knowledge-exhibiting-interpretation" where the question corresponds to an invitation to show one's knowledge of the events in the story (steps 1 and 2 as described in the previous paragraphs), and (3) The "psychological knowledge-exhibiting-interpretation" where the question corresponds to an invitation to report the character's false beliefs about the location of the object (steps 3 and 4)[5]. The child's task is to determine which

[5]These two additional interpretations were already evoked in (Perner et al., 1987, p. 126): "They may have misinterpreted the test question: 'Where will the protagonist look for the chocolate?' as meaning, 'Where should he look?' or 'Help him to find it!'" These authors changed the question to "Where does he think the chocolate is?" However, as pointed out in Westra and Carruthers (2017), the term "think" requires more cognitive resources than the term "to look." Also, this version complicates rather than simplifies the issue, which explains why it does not improve the performance of young children.

of these three competing interpretations is most likely to meet the experimenter's. Interpretation (3) is the one expected by the experimenter. Each of the other two leads to the incorrect answer of indicating the actual location of the chocolate. As indicated above toddlers do not yet have the pragmatic experience required to understand that people's beliefs are a valid topic of conversation. In consequence, they are more inclined to interpret the ToM question as a kind of indirect language act to verify their knowledge of the real location of the chocolate (interpretation 1). This will also help the character find the chocolate (interpretation 2). As children gain experience in discourse about the beliefs of others, they begin to be able to recognize the true purpose of the question and their true expectation (interpretation 3): reporting explicitly the false belief of the character called Maxi (Westra and Carruthers, 2017; Frank, 2018). They then understand that the question "Where will Maxi look for the chocolate?" implicitly means "What does Maxi falsely think about the location of the chocolate?"

A number of authors have tried to directly disambiguate the ToM question. Siegal and Beattie (1991) give the following question [reformulated to fit Maxi and the Chocolate]: "Where will Maxi look for the chocolate first?" which directly explains the experimenter's expectation. The authors observe a significant increase in correct answers (Yazdi et al., 2006; Białecka-Pikul et al., 2019). Hansen (2010) also observes much better results when the experimenter directly specifies in their question that they are not interested in the child's knowledge of the state of the world [reformulated to fit Maxi and the Chocolate]: "You and I know where Maxi's chocolate is, but where does he think it is?"

Another solution is to explicitly and conceptually explain the important clues in the story to make the correct interpretation (3) of the ToM question more conceptually relevant (Newen and Wolf, in press), for example by making the false belief of the main character more salient. Mitchell and Lacohée (1991) noticed that children participating in explicit FBT who kept an explicit aide-memoire of their prior belief (the cupboard where the chocolate was [reformulated to fit "Maxi and the Chocolate"]) was much more successful at avoiding a later deformation of this belief. Lewis et al. (2012) showed that the explanation of the false beliefs of another person is improved if we add another character to the story who is also observing object's change of location. The presence of the other person conceptually highlights the possible point of views in the story. In this situation the ToM question, being explicitly directed at the character who did not see the change of location, increases the relevance of interpretation (3) on the false beliefs of the character. Rubio-Fernández and Geurts (2013, 2016) demonstrated that toddlers can also succeed in explicit FBT if the task is modified in such a way that, first, the point of view of the other person is frequently repeated to the child during the experiment and, second, the ToM question asked to the child is transformed into "What happens next?" Here the disruption induced by the experimenter focusing on the item is no longer possible. It is also possible to make interpretation (2), of exposing the child's knowledge about the real location of the item, less contextually relevant. Wellman and Bartsch (1988), Mascaro and Morin (2015), and Mascaro et al. (2017) indeed notice better performances when the children themselves do not know where the actual location of the item is or if the item is removed from the scene.

Finally, it is possible to change the experimental procedure to make the spontaneous tendency of children to be useful, which usually drives children toward the "helpfulness-interpretation" (1), to become an indicator of the effective false belief of the character. Matsui and Miura (2008) showed that toddlers succeeded more easily when the task was changed to have them choose a character whom they had to help find the item (pro-social context).

To sum up: whether children can disambiguate the ToM question depends on their meta-cognitive development. Toddlers make the question more relevant by interpreting it as a question about their knowledge of the story or, with the same result, a question about their knowledge of the story to help the main character. Older children interpret it correctly to be a request for them to report their knowledge of the false belief of the character in the story.

3. CHANGING THE CONTEXT TO DISAMBIGUATE THE TOM QUESTION

In all these experiments the original task is modified. The ToM question is sometimes modified, the participant is sometimes asked to keep in memory the initial belief, a character is sometimes added or some information is sometimes removed. Our objective is to decrease the salience of incorrect interpretations without changing neither the story nor the question asked: by playing with the global context of the experiment itself. A good example is the length and number conservation task (Piaget and Szeminska, 1941). Assessing the conservation of number is done by presenting two lines of tokens, equal in number and arranged in a one-to-one correspondence, in front of a child who judges them to be the same. When the experimenter rearranges one of the rows the non-conserving child changes their judgment in favor of the longer row. McGarrigle and Donaldson (1974) showed that when the transformation of the row of tokens is the indirect result of an action with a different goal, such as a transformation effected by a "naughty teddy bear" who wants to "spoil the game," children are more conservant. In this "accidental transformation," there are no structural modification of the task.

As explained above, the way the child interprets the questions of the experimenter in explicit FBT depends, in part, on their understanding of the nature of the communicative exchange (i.e., its topic and goal). For toddlers, the context of the task, as shown above, strongly expresses that of a school activity with the status of the experimenter-teacher, able to judge, and the location. Thus, the child infers effortlessly their role in this task will be the one they already know and are used to during classes: that of a pupil with the goal of learning and show their knowledge. These assumptions made by the child for the experimenter to be testing their knowledge are the origin of interpretations (2) and (3). The "helpfulness-interpretation" (1) can be considered to be the desired expectation in order to help the character in the story (numerous studies cited above indicate how spontaneously, and without ulterior motives, the toddler displays an altruistic behavior). Thus, if we had an experimental context in which exposing the knowledge of the false beliefs of the character (interpretation 3) could also satisfy a "helpfulness-interpretation" (interpretation 1), then interpretation (2), about the actual state of the world described in the story, could be inhibited.

3.1. A Mentor-Child and an Ignorant, Naive, and Slow Pupil

To do this we must consider a situation which would change the assumptions of the child about the person asking the ToM question; a situation in which the child could spontaneously infer that an answer indicating the false belief of the character would help the person asking this question[6]. A first modification of the context would then have the person asking the ToM question display an explicit need to know the false belief of the character. The person would have trouble understanding the story, as for them the answer to the ToM question is far from obvious, even if they asked it. This person must have less knowledge than the child and must consider the child to be someone who knows more. Thus, we must consider a context in which the status of the child and of the experimenter are switched compared to the original context.

We can imagine a "mentor-child" context in which the young child must answer the questions of an ignorant entity introduced by an authority figure: "You are the teacher and this is your pupil. It doesn't know much. It needs you[7]." In the conversational act, the expectation of the child regarding the questions of the entity is to be able to help it learn new things. Let us imagine that this ignorant being tells the child: "I was told a story that I didn't understand very well. I'll tell it to you and then please explain it to me." After telling the story, the ignorant entity asks the ToM question in a naive tone. The child answering correctly shows their knowledge while helping the entity. The question here is disambiguated and reliably drives the child toward interpretation (3). The question asked in this context becomes natural, for the child knows the entity to be ignorant and that it can ask trivial questions. This is not the case in the traditional context where it can seem surprising that a "knowing" adult could ask such a question.

Another important aspect is to highlight the "naive," "unsure of itself," and "slow" traits of the ignorant entity. This aspect helps the child consider themselves knowledgeable compared to it. It also helps the child feel useful when helping it. More importantly, the "slow" aspect of the entity can favor the interpretation of the control questions asked depending on the success or failure in the ToM question (respectively the reality question and the memory question). To our knowledge, the pragmatic analysis of these questions has never been explicitly done in the literature. This can certainly be explained by the fact that in Wimmer and Perner (1983), all children succeeding in the ToM question also correctly answered the reality question[8]. In the standard context, the interpretation of the reality question is indeed completely obvious for the child. It corresponds to the question that is the most expected; which has the strongest contextual effect and requires the least cognitive cost to answer it. After indicating the false belief of the character in the ToM question, the reality question makes it even more explicit by indicating where the item actually is. This second question does not seem to be incongruous in the standard context in which the child assigns the status of teacher to the experimenter. A teacher often asks multiple questions to test the knowledge of the child. In our "mentor-child" context, the reality question asked by the ignorant entity can seem to be a bit odd to the child in their role of teacher. Indeed, asking this second question requires understanding that the chocolate is in a different place than where the character believes it is[9]. Thus, the ignorant entity, if it did understand correctly the answer given by the "mentor-child" to the ToM question, should have also understood that Maxi has a false belief and will look into the green cupboard which is now empty. Frequently, when a pupil asks a second question to the teacher just after receiving an answer to another, it is often because they need more precision or because they did not understand the answer. In this case, there are two possible answers for the "mentor-child": (1) Thinking that they were not clear enough with their first answer and be inclined to repeat the same answer as in the ToM question, or (2) Accurately answer the reality question to give some new information to help the entity understand their first answer to the ToM question. In order to increase the chances of this second option, the entity must not simply be perceived by the "mentor-child" as "ignorant" but also "a bit slow."

In a similar fashion, the memory question, asked after an incorrect reply to the ToM question, can also be interpreted as a request for confirmation of the understanding of the first answer. Yet, in the standard context, the memory question can seem to be disrupting for children younger than 4 incorrectly answering the ToM question as the final location of the item is given at the end of the story. Indeed, this answer implies having followed the change of location of the chocolate during the story and to remember the initial location of the chocolate. The weak performances observed (37.8% of success in the memory question) in Wimmer and Perner (1983) for children between 3 and 4 may not be the result of the difficulty of the task but instead

[6]Several pieces of experimental evidence indicate that 3 years-old children easily distinguish between what another person knows and does not (Hogrefe et al., 1986; Perner and Leekam, 1986).

[7]Young children seem to better understand their role in educational activities when they are explicitly formulated (Jeong and Frye, 2018a).

[8]It was only children 4 years-old (no younger children had answered the ToM question correctly).

[9]The reality question, in this context, looks like a violation of the principle of informativeness (Grice's Maxim of Quantity, 1975; Ducrot's law of exhaustiveness, 1980/2008) which requires that each participant in a conversation answer their partner's utterance with an appropriate quantity of information (neither too little nor too much). If multiple experimental clues question the complete acquisition of this principle at the age of 3 (Conti and Camras, 1984; Noveck, 2001; Eskritt et al., 2008), other studies indicate that some children of that age show skills like adapting their communicative behavior to the state of knowledge of their partners (O'Neill, 1996; Dunham et al., 2000; Ferrier et al., 2000). Perner and Leekam (1986) show that from the age of 3, children prefer mentioning first the most informative element and avoid mentioning elements already known by their listener.

be the result of the ambiguity of the question for their age. Older children, because of their conversational experience, may more readily reinterpret the memory question to be controlling their initial answer to the ToM question[10].

3.2. The Robot-Pupil Solution

There is an important literature showing the advantages of using a humanoid NAO robot in social interactions with young children, especially in situations of *learning by teaching* (see Jamet et al., 2018). Studies have shown that in conversational interaction with an artificial agent, even completely virtual ones, humans automatically detect pragmatic violations of their speaker (Jacquet et al., 2018; Jacquet et al., 2019a,b,c; Lockshin and Williams, 2020). It was shown that children as young as two can be susceptible to the conversational violations of a robot (Ferrier et al., 2000). Recent studies (Yasumatsu et al., 2017; Martin et al., 2020a,b) also showed that the natural and spontaneous propensity of young children to try being useful extends to humanoid robots seeming to be in difficulty. It seems that 3 years-old children assign mental states to a robot (Di Dio et al., 2018, 2020a; Marchetti et al., 2018). Di Dio et al. (2020a) observed in 3 years-old children who had already developed a first-order ToM skill a tendency to represent the emotional state of a robot in terms of mental states. For these authors, there could be an attempt to anthropomorphize the robot on the emotional dimension which, at the age of 3, could be particularly salient. This suggests that young children are eager to think about the robot mind in the same way they do about the human mind (Di Dio et al., 2018). The NAO robot was also used to study the endowment effect in adults (Masson et al., 2015, 2016; Masson et al., 2017a,b).

The effectiveness of our "mentor-child" context[11] was tested with children between 5 and 6 in the class inclusion task and successfully made the question of class inclusion more relevant for the child when it was asked (Masson et al., 2017a; Jamet et al., 2018). We hypothesize that the "mentor-child" context should similarly decrease the ambiguity of the ToM question to make it clearer that it is a request about the mental states of the character Maxi. The performance of preschool children should then be significantly improved without changing the original explicit FBT. Should this be observed, we would conclude that the understanding of false beliefs develops before the age of 4 and that the abilities of young children are underestimated due to pragmatic factors.

We also believe that the "mentor-child" context can keep the control questions unambiguous. Therefore, we expect to have a rate of correct responses to the control questions that should be roughly equivalent to that of older children in the standard context.

[10]It can be noted that this interpretation of the memory question (an expectation of the experimenter to be controlling the answer to the ToM question) requires skills of second order ToM.

[11]Since the "ignorant," "naive," and "slow" robot was only there to strengthen the child's impression to be the one with the knowledge, its presence will be implied each time we refer to the "mentor-child" context.

4. EXPERIMENT: EXPLICIT FALSE BELIEF TASK IN THE MENTOR-CHILD CONTEXT

4.1. Materials and Methods

4.1.1. Participants

We recruited 62 native French children in preschool at "Les Petits Princes" in Versailles, France. The sample chosen in the classes was composed of 34 girls and 28 boys, from 38 months-old (3 years and 2 months) to 49 months-old (4 years and 1 month)[12]. The mean age of children was 44 months-old ($N = 62, M = 44$ months-old, $SD = 2.82$ months-old)[13]. The children were randomly assigned a condition depending on their age and gender. These conditions were "human experimenter" ("human" condition) and "robot experimenter" ("robot" condition). Each condition contained 31 children between 38 months-old and 49 months-old ($N = 31, M = 44$ months-old, $SD = 3.47$ months-old for the "human" condition and $N = 31, M = 44$ months-old, $SD = 3.09$ months-old for the "robot" condition).

4.1.2. Materials

The story "Maxi and the chocolate" was shown to the child with the clips displayed in **Figure 1**. Each clip was 6.4 × 5.8 cm (2.5 × 2.3 in). The clips were shown in a black and opaque folder containing a cardboard spacer in A4 format (21 × 29.7 cm or 8.3 × 11.7 in). All three clips of the task were attached to the cardboard spacer in advance. The robot used in this experiment was a 58 cm tall (23 in) NAO robot created by Aldebaran Robotics (Aldebaran version 4—"Evolution"). It has a moving head, arms and hands, each with three fingers, allowing it to point at the clips of the story to punctuate its discourse with gestures. NAO is also equipped with a microphone and speakers to communicate with humans. The robot was remotely controlled by the experimenter using a computer, but its gestures and speech were recorded in advance. They could see the child thanks to a camera in the eyes of the robot. The movements and the speech sections triggered in real time avoided having too much variability between the different participants, while still making it possible to make the answers of the robot fit those of the child. We chose to remotely control the robot for logistical reasons: even though NAO does have the ability to recognize speech making it possible for it to autonomously react, the behaviors of children can sometimes be unpredictable. Some flexibility was needed to reproduce with fluidity a natural conversation with a human. Moreover, children

[12]Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin. All data was collected anonymously. The experiment was reviewed and approved by the Ethics Committee of the CHArt Laboratory. The Ethics statement can be obtained here: https://osf.io/wk4af?view_only=d8d2e16f39ea4186b994e2468a7408cd.

[13]The initial sample contained five classes of preschool children for a total of 70 children from 34 to 49 months-old. We had at least one 34 months-old child, one 35 months-old child, and so on, in each of the two conditions. During the experiment, we noticed that 3 children in the "robot" condition (the youngest: 34, 35, and 36 months-old) became really scared when the NAO robot started moving, lifting its head and looking at the child. The movement of the robot is not as fluid as that of a human, and the noise of the motors is quite noticeable. In consequence these three children had to be removed from the condition. In order to keep the conditions homogeneous in terms of age, we removed one child under 3 years-old in the "robot" condition who had succeeded in the task, and all 4 youngest children in the "human" condition, who had all failed in the task.

could sometimes speak too low to be understood by the robot, which would have made the interaction impossible. Finally, the robot also allowed a better standardization of the enunciation context thanks to its intonations and utterances being strictly identical across all participants. To make NAO more childish and less intimidating, its voice was manipulated so that it had a higher pitch and spoke more slowly. NAO was programmed to blink randomly during the experiment to strengthen its humanness.

4.1.3. Procedure

Before the beginning of the experiment one member of the research team, that we call the companion, was welcomed into the class and gave their name. Children were sitting in a circle in front of the teacher. She explained that this new person was there to make all the children of the class work on a task, a bit like teacher. The procedure in both conditions was subdivided into two sequential steps: the priming step and the explicit FBT.

4.1.3.1. Human Condition

In this condition the companion told the children they would be participating in an activity if they agreed. After this introduction each child was guided to the location of the experiment, in a quiet multi-purpose room of the school. During the walk, the companion told the child the didactic contract: "You're about to listen to a story, like in class, and my colleague [name of the experimenter] will ask you some questions. You will need to answer them." The companion then asked for the agreement of the child. If the child agreed, the child then entered the room without the companion and stayed with the experimenter.

The experimenter then introduced themselves to the child who was seated on a chair in front them. The child's ability to correctly name the two colors (blue and green) was checked before the main task[14]. The false belief story was then verbally told and illustrated with clips, which allowed non-verbal answers for children which preferred to point at their answer instead of saying them.

If the child's answer to the ToM question was the green cupboard, the experimenter pointed at it on the clip and said "ah it is there." If the child did not change their initial answer, the answer was considered to be correct. When the child instead gave the incorrect answer, no confirmation was required, and the answer was immediately considered to be false.

The reality question and the memory question were then asked (respectively following the success and failure to the ToM question).

Finally, the experimenter thanked the child, and the companion guided them back to the classroom while congratulating them.

4.1.3.2. Robot Condition

In this condition, the companion explained that they came with a NAO robot. They told the class NAO needed the children's help because it knew nothing while they all knew a lot. If one child doubted of their knowledge, the companion told them that they were learning many things in class but also that they already knew a lot. More importantly: they knew more than the robot. The companion then asked if the children agreed to teach things to NAO[15].

Like in the "Human" condition, the companion guided each child individually from the class to the location of the experiment and told them the didactic contract: "Your job is to teach lots of new things to NAO. NAO is a little robot who knows nothing. NAO needs you to learn new things. NAO doesn't know anything. You will be his teacher. Do you agree to be his teacher?" To make the child understand NAO's ignorance the companion pointed at the child's clothes, or various items in the location of the experiment. They asked the child to name them, which was done without any difficulty, and then they told the child:

> "You see, NAO doesn't know all that. If NAO asks you weird, strange questions, you must answer him. Remember that he knows nothing. If NAO tells you strange things, or if he makes mistakes, you correct him[16]. You are his teacher. Do you agree to be NAO's teacher [name of the child]?"

If the child agreed, the companion let the child enter the experiment room and left the child "alone" with the robot (see **Figure 2**). This is an especially important detail with the robot. Indeed, should the companion remain in the room, the child may be tempted to answer the robot in the same way they would with a human experimenter because of the presence of an adult in the room. Pragmatic interpretations would then be modified. The actual experimenter was hidden behind a screen, without the child knowing about it, and remotely controlled NAO using a laptop.

NAO introduced itself to the child. It asked if the child agreed to be its teacher because he was there to "learn many things." Once again, if the child did not agree, the experiment stopped. The robot then asked the child if they can help it learn colors. NAO then pointed the colored cardboard sheets and made mistakes (for example: NAO said "That's yellow?" while designating the blue cardboard, making it more believable the fact that NAO did not know much and thus strengthening the role of the child as a teacher). To further strengthen the naive aspect of the robot, NAO insisted on its ignorance all along the experiment (e.g., "Alright, I had not understood that. I am really stupid." It is important to note that great care was given to not overdoing the "stupidity" of the robot. Indeed, if its mistakes became too predictable, there was a great risk of losing the child's interest in teaching it anything. A child could quickly have inferred that "NAO will make mistakes no matter what I tell him." which could have biased the child's experience in the task if it had not been controlled.

NAO initiated the story "Maxi and the Chocolate" by telling the child "A man told me a story that I did not understand. Do you want to help me?" Identically to the "Human" condition, NAO told the story and then asked the ToM question and the control question.

The answer to the ToM question was considered to be correct if the robot was corrected by the child when it

[14]In both conditions all children correctly named the two colors.

[15]A script of the interaction between a "mentor-child" and the NAO robot, written as a clinical and critical Piagetian interview (Ducret, 2016) can be found at https://osf.io/z5s7k/?view_only=d8d2e16f39ea4186b994e2468a7408cd.

[16]The companion insisted on this specific point.

FIGURE 2 | Robot experimenter and materials for the "Robot" condition. The NAO robot is seated on a table in front of the child.

made a mistake trying to repeat the answer. For example, if the child answered that Maxi will look for the chocolate in the green cupboard (initial position), NAO said: "Ah thanks, so if I understood well the chocolate is in the blue cupboard." If the child corrected NAO and said: "No, the chocolate is there." (indicating the green cupboard) or "No, it is in the green one." the answer was considered to be correct. Note that, just like in the human condition, the child could also point at the clips directly instead of answering verbally.

Once the task was over, NAO thanked the child for being its teacher "Thank you, you've been an awesome teacher. I've learned many things thanks to you!" and told them goodbye. The companion then came to bring the child back to the classroom. Sometimes the teacher asked how the task went. The companion congratulated the child for the quality of their teaching. They told the rest of the class that NAO still needed to work to learn things. This way, the fact that NAO needed help was progressively very well-communicated to the whole class while they did their usual class activities.

4.2. Results

In this experiment, the dependent variable was a dichotomous variable which modalities were interpreted in terms of *success* or *failure*. According to the procedure used by Wellman and Liu (2004), the child's response was a *success* when they produced correct answers to both the ToM question and the reality question. This variable will be noted below: *TR* (ToM and Reality). We also analyzed the data from a less conservative perspective (Wimmer and Perner, 1983) by interpreting the *success* as being simply a correct answer to the ToM question. This second version of the dependent variable will be symbolized by the letter *T*. Finally, we also analyzed the answers to the memory question for children who had failed to answer the ToM question correctly. This variable will be designated by $\neg TM$ (Not ToM and Memory)[17].

The independent variable (noted *C*) had two modalities: "Human" vs. "Robot." We also tested the influence of two other variables: the sex of the child (noted *S*, with two modalities: Girls vs. Boys), and the age of the child in months (noted *A*, numerical variable ranging from 38 to 49 months-old). In the first step of the analysis, we adjusted a linear model on our data with a link *logit* function and a *binomial* distribution of the errors. We applied this treatment to all three versions of the dependent variable *TR*, *T* and $\neg TM$. For all of them we included, in the linear predictor of the models, the main effects of each of the three factors *C*, *S*, and *A*, as well as all the possible interactions which includes the triple interaction. We refer to these *saturated* models by using the following expressions: firstly $TR \hookleftarrow C * S * A$, secondly $T \hookleftarrow C * S * A$ and thirdly $\neg TM \hookleftarrow C * S * A$. The "$\hookleftarrow$" symbol refers to the influence, supposed or real, of the independent variables on the dependent variable while the "$*$" symbol indicates that all the possible interactions between the independent variables are taken into account. We then used a procedure of automatic *backward* simplification on all the saturated models to lead to the corresponding final models.

The principal characteristics of these four models are shown in **Table 1**. Results show, regardless of the version of the dependent variable (*TR*, *T*, and $\neg TM$), that the simplification model systematically terminated on a final model containing only the *C* factor. This means that the success rate for ToM, defined either as the conservative model (*TR*) or as a more permissive

[17]The complete R script of the analyses is available at https://osf.io/34hzn/?view_only=d8d2e16f39ea4186b994e2468a7408cd and the data itself is available at https://osf.io/wzx7g/?view_only=d8d2e16f39ea4186b994e2468a7408cd.

TABLE 1 | Main characteristics of the data-adjusted models.

Models	Residual deviance	ddl	AIC
$TR \hookleftarrow C * S * A$ (saturated)	69.86	54	85.86
$TR \hookleftarrow C$ (final)	73.15	60	77.15
$T \hookleftarrow C * S * A$ (saturated)	73.37	54	89.37
$T \hookleftarrow C$ (final)	77.57	60	81.57
$\neg TM \hookleftarrow C * S * A$ (saturated)	40.06	28	56.06
$\neg TM \hookleftarrow C$ (final)	43.00	34	47.00

For the different versions of the dependant variable (TR, T, and ¬TM), the simplification of the saturated models led to final models containing only the predictive variable C (the influence of the experimental conditions). In all situations, the resulting models are more parsimonious with a reduction of the AIC (Akaike Information Criterion) of about 8 points.

model (T), remained completely explainable by the condition (i.e., "Human" vs. "Robot"). The same was also observed for the final model of the memory question ($\neg TM$). Therefore, in our study neither the sex (S) nor the age (A) of the children can significantly improve the prediction of the success we observed. Thus, in the rest of the paper these two variables will be omitted.

A summary of the data we collected is shown in **Table 2**.

Table 3 shows the coefficients associated with each condition for the three resulting models required to estimate the effect size of the condition (C).

The model $TR \hookleftarrow C$ has a significant coefficient ($\beta = 1.23, p < 0.05$). This coefficient is also significant for the model $T \hookleftarrow C$ ($\beta = 1.38, p < 0.05$). We show in **Table 3** the odds ratio (OR) corresponding to the β coefficients. We obtained $OR = 3.43$ for the model $TR \hookleftarrow C$, which means that the chances of success for a child in the "Robot" condition are almost 3.5 times greater than that of children in the "Human" condition. Regarding the model $T \hookleftarrow C$, we obtained $OR = 3.98$ indicating that, when simplifying the success criterion, a child was four times more likely to succeed in the "Robot" condition than one in the "Human" condition. We also observed a tendency for children who failed the ToM question to answer the memory question with more success when it was asked by the robot ($\beta = 1.62, p = 0.06$). While not significant we can still point out that children were five times more likely to correctly answer with the robot than they were with the human ($OR = 5.04$).

Table 2 shows the distribution of the participants depending on the condition and on whether they succeeded in the task (depending on the criterion used to define success). An unilateral proportion test with no continuity correction reveals that the success rate for TR is significantly different from chance ($\chi^2 = 2.77, df = 1, p < 0.05$). When only looking at the ToM question (T) the test does not show a significant difference ($\chi^2 = 0.4, df = 1, p > 0.05$). However, as explained above, an answer scored as "correct" for the ToM question needed to be confirmed. Thus, we can probably think that the 58% of children in the "Robot" condition did not simply give the correct answer at random. Only 2 children changed their choices for ToM question in the "Robot" condition (and were counted as a wrong answer for ToM) and none in the "Human" condition.

5. DISCUSSION

The goal of this study was to propose a new methodology of the explicit FBT. With it, we hoped to inhibit the erroneous interpretations made by 3 years-old children regarding the ToM question. Our "mentor-child" context seems to have changed the prevailing interpretation of the ToM question in the way we hoped: a request to report the false belief of the character. The young children who participated in our study did better in the "Robot" condition than those in the "Human" condition. This result has three important consequences:

1. It provides new experimental arguments for a pragmatic explanation of the failure of young children in explicit FBT (Cummings, 2013; Helming et al., 2014, 2016; Westra, 2017; Westra and Carruthers, 2017; Frank, 2018).
2. It indicates that a significant proportion of pre-school children can correctly answer the original ToM question.
3. This result, following those of Jamet et al. (2018) on Piaget's class inclusion task[18], supports the relevance of our methodology to disambiguate the experimenter's expectations through their question in developmental tasks.

In our study, the performance of children in the conjunction of the ToM and reality questions was significantly improved, with children in the "Robot" condition being about 3.5 times more likely to succeed than those in the "Human" condition. Moreover, in the "Human" condition the performances were comparable to those observed in the literature (Wimmer and Perner, 1983; Hogrefe et al., 1986; Perner et al., 1987). The previous result is also amplified if, as Wimmer and Perner (1983), one adopts a laxer interpretation of the success. Indeed, looking only at the recorded responses to the ToM question, our results show that children belonging to the "Robot" condition are 4 times more likely to succeed. Furthermore, although we focused on the performance of pre-school children with participants between 3 and 4 years-old, it is interesting to note that the success rate in our "Robot" condition (58%) is similar to what Wimmer and

[18] Jamet et al. (2018) randomly assigned 40 children (between 5 and 6 years-old) to two conditions similar to those we created for the present study ("Human Experimenter" vs. "Ignorant NAO Robot"). The authors observed a clear improvement in performance in the "Ignorant NAO Robot" condition: one child out of five answered correctly in the "Human Experimenter" condition, and more than six children out of ten in the "Ignorant NAO Robot" condition.

TABLE 2 | Distribution of the children's answers depending on the experimental condition ($N = 62$).

Conditions (*C*) Questions	"Human"	"Robot"	Total	"Human"	"Robot"	Total
ToM: "Where will Maxi look for the chocolate?"	"Green cupboard" (*T*)			"Blue cupboard" (¬*T*)		
	8 (26%)	18 (58%)	26 (42%)	23 (74%)	13 (42%)	36 (58%)
Reality: "Where is the chocolate really?"	"Blue cupboard" (*TR*)					
	6 (19%)	14 (45%)	20 (32%)			
Memory: "Do you remember where Maxi put the chocolate in the beginning?"				"Green cupboard" (¬*TM*)		
				12 (39%)	11 (35%)	23 (35%)
Success rate for the control question depending on the ToM answer	(*R*/*T*)			(*M*/¬*T*)		
	75%	78%	77%	52%	85%	63%

TR (correct joint answer to both the ToM & reality questions), T (correct answer to the ToM question), and ¬TM (correct answer to the memory question for those who only gave an incorrect answer to the ToM question). The breakdown does not take into account the variables sex (S) and age (A) of children because, as the regression analyses have shown, neither of these two variables affects the probability of success to the ToM question. $N_{Robot} = 31, N_{Human} = 31$.

TABLE 3 | Estimated β coefficients associated with belonging to the conditions for the three models.

Models	β (OR)	*SD* (β)	*z*-Value	*p*-Value
TR ↫ *C*	1.23 (3.43)	0.58	2.12	0.03*
T ↫ *C*	1.38 (3.98)	0.55	2.52	0.01*
¬*TM* ↫ *C*	1.62 (5.04)	0.87	1.85	0.06

The Odds Ratio corresponding to each of the coefficients are shown between parentheses. Since the link function of the models is a logit, calculating the exponential of the coefficients is the only thing required to get the OR.
*$p \leq 0.05$.

Perner (1983) considers to be a successful completion of the task for children between 4 and 6 years-old (57%). However, this proportion remains lower than the one recorded by the same authors for children between 6 and 9 years-old (89%). We can point out that this success rate is not as sensational as those observed in some studies (such as the 90–100% observed in Rubio-Fernández and Geurts, 2013, 2016). To our knowledge, we are the first to find such a performance without any modification being made to the initial paradigm with the same scenario, the same questions and the same procedure for analyzing the answers given by the child. Besides, the experimental protocol also considers several methodological criticisms made in the studies cited above (Wellman et al., 2001; Wellman and Liu, 2004; Kammermeier and Paulus, 2018; Priewasser et al., 2020). Indeed, we considered a correct answer to be when the child answered both questions (ToM and reality) correctly. Our participants were also randomly assigned to the "Robot" and "Human" conditions in a homogeneous way.

Replicating our procedure with children between 4 and 9 would be important and interesting in order to see if our methodology produces a similar improvement for the 4–6 years-old age group or if this level of performance corresponds to a plateau for children below the age of 6. In the first case, the traditional results found in the literature of explicit FBT, showing a progression with age, would not qualitatively change but simply be shifted toward younger age groups. It would then be essential to replicate our procedure with children between 2 and 3 to decide at what age the explicit FBT can start to become successful. In the second case, with a limited success rate before the age of 6, the 6–7 age group would be the pivotal age for reaching almost a 90% success rate with explicit FBT. This would imply that important pragmatic and/or cognitive capacities would still be lacking at the age of 5, preventing a total success at this age. This would not necessarily contradict our pragmatic approach. Indeed, numerous studies report that 6 is the pivotal age to be able to correctly generate relevance implicatures (Bosco and Gabbatore, 2017; Grigoroglou and Papafragou, 2017). As explained above, explicit FBT are complex as they require a "triple attribution of mental states" (Helming et al., 2014, 2016; Westra and Carruthers, 2017). They imply not only that the child must take into account the perspective of the character of the story but also that of their interlocutor, who is an adult experimenter in the standard test, since the child infers expectations from them and finally their own perspective. Consequently, this task would not be a first order task, but rather a second order task, thus explaining the threshold of a 60% success rate.

It is also interesting to look specifically at how the children responded to the control questions in our "mentor-child" context. As was shown by Perner and Wimmer (1985) the two types of success coding (with or without the reality question) slightly modify the results downwards without changing the interpretation: the chances of success in the "Robot" condition relative to that in the "Human" condition went from 4 times higher to about 3.5 times higher. The success rate decreased when the answer to the reality question was considered. In terms of proportions, both conditions had a similar success rate in the reality question (75% in "Human" and 77.7% in "Robot" conditions). This may confirm that the emphasis on the "slow" trait of the robot allows us to disambiguate a large part of the reality question. For the memory question, as predicted, we found a higher success rate (85%) in the "Robot" condition which is similar to the 83.7% observed in Wimmer and Perner (1983) with children between 4 and 5 years-old. This result seems to confirm our hypothesis that this question is noticeably ambiguous in the standard context for preschool children.

The fact that this "mentor-child" context works with 3 years-old children also provides new arguments in favor of the use of a humanoid robot as a tool in experimental research on children and adults. Our study did not have as its main objective to measure the importance of the robot tool itself but rather the influence of the context it allowed to produce. However, it would be important in a future study to see if there is a specific robot effect in our results that can stand out on its own. We can run the experiment with puppets or other objects representing an "ignorant," "naive," and "slow" entity (in an unpublished exploratory study on the class inclusion task Jamet, Saïbou-Dumont and Baratgin (2018) obtain, from children of French Guyana, similar performances to those obtained in Jamet et al. (2018) with the use of a puppet or a man disguised as a robot instead of the NAO robot[19]). A second possibility would be to run the study with a knowledgeable and intelligent "NAO teacher" in addition to the human experimenter and to the slow robot. Many studies have shown that children as young as 3 years-old accepted the NAO robot as a possible teacher (Rosanda and Istenic Starcic, 2020). Oranç and Küntay (2020) observed in children from 3 to 6 years-old a clear preference to ask the robot questions about machines, and less about biology and psychology. Thus, one could expect that in this situation children would be even less inclined to interpret the ToM question correctly as being a question about Maxi's beliefs. All this seems to indicate that our results are largely the consequence of the "mentor-child" context.

Our study also brings two important new elements on child-robot interaction. Firstly, our study seems to confirm that preschool children attribute beliefs to the robot as was also indicated in recent studies (Di Dio et al., 2018, 2020a; Marchetti et al., 2018). Secondly, in our study the child can behave like a mentor, with the motivation to help a robot understand a story. This helping behavior still happened even though physical interactions are quite limited. Indeed, the robot did not have a great autonomy of movement when seated in front of the child and it displayed few expressions (the NAO robot cannot smile and its facial expressions are very limited: only its eyes can change colors to signify an emotion). This is coherent with results from Martin et al. (2020a,b) which indicate that the helping behavior of children does not seem to be conditioned to the level of animated autonomy nor to the friendly expressions of the robot's voice.

While our methodology seems to work for an interaction with children older than 3 years and 2 months, children between 5 and 6 years-old, and also with adults (Masson et al., 2015, 2016; Masson et al., 2017a,b), children under the age of 3 did not agree to stay "alone" with NAO. It is possible that the choice of a humanoid robot may trouble young children. Di Dio et al. (2020b) shows that 3 years-old children tend to trust humans more than robots, as opposed to 7 years-old children. Manzi et al. (2020) showed that children of 5, 7, and 9 years-old differently assign mental states to two humanoid robots, NAO and Robovie, differing on their level of anthropomorphism. It is possible that, for very young children under 3 years-old, the NAO robot may not be the most adequate tool (see Damiano et al., 2015, for a review of the different types of robots). This would explain the low number of studies with children of this age. Recent reviews on the interactions between neuro-typical children and a robot (Jamet et al., 2018; Neumann, 2020; van Straten et al., 2020) indicate that only one study was conducted using NAO and a group of children from 2 to 8 years-old (Yasumatsu et al., 2017). The few other studies conducted on 2 years-old either used the tiny humanoid robot QRIO that is smaller than a 2 years-old child (Tanaka et al., 2007), the iRobiQ robot that looks more like a toy (Hsiao et al., 2015), or robots specifically designed to be enjoyed by young children like the stuffed dragon robot Dragonbot (Kory Westlund et al., 2017) and the RUBI-4 (Movellan et al., 2009). Thus, should we decide to do a longitudinal study from 2 to 9 years-old using our contextual procedure we would need to study which robot is the most relevant to play the role of a rather slow and ignorant being for all ages.

6. CONCLUSION

The essential proposition that has been developed and tested in our study is that the answer to the ToM question crucially depends on the "conversational logic" at play in the contextualized interactions between the experimenter and the child. This interaction shapes the child's interpretation of the question. Our contextual modification pragmatic filters the ToM question, removing irrelevant interpretations. The standard paradigm forces the child to perform a relevance search to interpret an ambiguous question asked by an expert (with a status like that of a teacher) within the limits of the child's own meta-cognitive knowledge. In our "mentor-child" context the child answers an unequivocal question about the beliefs of the protagonist of the story asked by a somewhat slow entity who needs their help. Here, the 3 years-old child can answer correctly even if their meta-cognitive knowledge is poorly developed. This procedure helps us become more "competent" speaker-experimenters (Sperber, 1994) as it offers a tool to place ourselves at the level of the young child's interpretation strategy. This allows them to realize what is relevant to answer the question correctly. For similar reasons we believe that this procedure may also help with the understanding of the second-order ToM (Perner and Wimmer, 1985). It could reduce the ambiguity of the question of the experimenter which exists in many experimental paradigms. Results of Lombardi et al. (2018) indeed indicate, using a dialogical perspective, that a considerable part of the supposed failures observed with children in the second order task are in fact the result of an adverse pragmatic context. In addition to the Piagetian

[19]Experiments were carried out during the MIN formation of teachers requested by the rector of the academy of French Guyana.

tasks of length and number conservation (McGarrigle and Donaldson, 1974), volume conservation (Jamet et al., 2014), or class inclusion (Politzer, 2016), there are a variety of experimental paradigms that lend themselves well to our disambiguation methodology. The "mentor-child" context could also facilitate some studies with atypically developing participants, such as individuals with an Autism Spectrum Disorder who show both deficient performance on the false belief task (Baron-Cohen, 1997) and in language pragmatics (Angeleri et al., 2016). Finally, our methodology also offers new clues on the relevance of human-robot interaction, and in particular on child-robot interaction. More studies should most certainly focus on the interaction between children and robots, taking in consideration the beliefs they associate to these tools, and their effect on well-known psychological results.

DATA AVAILABILITY STATEMENT

The datasets analyzed for this study can be found in the Open Science Framework repository at the following address https://osf.io/ey4n5/?view_only=d8d2e16f39ea4186b994e2468a7408cd.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by M. Charles El-nouty, Professeur des Universités en Mathématiques, LAGA UMR7539, Université Paris 13: President of the Committee. M. Jean-Yves Henry, Chirurgien-Dentiste diplômé de l'Université Paris 7; M. Michel Dionnet, Chef de cuisine, Membre titulaire de l'Académie Culinaire de France; M. Fabrice Gutnick, MCF associé en Sciences de l'Éducation, Université Jules Vernes Amiens, Psychologue du travail; Mme Dominique Klarsy Médecin du travail. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

JB and FJ: conceptual elaboration. JB, FJ, and MD-S: design of the study. MD-S and FJ: data collection. J-LS: data analysis. JB and MD-S: draft of the manuscript. JB, BJ, and FJ: critical revision of the manuscript. All authors contributed to the article and approved the submitted version.

FUNDING

We thank the P-A-R-I-S Association for the technical and financial help we received as well as the CHArt laboratory which participated in financing the publication of the article in open access. P-A-R-I-S Funding number: 2020-0301728-5 CHArt-Paris8 Funding number: 2020-0331087-0.

ACKNOWLEDGMENTS

We would like to express our gratitude to the National Education Inspector Eugénie Montes of Versailles and to the pedagogical team of Les Petits Princes de Versailles school for welcoming us, for their involvement and for their interest in this research project. We would like to thank in particular the headmaster Mrs. Wiklacz, as well as the teachers of the school: Mrs. Moussette, Combe, Dupuy, and Delehaye. We also thank Natalia Obrochta, Olivier Masson, and Youri Minne for their help during the pre-tests of this experiment. We also thank Research Director (DR) Béatrice Desgranges and Anne Chevalier, copyright manager of *Revue de Neuropsychologie*, for their authorization to republish **Figure 1**, originally from Duval et al. (2011). We would finally like to thank Andrew Hromek for proof-reading the paper and Guy Politzer for his careful review of the first draft of this document.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

BRIEF RESEARCH REPORT
published: 07 December 2020
doi: 10.3389/fpsyg.2020.586065

A Further Look at Reading the Mind in the Eyes-Child Version: Association With Fluid Intelligence, Receptive Language, and Intergenerational Transmission in Typically Developing School-Aged Children

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A number of tasks have been developed to measure the affective theory of mind (ToM), nevertheless, recent studies found that different affective ToM tasks do not correlate with each other, suggesting that further studies on affective ToM and its measurement are needed. More in-depth knowledge of the tools that are available to assess affective ToM is needed to decide which should be used in research and in clinical practice, and how to interpret results. The current study focuses on the Reading the Mind in the Eyes Test (RMET) primarily to investigate in a sample of 112 children the currently unexplored relationships in middle childhood between performance on the RMET and fluid intelligence. Relationships with receptive vocabulary, age, and sex were also investigated. Moreover, because studying the family's influence on children mentalization could have important implications in developing prevention and treatment interventions, this study offers a novel contribution to the field by exploring the family's influence on children's RMET performance. Although significant positive correlations were found among RMET-C performance, fluid intelligence, and receptive language, regression analysis revealed that fluid intelligence was the only predictor. No family influence was found on children's RMET performance. On the whole, results from the current study offer some support to the hypothesis that RMET-C is not a "pure" ToM task, specifically the effect of fluid intelligence on RMET performance should be taken into account when RMET is used both in research and in the clinical setting.

Keywords: reading the mind in the eyes, receptive language, fluid intelligence, theory-of-mind, intergenerational transmission

OPEN ACCESS

Edited by:
Douglas Frye, University of Pennsylvania, United States

Reviewed by:
Beth Oakley, King's College London, United Kingdom
Pietro Spataro, Mercatorum University, Italy

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Specialty section:
This article was submitted to Cognitive Science, a section of the journal Frontiers in Psychology

Received: *22 July 2020*
Accepted: *16 November 2020*
Published: *07 December 2020*

Citation:
Rosso AM and Riolfo A (2020) A Further Look at Reading the Mind in the Eyes-Child Version: Association With Fluid Intelligence, Receptive Language, and Intergenerational Transmission in Typically Developing School-Aged Children. Front. Psychol. 11:586065. doi: 10.3389/fpsyg.2020.586065

INTRODUCTION

Mentalization refers, in a broad sense, to the human ability to interpret one's own and others' behavior in terms of intentional mental states (e.g., desires, needs, feelings, and beliefs) (Allen, 2003; Fonagy and Target, 2005).

Over the last decades several tasks have been designed to evaluate mentalization, and an extensive body of studies has focused on its development in non-clinical samples and its impairment in clinical groups. As Luyten et al. (2019) stated, mentalizing has become over time an umbrella concept that overlaps with Theory of Mind (ToM), so that in literature mentalization and ToM are often used as interchangeable terms. At first, developmental studies focused largely on children's understanding of false belief (Wimmer and Perner, 1983), then research moved toward the investigation of emotion decoding (Baron-Cohen et al., 2001a), pragmatic language comprehension (Happé, 1994), and mental state talk (Bartsch and Wellman, 1995), while more recently studies have focused on children's reflective functioning in the context of close attachment relationships (Ensink et al., 2015).

A vast array of studies support the hypothesis that the construct of mentalization is a complex and multifaceted one (for a review, Fonagy and Bateman, 2019) that includes distinct components underpinned by different neural correlates (Schurz et al., 2014; for a review).

A number of instruments have been designed to assess mentalization in adults and in children, however, to date, it is not really clear which component(s) of mentalization each tool actually measures. Warnell and Redcay (2019) administered a diverse set of ToM tasks to three different sample groups, each of which contained children of the same age, and found that at any age, receiving high scores on one task did not predict performance on another task designed to assess the same underlying ability. In middle childhood, this study did not find any significant correlation between the scores obtained on the children's version of the Reading the Mind in the Eyes (RMET-C; Baron-Cohen et al., 2001b), the Strange Stories (Happé, 1994), and the Faux Pas Task (Baron-Cohen et al., 1999). In addition, in middle childhood full-scale IQ was significantly related only to Strange Stories performance, suggesting that the association between ToM and intelligence should be investigated regarding each ToM component, rather than assumed regarding ToM as a unitary construct.

Some recent developmental studies on samples of preschool children (e.g., Lecce et al., 2015; Longobardi et al., 2017) offered support for a distinction between cognitive and affective ToM—namely the ability to attribute beliefs and/or intentions above and beyond the appearance vs. the ability to recognize and infer emotions and feelings.

In addition, Gallant et al. (2020) found that different affective ToM tasks did not correlate with each other in a sample of preschool children, supporting the hypothesis that diverse instruments measure distinct facets of affective ToM, consequently they suggested that further studies on affective ToM and its measurement are needed.

The current study aims primarily to investigate in a sample of school-aged children the **currently** unexplored relationship between performance on the RMET—a widely used affective ToM task—and fluid intelligence. Relationships among RMET performance, receptive vocabulary, age, and sex were also investigated.

Baron-Cohen et al. (1997, 2001a) developed the adult version of the RMET both to measure sensitive to subtle dysfunction in the domain of social cognition in adults with a diagnosis of autism or Asperger syndrome, and for use with adults of normal intelligence. RMET consists of 36 photographs of the eye region of the face of different actors and actresses. At the four corners of each photo there are four words (the target word and its three foils), the subject is simply required to choose the correct term.

The test was conceived as a measure of the individuals' ability to put themselves into the mind of the other person by tuning into their mental state. Consequently, Baron-Cohen et al. (2001a) defined the test as an advanced theory of mind task which requires having a mental state language and, at a quick and automatic level, matching the eyes in each photo to eye region expressions stored in one's memory as seen in the context of a particular mental state, and to choose the word the eyes in the photo most closely match. Baron-Cohen et al. (2001a) specified that RMET only implies the first stage of theory of mind, namely the attribution of the relevant mental state, whereas it does not include the second stage consisting of inferring the content of that mental state (e.g., in the case sadness was identified as the mental state, participants were not required to infer the reason why). The test includes a control task consisting of showing the same photographs again and asking the participant to determine the gender of the person based on his/her eyes. This control task, named Gender Recognition task, implies a non-mentalistic social cognition from the eyes as well as attention to the stimuli.

The final version of the RMET was able to detect meaningful individual differences with normal performance significantly below ceiling. In the original study no effect of general intelligence was observed in the non-clinical sample with regard to RMET performance, while a trend toward a female advantage was found. On the contrary, the most recent meta-analyses (Baker et al., 2014; Peñuelas-Calvo et al., 2019) found that intelligence played a significant role in adults' non-clinical performance on the RMET and that verbal and performance abilities equally contribute to this relationship. The better performance by females on RMET was confirmed by another meta-analysis (Kirkland et al., 2013). Recently, Baron-Cohen et al. (2015) too, in an extensive study, found that females outperformed males in non-clinical samples, while no sex difference was found in individuals with autism.

A child version (RMET-C; Baron-Cohen et al., 2001b), conceptually derived from the adult version, consists of 28 photographs of the eye region of female and male adult actors. Like the adult version, each illustration is accompanied by four words that refer to mental states (e.g. "hate," "surprise," "cross," kind"). The child is asked to point to the one that best represents what that person feels or thinks. The Gender Recognition task may be used as a control test, like in the adult version.

Although the test has been very widely used, especially in the adult version, data regarding psychometric properties are rarely reported and are controversial, especially with regard to internal consistency that was found to be low in four studies (Voracek and Dressler, 2006; Harkness et al., 2010; Müller and Gmünder, 2014; Hayward and Homer, 2017), and minimally acceptable or acceptable in five other studies (Serafin and Surian, 2004; Dehning et al., 2012; Vellante et al., 2013; Girli, 2014; Vogindroukas et al., 2014). To our knowledge, only four studies have investigated internal coherence in the children's version (Girli, 2014; Müller and Gmünder, 2014; Vogindroukas et al., 2014; Hayward and Homer, 2017), and no studies have ever been conducted on an Italian sample. Test-retest stability was found to be acceptable for both the adult (Vellante et al., 2013) and the child version (Hallerbäck et al., 2009). Some studies confirmed the single factor structure assumed by Baron-Cohen et al. (2001a) both in the adult (Vellante et al., 2013) and in the child version (Carey and Cassels, 2013), while Olderbak et al. (2015) did not find a single-factor solution in the adult version.

RMET-C does not require reasoning about mental states but only recognizing them, thus it may be primarily considered a measure of affective mentalizing, mainly focused on emotion recognition (Oakley et al., 2016). Most studies (Rutherford et al., 2012; Ha et al., 2013; Fossati et al., 2014; Gallant et al., 2020) described RMET-C as a measure of affective ToM assessing the ability to understand the feeling of mental states. In addition, some studies (Lawrence et al., 2004; Carroll and Yung, 2006) found that it correlated with measures of empathy.

Although the child version of the RMET was used in several studies to compare ToM abilities in clinical and non-clinical samples, to our knowledge, no study has specifically aimed to investigate its relationship with verbal ability and non-verbal intelligence, nor with sex, age or family background.

Some studies reported data concerning the relationship between RMET-C performance and intelligence in typically developing school-aged children. Furthermore, these studies used different intelligence measures, making it hard to compare results. Some studies did not report a significant effect of intelligence on RMET-C performance (Sharp, 2008; Mary et al., 2016; Stevens et al., 2017), while Baribeau et al. (2015) found a significant effect, and Warnell and Redcay (2019) reported a trend toward statistical significance. Only two studies (Ibanez et al., 2013; Levy and Milgram, 2016) investigated the relationship between fluid intelligence and RMET-C performance, and reported a significant association.

Regarding sex, in children samples findings were contradictory in the few studies reporting data. A small effect of sex on RMET-C performance was found in two studies (Chapman et al., 2006; Baribeau et al., 2015), but no effect was reported in a more recent study (Warnell and Redcay, 2019).

Concerning the effect of age on RMET–C, results were inconsistent as well: some studies found a significant, positive correlation (Chapman et al., 2006; Baribeau et al., 2015; Durdiaková et al., 2015; Misailidi, 2018; Warnell and Redcay, 2019), whereas others did not (Sharp, 2008; Peterson et al., 2015; Hayward and Homer, 2017; Stevens et al., 2017).

To our knowledge, no previous study focused on the family's influence on children's RMET performance by investigating the effect of parents' education or the presence of older siblings, although parental level of education and the presence of older siblings were extensively taken into account when investigating their influences on children's ToM development, which resulted in mixed results (for a review, Hughes and Devine, 2017).

Concerning the intergenerational transmission of affective ToM, to our knowledge, only one study (Lecciso et al., 2013) has been conducted administering RMET both to mothers and children in a small sample of deaf and hearing children. However, they computed and reported a composite ToM score calculated from different ToM tasks, including RMET. Findings from this study showed that the maternal composite ToM index predicted the same ToM index in deaf children, but not in hearing children.

Two other studies investigated parental influences on children's ToM using RMET. Sabbagh and Seamans (2008) focused on intergenerational transmission of theory of mind skills in a typically developing population and found that parental performance on RMET correlated with the children's performance on a scaled battery of theory of mind tasks (not including RMET) in a sample of 46 children aged 3 and their parents (43 mothers and 3 fathers). Ragsdale and Foley (2011) studied maternal and paternal influences on RMET scores in an adult sample using correlations between pairs of full, maternal and paternal siblings and concluded that there was a maternal influence on RMET performance, although it remained unclear how much of this influence was genetic and how much was environmental.

Given the absence of previous studies on the family influence on children's RMET performance, and because studying the family's influence on children mentalization could have important implications in developing prevention and treatment interventions, this study aims to offer a novel contribution by investigating the effect of parents' education, the presence of older siblings, and of parental performance on RMET.

Because of the inconsistency of the findings from previous studies, the present study was exploratory regarding the effect of sex, age, and intelligence on RMET children's performance. Concerning intelligence, we decided to specifically investigate the effect of verbal ability and the effect of fluid intelligence using two measures designed to assess receptive vocabulary and abstract reasoning through perceptual stimuli.

Regarding the investigation of the relationship between parents' and children's performance on RMET, our study was also exploratory because, to our knowledge, this is the first study aimed at investigating the intergenerational transmission of affective ToM by assessing RMET performance both in children and in their parents.

MATERIALS AND METHODS

Participants

One hundred-twelve mothers (*M* age= 40.77 years ± 4.43; *M* education = 12.53 years ± 3.08), 42 fathers (*M* age = 43.73 years ± 5.19; *M* education = 11.78 years ± 3.49), and their children (55 males and 57 females, aged 77–139 months ($M = 108.02 \pm 17.13$) agreed to participate in the study.

Participants were from intact, mostly working class families. Regarding education, only 11 mothers (9.8%) and 11 fathers (9.8%) had obtained a university degree, while 42 mothers (37.5%) and 55 fathers (49.1%) had received an education below the high school level. In this sample, the level of education was lower than the Italian average.

Participation was voluntary and no fee or other incentive was provided for taking part in the study.

None of the participants suffered from psychiatric or neurological illness or severe sensory impairment, none of the children had special educational needs, as reported by the family pediatricians.

Measures

Affective ToM

The RMET was administered to mothers and fathers to assess affective ToM. The Italian version (Vellante et al., 2013) showed acceptable internal consistency (Cronbach's alpha 0.605) and good test-retest stability (ICC = 0.833). One point is assigned to each correct answer, 0 for the wrong or not given answer. The sum of the correct answers, ranging from 0 to 36, was the score used in the current study. The control task Gender Recognition test was also administered to mothers and fathers to control the effect of non-mentalistic social intelligence, as suggested by Baron-Cohen et al. (2001a).

The Italian version (Liverta Sempio et al., 2003) of the RMET-C was used to assess affective ToM in the children. As per administration guidelines, during the task participants could ask the examiner questions and look up a glossary available to them if they needed a better understanding of the words in the test. One point is assigned to each correct answer, 0 for the wrong or not given answer. The sum of the correct answers, ranging from 0 to 28, was the score used in the current study.

The control task Gender Recognition test was administered to the children as well.

Receptive Language

The standardized Italian version (Stella et al., 2000) of the Peabody Picture Vocabulary Test—Revised (PPVT-R; Dunn and Dunn, 1981) was used to assess children's receptive vocabulary. PPVT-R consists of 180 cards, each of them presenting four drawings. The child was asked to point to the picture corresponding to the word pronounced by the examiner, and the item was scored 1 point or 0 points if it matched the picture or not, respectively. The examiner stops the test when the child gives eight wrong out of eight consecutive answers.

The task does not involve immediate memory or recall component. Raw scores were used and analyses were performed controlling for age.

Fluid Intelligence

The standardized Italian version (Belacchi et al., 2008) of the Raven's Progressive Matrices (CPM; Raven et al., 1998) was used to assess fluid intelligence. It is a non-verbal test of analytic reasoning designed for children aged five to eleven, consisting of 36 items over three sets (A, Ab, B), each including 12 items with increasing difficulty. All items have a missing segment with six possible choices for completion. Children were asked to select the one fitting the drawing best. Raw scores were used and analyses were performed controlling for age.

Procedure

The study was presented to three family pediatricians who agreed to collaborate in the research by asking parents and their children (only those not suffering from psychiatric or neurological illness or severe sensory impairment, or having special educational needs) for consent to be contacted by researchers. 70% of parents agreed to be contacted, after which a researcher called them to schedule a meeting. All the families agreed to allow their children to participate. All the mothers agreed to participate as well, while only 42 fathers were willing to be administered RMET. All the children gave their assent. During the first meeting with parents and children, the study was further illustrated, then the RMET was administered to the parents and two subsequent appointments were scheduled to meet the child and to administer in counterbalanced order the RMET-C, the Raven Colored Progressive Matrices, and the PPVT-R. All the participants were met individually at the family pediatricians' office. As per administration guidelines, no time limit was given to complete the tasks, and a break of about 10 min between one task and the next was offered to the children. Each of the two sessions with the children lasted no more than 45 min, and on average, 7–10 days went by between appointments.

Ethical approval for this study was not required in accordance with local legislation and national guidelines. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

RESULTS

Preliminary analyses of the data indicated that the study variables, except paternal education and scores on Gender Recognition task, were normally distributed with skewness and kurtosis values falling within the accepted range of ± 2 (George and Mallery, 2010), thus appropriate for parametric statistical tests. Descriptive statistics are reported in **Table 1**.

Only 54 mothers, 12 fathers, and 34 children performed at ceiling on the Gender Recognition test, however no significant association was found between RMET and control task for mothers ($rho = 0.045$, $p = 0.645$), fathers ($rho = 0.214$, $p = 0.174$), or children ($rho = 0.132$; $p = 0.166$). As shown in **Table 1**, mean values on control task were near to ceiling.

RMET-C internal consistency, as measured by Cronbach's alpha, was 0.593.

A t-test was performed to analyze the effect of sex on the variables of interest. No significant effect of sex was found on children's age, scores on RMET-C, PPVT-R, or CPM (*ps* ranging from 0.178 to 0.959).

Since a significant correlation ($r = 0.391$; $p < 0.0001$) was found between age and children's performance on RMET, the effect of sex was investigated again by performing an analysis of covariance with age as the covariate. This analysis confirmed that

TABLE 1 | Descriptive statistics: Age, Reading the Mind in the Eyes Test, Gender Recognition task, Education, 4 Peabody Picture Vocabulary Test, Raven Progressive Matrices.

	Mothers (N = 112)		Fathers (N = 42)		Children (N = 112)	
Variable	**M**	**SD**	**M**	**SD**	**M**	**SD**
Age	40.77	4.43	43.73	5.19	108	17.43
RMET	23.82	4.03	22.67	3.67	17.81	3.85
GR task	34.92	1.93	34.48	1.66	26.29	1.88
Educ.	12.53	3.08	11.78	3.49		
PPVT-s					103.13	11.88
PPVT-r					121.71	20.88
CPM-p					61.20	25.55
CPM-r					26.96	4.96

M, mean; SD, standard deviation; RMET, global score on The Reading the Mind in the Eyes Test; GR task: score on Gender Recognition task; Educ., Years of education; PPVT-s, standard score on Peabody Picture Vocabulary Test; PPVT-r, raw score on Peabody Picture Vocabulary Test; CMP-p, percentile scores on Raven Progressive Matrices; CMP-r, raw scores on Raven Progressive Matrices.

TABLE 2 | Partial correlations between RMET-C, CPM, and PPVT scores, controlling for children's age.

	CPM	PPVT
RMET-C	0.408***	0.258**
CPM		0.377***

CPM, raw scores on Progressive Matrices; PPVT, raw score on Peabody Picture Vocabulary Test; RMET-C, global score on The Reading the Mind in the Eyes Test –Child version.
$^{**}p < 0.01$; $^{***}p < 0.001$.

TABLE 3 | Multiple regression analyses for predicting RMET-C performance.

	Children's RMET-C score $F_{(3,108)}$ =15.784; R^2 =0.305; $p < 0.0001$				
	B	***SE***	***β***	***t***	***p***
CPM	**0.291**	**0.076**	**0.387**	**3.843**	**<-0001**
PPVT	0.026	0.020	0.143	1.294	0.198
Age	0.023	0.023	0.106	1.004	0.318

final model in bold; CMP, raw score on Progressive Matrices; PPVT, raw score on Peabody Picture Vocabulary Test.

there was no effect of sex on children's affective ToM ($F = 0.934$, $p = 0.336$).

Partial correlation analysis, controlling for age, was used to investigate the association between RMET-C, PPVT-R, and CPM scores. Results yielded significant correlations between children's performance on RMET-C, PVVT-R ($r = 0.258$, $p = 0.006$), and CPM scores ($r = 408$, $p < 0.0001$). Results are shown in **Table 2**.

To explore the extent to which PPVT-R and CPM scores predict RMET-C performance in children, a multiple regression analysis was carried out using children's PPVT-R, CPM scores and age as predictors of the children's RMET-C performance.

TABLE 4 | Partial correlations between RMET-C, mother's education, father's education, mother's performance on RMET, and father's performance on RMET, controlling for children's age.

	ME	FE	M-RMET	F-RMET
RMET-C	0.173	0.140	–0.017	0.140

ME, mothers' education; FE, fathers' education; M-RMET, global score on the Reading the Mind in the Eyes Test –Adult version reported by mothers; F-RMET, global score on the Reading the Mind in the Eyes Test –Adult version reported by fathers; RMET-C, global score on the Reading the Mind in the Eyes Test –Child version.

The final model, shown in **Table 3**, accounts for approximately 30% of the variance in children's RMET-C score. Specifically, only the CPM score predicted children's RMET-C score ($t = 3.843$, $p < 0.0001$).

With regard to the effect of the family's influence on affective ToM, partialled correlation analysis, controlling for children's age, was conducted to investigate the association of the children's affective ToM with parents' education and parents' performance on RMET scores. Results yielded no significant correlation, as shown in **Table 4**.

Finally, the effect of having older siblings on affective ToM was investigated using an analysis of covariance with age as the covariate. Forty-six of 112 children had older siblings. No significant effect with regard to older siblings was found ($F = 0.200$, $p = 0.655$).

DISCUSSION

Preliminary results found that the data produced robust variability in distribution, thus supporting the notion that RMET is not susceptible to the ceiling effect in middle childhood (Baron-Cohen et al., 2001b). Internal consistency for RMET-C was less than acceptable (Devellis, 2012), replicating findings from the Italian validation study of the adult version of RMET (Vellante et al., 2013), and from other studies on the psychometric properties of the children's version (Müller and Gmünder, 2014; Hayward and Homer, 2017), thus raising further questions regarding its unidimensionality. Positive and negative affect subscales were previously hypothesized (for a review, Hudson et al., 2020).

In line with some previous studies (e.g., Chapman et al., 2006; Misailidi, 2018), a significant effect of age was found on children's performance. No effect of sex was found, even when controlling for age, thus replicating Warnell and Redcay (2019) findings in middle childhood.

Significant positive correlations were found between RMET-C performance, fluid intelligence, and receptive language. A significant association between fluid intelligence and RMET-C performance had also previously been found by two studies (Ibanez et al., 2013; Levy and Milgram, 2016). To our knowledge, only two studies on school-aged children (Lecciso et al., 2013; Peterson et al., 2015) used PPVT-R to investigate the association between receptive language and RMET performance. Lecciso et al. (2013) found that receptive language predicted RMET performance, whereas Peterson et al. (2015) did not find any significant associations. In our study, a regression analysis using CPM, PPVT-R, and age as predictors of the children's RMET-C performance revealed that fluid intelligence was the only predictor, and that the model accounts for approximately 30% of the variance. It is noteworthy to point out that the effect of fluid intelligence was observed above and beyond the effect of age. Findings from the current study show that the effect of fluid intelligence on RMET performance, previously reported in a sample of secondary school students (Ibanez et al., 2013) and in two non-clinical adult samples (Bates and Gupta, 2017; Meinhardt-Injac et al., 2020), is also substantial in middle childhood. The effect of fluid intelligence on RMET performance may be related to the fact that RMET involves facial processing, which is also associated with fluid intelligence (Wilhelm et al., 2010), and that both fluid intelligence and social cognition engage the frontal lobe (Roca et al., 2010).

In the current study no family influence was found on children's RMET performance: neither parental education nor the presence of older siblings had an effect on children's scores on RMET. Interestingly, no correlation has ever been found between parents' and children's RMET performance either. A vast array of studies showed that maternal mentalization had a significant effect on children's mentalizing abilities (e.g., Meins et al., 2002, 2003; Ensink et al., 2015; Rosso et al., 2015; Scopesi et al., 2015; Rosso and Airaldi, 2016), and the only previous study investigating the association between mothers' and children's RMET performance (Lecciso et al., 2013) reported a significant correlation in a sample of hearing mothers and deaf children, whereas the association was not found in the hearing dyads. However, unlike our study, Lecciso et al. used a composite ToM index combining RMET and Recognition of Faux Pas (FPT-C; Baron-Cohen et al., 1999), thus findings are not fully comparable. The absence of association between parents' and children's RMET performance observed in our study raises further questions about the diagnostic meaning of the RMET scores. Fonagy and Bateman (2019) reported that both high and low scores on RMET might suggest mentalizing deficits, thereby signaling, respectively, hypermentalizing and hypomentalizing. In fact, a number of studies (e.g., Dinsdale and Crespi, 2013) showed that individuals suffering from Borderline Personality Disorder (BPD) outperformed non-clinical individuals on RMET because of their increased proneness to focus on external features that, in the absence of genuine reflective mentalizing, makes them highly vulnerable in social contexts, generating high interpersonal hypersensitivity. In line with Fonagy and Bateman (2019), it could be argued that the absence of association between parents' and children's RMET performance emerging from our study might be attributable to a non-univocal interpretation of RMET scores, therefore, low scores, like high ones might indicate mentalizing deficits.

On the whole, results from the current study offer some support to the hypothesis proposed by Mary et al. (2016) that RMET-C is not a "pure" ToM task. Specifically, findings from the current study highlight the effect of fluid intelligence on RMET performance, an effect that should be taken into account when RMET is used both in research and in the clinical setting.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

ARo designed the study, performed the statistical analyses, and wrote the article. ARi contributed to the search for references, coordinated data collection and scoring, and contributed to the final version. Both authors contributed to the article and approved the submitted version.

ACKNOWLEDGMENTS

We are grateful to the children and their parents who kindly took part in the study, as well as the pediatricians who agreed to collaborate in this research.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

ORIGINAL RESEARCH
published: 14 January 2021
doi: 10.3389/fpsyg.2020.596419

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When a Circle Becomes the Letter O: Young Children's Conceptualization of Learning and Its Relation With Theory of Mind Development

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In two independent yet complementary studies, the current research explored the developmental changes of young children's conceptualization of learning, focusing the role of knowledge change and learning intention, and its association with their developing theory of mind (ToM) ability. In study 1, 75 children between 48 and 86 months of age (M = 65.45, SD = 11.45, 36 girls) judged whether a character with or without a genuine knowledge change had learned. The results showed that younger children randomly attributed learning between genuine knowledge change and accidental coincidence that did not involve knowledge change. Children's learning judgments in familiar contexts improved with age and correlated with their ToM understanding. However, the correlation was no longer significant once age was held constant. Another sample of 72 children aged between 40 and 90 months (M = 66.87, SD = 11.83, 31 girls) participated in study 2, where children were asked to judge whether the story protagonists intended to learn and whether they eventually learned. The results suggested that children over-attributed learning intention to discovery and implicit learning. Stories with conflict between the learning intention and outcome appeared to be most challenging for children. Children's intention judgment was correlated with their ToM understanding, and ToM marginally predicted intention judgment when the effect of age was accounted for. The implication of the findings for school readiness was discussed. Training studies and longitudinal designs in the future are warranted to better understand the relation between ToM development and children's learning understanding.

Keywords: theory of mind, learning concept, knowledge state change, learning intention, epistemic egocentrism

OPEN ACCESS

Edited by:
Peter Bright,
Anglia Ruskin University,
United Kingdom

Reviewed by:
Chiara Fini,
Sapienza University of Rome, Italy
Francesco Margoni,
University of Oslo, Norway

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Specialty section:
This article was submitted to Cognitive Science, a section of the journal Frontiers in Psychology

Received: *19 August 2020*
Accepted: *22 December 2020*
Published: *14 January 2021*

Citation:
Wang Z and Frye DA (2021) When a Circle Becomes the Letter O: Young Children's Conceptualization of Learning and Its Relation With Theory of Mind Development. Front. Psychol. 11:596419. doi: 10.3389/fpsyg.2020.596419

INTRODUCTION

From an early age, discovery learning is important for children's cognitive development. Gopnik and Wellman's (2012) probabilistic learning model proposes that infants and young children's discovery of causal structures based on statistical information gained from exploration and observation is the driving force for cognitive development. However, little is known about children's understanding of the concept of learning. Do they understand that learning something means acquiring new knowledge? Do they understand that some forms of learning are intentional while others are not? The conceptualization of learning is critical for children's epistemological thinking (Kuhn, 2000) and affects the outcome of actual learning (Jeong and Frye, 2018a). Focusing on children's understanding of how the mind works, theory of mind (ToM) research breaks ground for its inquiry into the origins of understanding the mental characteristics of teaching and learning (Kruger and Tomasello, 1996; Olson and Bruner, 1996). In two independent yet complementary studies, the current research explores developmental changes in young children's conceptualization of learning, focusing on knowledge change and learning intention, and their associations with the development of ToM.

A THEORY OF MIND FRAMEWORK FOR THE CONCEPTUALIZATION OF LEARNING

Although there is evidence that young children, even infants, have an implicit awareness of others' mental states and can use that information to facilitate their own learning (e.g., Sabbagh and Baldwin, 2001; Birch and Bloom, 2002; Saylor and Troseth, 2006; Harris, 2012), little is known about children's explicit understanding of the mental activities and processes in learning. Language as Vygotsky's *psychological tools* (as cited in Fini and Borghi, 2019) functions as an important mechanism in the acquisition of the abstract concepts such as learning. Fini and Borghi (2019) argue that abstract concepts evoke the metacognitive feeling that our knowledge is not sufficient, and we need to learn from more informative others. Infants utilize psychological tools such as imitation, turn-taking, and shared attention to communicate with others and seek help. With the emergence of language, however, abstract language could function as a social tool in metacognition, likely through inner speech (Borghi et al., 2018). Inner speech helps children to retrieve exemplar information, reflect on the meaning of the word, reconstruct the linguistic explanation, and predict what is needed to learn from other sources.

The mental awareness of agency, representational ability, and time perspective are essential to the understanding of learning. Realizing "self as an active cognitive agent and as the causal center of one's own cognitive activity" (Flavell, 1987, p. 26) might be one of the early ToM achievements that contribute to children's acquisition of the concept of learning. The distinction between self and others enables children to appreciate others as cognitive agents too. Representational ability gives rise to the awareness of mentality and its fluidity (Perner, 1991). The development of episodic memory (Naito, 2003) and the ability to mentally travel from one time point to another (Atance and Meltzoff, 2005; Atance and O'Neill, 2005; Busby and Suddendorf, 2005) further enable children to appreciate the knowledge state change in the learning process.

While ToM research has primarily focused on children's understanding of false belief, recent advances include children's understanding of other epistemic processes such as knowing, remembering, and understanding (Louca, 2019). These topics overlap with those scrutinized in the area of metacognition. Although they share similar research questions, metacognition and ToM research differ in the multiple ways. Research on metacognition focuses on how metacognitive knowledge and regulation affect cognitive achievement in school-aged children. ToM research, on the other hand, mainly focuses on the conceptual underpinnings of these abilities during preschool years. Furthermore, metacognition directs one's own learning, whereas ToM helps children to understand other people's mental states (Lockl and Schneider, 2007; Proust, 2012).

Focusing on early development in young children, recent studies have demonstrated that children's developing ToM is associated with their understanding of knowledge state and intention in the context of teaching (Ziv and Frye, 2004; Frye and Ziv, 2005; Jeong and Frye, 2018b). Children are sensitive to the teacher's knowledge state in their learning. They choose more knowledgeable informants to learn from (e.g., Sabbagh and Baldwin, 2001; Birch and Bloom, 2002; Harris, 2012). They also demonstrate better learning performance when the informant is knowledgeable compared to ignorant (Jeong and Frye, 2018b). ToM development also contributes to children's own teaching. Baer and Friedman (2018) asked 4–6-year-old children to describe objects to a listener who was either knowledgeable about the topic or ignorant. Children of all ages were less likely to mention specific facts to a listener who was ignorant of the topic compared with one who was knowledgeable. Older children were also more likely to mention general facts to a knowledgeable listener compared to an ignorant one. Bass et al. (2019) found that children who passed the false belief understanding tasks were more likely to select pedagogical evidence to correct other's false belief in their teaching. They also found that training children's pedagogical evidence selection improved their ToM, indicating a reciprocal relationship between ToM and teaching and learning experiences. Jeong and Frye (2018a) found that when children were explicitly told the intention of a teaching event in the direct instruction condition, their intention understanding significantly contributed to the learning outcome. However, this effect was not present in the indirect condition where children were simply told that they were going to play a game without explicit labeling of the teaching intention.

Learning has served as a central construct in psychology, education, neuroscience, artificial intelligence, among many other disciplines (Barron et al., 2015). A full definition of learning is beyond the scope of the current paper; however, a working definition specifies that learning requires enduring changes in knowledge that result from experience (Barron et al., 2015). There are two implications of this definition; first, learning must involve a change in knowledge, and second, the change can either be intentional or unintentional. Knowledge here refers to both declarative knowledge and procedure knowledge, or skills. Knowledge state change involves both updating or gaining descriptive knowledge (i.e., knowing *that*) and gaining new skills (i.e., knowing *how*). Jeong and Frye (2020) recently investigated young children's understanding of learning as a knowledge-based concept. Children were asked to judge whether they themselves or someone else had learned something new after comparing the knowledge state difference before and after the learning event. The study found that a concept of learning based on knowledge change developed during early childhood: 3-year-olds did not think learning involved a change in knowledge or skill, but 5-year-olds did.

Despite the basic understanding that learning requires a change in knowledge state, there are still unanswered questions about other aspects of children's concept of learning. For example, when and how do children understand that learning involves an enduring mental representational change? Do children's own knowledge states affect their judgments of others' learning? Do children understand that learning can take place with or without intention? Finally, is children's ToM development related to their understanding of learning?

LEARNING AS MENTAL REPRESENTATIONAL CHANGE

Psychological explanations are essential for children's teaching and learning (Wellman and Lagattuta, 2004). Young children's spontaneous utterances about *learning* and *teaching* increase between the ages of 3 and 5 years (Bartsch et al., 2003). However, their narratives about learning and teaching tend to focus on the behavioral terms instead of mental state terms. For example, young children describe learning as "listen to the teacher;" "sit up... so you can learn more," instead of "thinking" (Thorpe et al., 2004). Young children describe teaching as "showing," while older children who have acquired false belief understanding describe teaching as "telling" (Astington and Pelletier, 1996). Pramling (1988) characterized young children's initial concept of learning as that of behavioral change, i.e., *learning to do*. At this point, the content to be learned is usually a skill, an activity, or a behavior. With age, children proceed to a higher level understanding of learning as representational change, i.e., *learning to know*. They begin to talk about facts or knowledge as intellectual properties. Only in elementary school do children begin to appreciate that learning changes thinking itself, i.e., *learning to understand*.

Sobel and Letourneau (2018) presented 3–5-year-olds with stories of a character who either learned something through own exploration or from explicit instructions given by others. Younger children could correctly report learning from exploration, but they underestimated learning from direct instruction. In fact, they tended to attribute learning in both types of stories to actions. Older children were more likely to differentiate the two types of learning and correctly identify the knowledge source. The authors concluded that younger preschoolers' action-oriented learning concept showed that they were yet to develop a metacognitive understanding of how learning occurred.

The first goal of the current study was to explore when children understand that learning requires genuine knowledge change. In other words, when do they appreciate that learning is more than just a change in behavior, but also a mental representational change? To answer this question, children were given a new task which featured a person who did not know how to write a letter O, but nevertheless learned how to draw a small circle perfectly. Children were asked whether the person had learned to write the letter O or not. To understand that the behavior of drawing a circle is not enough for learning to happen requires a mental representational concept of learning. The behavioral change without mental representational change is not replicable or enduring. Learning only occurs when the new representational meaning of the circle is acquired.

EGOCENTRISM

Young children tend to erroneously assign their own knowledge and belief to others. In the unexpected content false belief task (Gopnik and Astington, 1988), after seeing the real content of a misleading container firsthand, 3-year-old children could not understand that a naïve protagonist who had not seen the content would not know what was really in it. Similarly, children in the unexpected location false belief task (Wimmer and Perner, 1983) witnessed an object being moved from one location to another while the story protagonist was away. However, young children consistently claimed that the protagonist would look for the object in the new location, even though they knew that he had not seen the location change.

Arising from self-agency, this self-centered perspective has been extensively researched under various labels, such as egocentric perspective taking (Piaget and Inhelder, 1956), curse of knowledge (Camerer et al., 1989; Birch and Bloom, 2003; Birch, 2005), and epistemic egocentrism (Royzman et al., 2003). For example, Birch and Bloom (2003) tested 3–5-year-old children who either knew or did not know what was inside a toy. They were then asked to judge whether a character knew the content. The results revealed that when 3- and 4-year-old children were ignorant of the content, they were more accurate at judging other's knowledge state. In contrast, when young children knew what was inside the toy, they overestimated other's knowledge, as if their judgments were "cursed" by their own knowledge. The magnitude of the bias decreased with age, indicating younger children were more prone to the curse of knowledge. Interestingly enough, when the other party was familiar with the toy, there were no differences in children's judgment of whether the other party knew the content or not between the child-knowledgeable and the child-ignorant conditions across the age groups. Even the youngest children were able to judge the informed other party knew what was inside of the toy, suggesting children were indeed able to take other people's perspectives; they were only biased by their own knowledge when making judgment about someone who was more ignorant than themselves.

Given the epistemic egocentrism, would children's own previous knowledge affect their judgment of others' learning? The second goal of the study was to explore the effect of egocentrism on children's judgments of learning. If children are familiar with the material being learned, would they be more prone to say that others have learned it too? On the other hand, would children's learning judgments be more accurate if the learning content is entirely novel to them and they do not have any previous knowledge to interfere with their judgment? Finally, if children show an egocentric bias, does it affect children of different developmental stages equally? To our knowledge, this is the first study examining the potential impact of epistemic egocentrism on children's concept of learning.

INTENTION TO LEARN

Unlike teaching, which is "an intentional activity to increase the knowledge (or understanding) of another" (Ziv and Frye, 2004, p. 458), learning does not have to be intentional. While intentional or deliberate learning is often associated with optimal learning outcomes, learning could happen without intention, such as in discovery learning and implicit learning. It has been found that young children generally have difficulty understanding when a desired outcome is achieved by coincidence (Phillips et al., 1998). For example, preschoolers fail to recognize that certain bodily functions, such as knee-jerk reactions or sneezes, are unintentional (Lang and Perner, 2002; Montgomery and Lightner, 2004). Young children also find it difficult to judge whether an act is moral or not based on intentions. Studies have documented that around 4–5 years of age, children's moral judgment goes through an outcome based to intent based shift (Cushman et al., 2013; Margoni and Surian, 2016, 2017, 2020; Nobes et al., 2017).

In studies on children's understanding of teaching intentions (Frye and Ziv, 2005; Ziv et al., 2008), 3- and 5-year-olds were told stories about an instance of imitation where the teacher was not aware of the presence of the learner. Three-year-olds reported that the teacher tried to teach even without knowing the learner was there. Only 5-year-olds who passed the false belief task could distinguish the intention to teach from the intention to learn in the imitation task. Another story described an instance of a hidden teaching intention, in which a teacher did not make the teaching intention explicit; instead, she specified that she was going to "play a game" with the children. Three-year-olds failed to detect the teaching intention embedded in an educational game; only 5-year-olds could tell that the teacher was really trying to teach. It seems at least in the case of teaching, young children found it difficult to understand an intention that was not explicitly stated, or in conflict with the teaching and learning outcome.

Sobel et al.'s (2007, study 2) has examined children's understanding of motivational mental states in learning, including desire, attention, and intention. In this study, 4- and 6-year-olds were told stories of children learning a song from a teacher. Each story presented two mental states that were either consistent or inconsistent with each other. For example, a character who had the desire to learn might be either paying attention to the teacher's demonstration (Desire+/Attention+) or not (Desire+/Attention−). Children were asked whether the character learned the song and why. Children performed well in the consistent stories, but not in the inconsistent ones. Four-year-olds were more likely than 6-year-olds to judge that the character who wanted to learn but did not pay attention nonetheless learned. Young children's performances on the inconsistent stories were not different from chance level. The authors argued that 4-year-olds tended to judge whether someone learned based on desire, whereas 6-year-olds were more likely to integrate desire, intention, and attention in learning together.

By posing the task questions in an open-ended manner ("Did the person learn how to sing the song?"), the design of this study assumed a causal relation between the motivational mental states and the learning outcomes, which is not always the case. As discussed, learning does not have to be intentional; and even intentional learning does not always bring out the intended outcome. In other words, the design of the study implicitly defined learning as a direct outcome of motivation, instead of representational knowledge change. The consequence of such is especially problematic in the inconsistent stories. The answer to the question of whether the character learned the song in those stories is rather arbitrary. It is equally possible for one to learn a song or fail to do so in the inconsistent stories, which could explain children's chance level performance.

The third goal of the current study was to explore children's understanding of intention to learn and its correlation with their developing ToM. Different from previous studies, purposely designed tasks in the current study presented scenarios with various learning intentions coupled with either successful or failed learning outcomes, such as discovery learning when someone learned to make the color green by accidentally mixing blue paint and yellow paint; or implicit learning when someone learned a song simply by overhearing it, in order to explore whether and when children understand that having an intention to learn is not necessary for learning to occur.

THE PRESENT STUDY

The two studies reported in the current paper were part of the doctoral dissertation of the first author (Wang, 2010). Study 1 investigates when children understand that learning is a mental representational change instead of a behavioral one. It also examines whether children's own knowledge state affects their judgments of others' learning. Study 2 explores children's understanding of learning intention in different learning scenarios. In addition, both studies scrutinize the association between children's comprehension of the learning concept and their ToM development.

STUDY 1: KNOWLEDGE CHANGE AND EPISTEMIC EGOCENTRISM

Method

Participants

Jeong (2018) reported correlations between ToM and judgment of whether learning occurred ranging from 0.287 to 0.342. *A priori* power analysis was conducted in G*Power (Faul et al., 2009) adopting a conservative 0.287 as the correlation between ToM and learning judgment. Due to the one-directional nature of the correlation, one-tailed test was used with the alpha level set at 0.05. The results showed that 73 participants were required to achieve 80% power. Seventy-five children (36 girls) aged between 48 and 86 months from two preschools and two primary schools representing a wide range of social economic status neighborhoods in Hong Kong were recruited, including 25 4-year-olds (*M* = 52.80, *SD* = 3.22, 11 girls), 25 5-year-olds (*M* = 64.52, *SD* = 3.81, 12 girls), and 25 6-year-olds (*M* = 79.04, *SD* = 4.38, 13 girls). All children were fluent in Cantonese.

Measures and Procedure

The study protocol was reviewed and approved by a local university's Human Research Ethics Committee. Parents signed informed consents and children gave oral consents for participating in the study. Children individually participated in six learning tasks purposely designed for this study and three ToM tasks in one or two sessions of 15 min each in a quiet room in school with a trained experimenter. The tests were administered in Cantonese. The sequence of the learning tasks and the ToM tasks was counterbalanced.

The learning task

The purposely designed learning task in this study included three familiar content stories and three unfamiliar content stories. In each of these six stories, there were two characters who both produced a symbol, such as drawing a circle. One of the characters was told by the teacher the representational meaning of the symbol, hence acquiring a genuine knowledge change in the process, while the other failed to realize the representational meaning of the symbol and therefore did not achieve genuine knowledge change. The learning contents of the six stories were designed to include both knowledge that children were familiar with and novel knowledge that children would not possess, such as a symbol from a foreign language. At the end of each story, children were asked two memory control questions to check their comprehension of the stories, and a learning question to judge which character *learned* the knowledge. Stories used in the Study 1 are available in **Supplementary Material**.

The six stories were presented to children in a random order with props including paper, pencil, wooden letter blocks, and toy figurines. Children were given one point for each correctly answered learning question. The maximum scores for the familiar and unfamiliar learning tasks were both 3.

ToM measure

Theory of mind was measured using the *Knowledge Access* task, the *Contents False Belief* task, and the *Explicit False Belief* task as described in Wellman and Liu's (2004) ToM scale. The three tasks were selected in the current study because they measure the epistemic mental states of knowledge, belief, and false belief that are closely related to learning. The sequence of the three tasks was randomized in administration. Children scored 1 point for passing each task, making the maximum score for the ToM tasks 3 points.

Results

Five 6-year-old children did not finish the learning tasks. Listwise deletion was adopted in the following analysis. There were no significant differences between boys' and girls' performances, $t(68) = 0.084$, and $p = 0.933$ for unfamiliar tasks, with $M = 1.94$, $SD = 1.03$ for girls and $M = 1.92$, $SD = 1.01$ for boys; and $t(68) = 0.403$, $p = 0.688$ for familiar tasks, with $M = 1.91$, $SD = 0.95$ for girls and $M = 1.81$, $SD = 1.08$ for boys.

Table 1 presents the descriptive statistics for the variables in study 1. **Figure 1** shows the developmental changes in children's learning judgment in familiar and unfamiliar tasks by age group, with the error bars representing 95% CIs. Repeated measures multivariate analysis with familiarity as a within-subject factor and age as between-subject factor showed that familiarity did not significantly affect children's learning judgment, $F(1,67) = 0.135$, $p = 0.714$, $\eta^2 = 0.002$, Cohen's $f = 0.04$. There were no significant differences among age groups either, $F(2,67) = 2.597$, $p = 0.082$, $\eta^2 = 0.072$. However, the interaction between familiarity and age group did occur, $F(2,67) = 3.126$, $p = 0.045$, $\eta^2 = 0.089$, Cohen's $f = 0.31$. Four-year-old children performed marginally better in unfamiliar tasks ($M = 1.84$, $SD = 0.85$) than in familiar tasks ($M = 1.44$, $SD = 0.82$), $t(24) = 1.732$, $p = 0.096$, Cohen' $d = 0.48$ (Cohen, 1988). Six-year-old children, however, did slightly better in the familiar tasks ($M = 2.40$, $SD = 0.94$) than the unfamiliar tasks ($M = 2.05$, $SD = 1.23$), Cohen' $d = 0.32$, although the difference was not statistically significant, $t(19) = -1.584$, $p = 0.130$.

ANOVA with age as between-subject factor predicting learning judgment in familiar tasks showed that the means of the learning judgments in the familiar tasks increased with age, $F(2,67) = 5.693$, $p = 0.005$, $\eta^2 = 0.145$, Cohen's $f = 0.41$. Four-year-olds performed at chance level when they were asked which character learned in the story, $t(24) = -0.366$, $p = 0.718$. Scheffé *post hoc* comparisons further demonstrated that 6-year-olds ($M = 2.16$, $SD = 0.90$) outperformed 4-year-olds ($M = 1.44$, $SD = 0.82$) in their learning judgment in the familiar tasks, $p = 0.005$, Cohen' $d = 0.84$. On the contrary, the means of the learning judgments in the unfamiliar tasks were unchanged with age, $F(2,67) = 0.235$, $p = 0.791$; $\eta^2 = 0.007$, Cohen's $f = 0.08$, although the overall mean was above chance level, $t(69) = 3.544$, $p = 0.001$.

Children's performance on the ToM tasks increased with, $F(2,72) = 13.079$, $p < 0.001$, $\eta^2 = 0.266$, Cohen's $f = 0.60$. While children's ToM performance was not correlated with their learning judgments in the unfamiliar tasks, $r = 0.034$, $p = 0.782$, the correlated between ToM performance and learning judgments in the familiar learning tasks was significant, $r = 0.288$, $p = 0.016$; but the correlation became statistically non-significant once age was taken into consideration, $r = 0.121$, $p = 0.322$. Liner hierarchical regression was performed to predict learning judgment in familiar tasks with age entered in the first step and ToM entered in the second step. Only age significantly predicted children's learning judgment, explaining 17.4% of the variance, $F(1,68) = 14.365$, $p < 0.001$. ToM explained extra 1.3% of the variance, $F(1,67) = 1.049$, $p = 0.310$. Regression coefficients are presented in **Table 2**.

Discussion

Study 1 found that children's learning judgment in familiar tasks improved significantly with age between 4 and 6 years. Four-year-old children attributed learning randomly between somebody who gained knowledge and somebody who performed an accidental coincidence that did not involve mental state change

TABLE 1 | Descriptive statistics of Study 1.

	ToM	Familiar learning tasks	Unfamiliar learning tasks
	Mean ± SD [95% CI]	**Mean ± SD [95% CI]**	**Mean ± SD [95% CI]**
4-year-old	0.92 ± 0.76 [0.61, 1.23]	1.44 ± 0.82 [1.10, 1.78]	1.84 ± 0.85 [1.49, 2.19]
5-year-old	1.44 ± 0.92 [1.06, 1.82]	1.84 ± 1.07 [1.40, 2.28]	1.92 ± 1.00 [1.51, 2.33]
6-year-old	2.16 ± 0.90 [1.79, 2.53]	2.40 ± 0.94 [1.96, 2.84]	2.05 ± 1.23 [1.47, 2.63]
Total	1.51 ± 0.99 [1.28, 1.73]	1.86 ± 1.01 [1.62, 2.10]	1.93 ± 1.01 [1.69, 2.17]

N = 70.

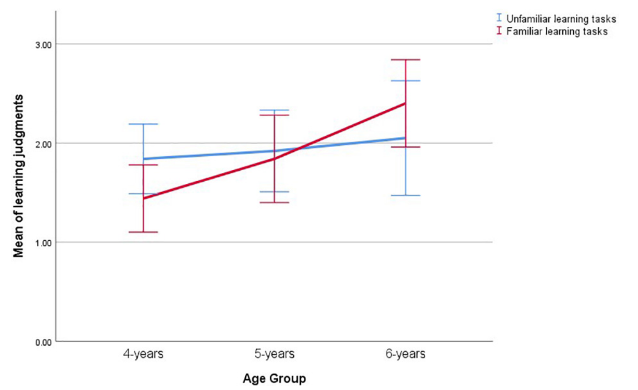

FIGURE 1 | Children's learning judgments in study 1 across age groups (error bars representing 95% CIs).

when they were familiar with the learning contents. Six-year-old children could correctly judge that accidental coincidence without representational change did not count as learning, and attribute learning only to situations where genuine knowledge change happened. Contrary to that in the familiar tasks, children's learning judgment did not improve with age in the unfamiliar tasks. Four-year-old children performed better in the unfamiliar tasks comparing to familiar tasks, while 6-year-old children did better in the familiar tasks. ToM was associated with children's learning judgment, but only when the learning contents were familiar. Furthermore, this association was largely driven by age. Once age was accounted for, the correlation between ToM and learning judgment in the familiar learning tasks was no longer significant.

The finding of younger children's indiscriminative learning attribution adds to the earlier reports on children's immature learning concept. It is worth noting that although it was already explicitly stated at the end of the story that one character now *knew* that was how to write a letter O while the other character still *did not know*, children were not making their learning judgment by simply relying on this statement. If they were indeed echoing this statement, they should have only attributed learning to the character who *knew*. The fact that younger children randomly attributed learning regardless whether or not the character knew its representational meaning indicates that they were not relying on knowledge change in their learning judgment.

Echoing Birch and Bloom's (2003) findings on curse of knowledge, the current result showed that younger children were affected by the familiarity of the learning contents. For 4-year-old children, being familiar with the learning contents themselves hindered their learning judgments. In contrast, being familiar with the content actually helped 6-year-old children to realize the protagonist's knowledge state had changed from being ignorant to being knowledgeable like themselves, although the effect was not statistically significant. The transition from *everybody should know what I know* to *you now learned what I know* reflects a developing self-other distinction that bridges mental state understanding of self (metacognition) and that of others (ToM). Although children's performance on the unfamiliar learning tasks was above chance level across age groups, even 6-year-olds' answers were still not perfect, indicating that by the time of school entry children were yet to develop a mature understanding of the concept of learning when facing novel tasks. Reflecting on their own knowledge state might be helpful for older children to develop an appreciation of how learning occurs in others.

TABLE 2 | Hierarchical linear regression predicting learning judgment in familiar tasks in study 1.

Model		Unstandardized coefficients		Standardized coefficients	*t*	*P*	95% Confidence interval for B	
		B	**SE**	**Beta**			**Lower bound**	**Upper bound**
1	(Constant)	−0.623	0.664		−0.939	0.351	−1.948	0.701
	Age	0.039	0.010	0.418	3.790	0.000	0.018	0.059
2	(Constant)	−0.478	0.678		−0.705	0.483	−1.832	0.876
	Age	0.033	0.011	0.361	2.929	0.005	0.011	0.056
	ToM	0.131	0.128	0.126	1.024	0.310	−0.124	0.387

N = 70.

The current results demonstrated a preliminary correlation between children's learning judgment and their developing ToM, consolidating Jeong and Frye's (2018b) finding. However, ToM was not a significant predictor to children's learning judgment in familiar tasks when the effect of age was accounted for, indicating that the changes in learning judgment were mostly driven by maturation.

Knowledge change is a necessary and sufficient condition for learning. Intention, on the other hand, is neither, even though it plays an important role in learning. Learning takes place as long as there is genuine knowledge change, no matter whether it is done on purpose or occurs as an accidental discovery. Study 2 explores how well young children understand the complex mechanism of intention's involvement in learning, especially when there is a conflict between the learning intention and its outcome.

STUDY 2: LEARNING INTENTION IN DISCOVERY AND IMPLICIT LEARNING

Method

Participants

There are no known studies reporting the correlation between ToM and learning intention judgment. Jeong and Frye (2018a) reported a correlation of 0.374 between ToM and teaching intention judgment, which was adopted here as reference in power analysis. *A priori* power analysis was conducted in G*Power (Faul et al., 2009). Due to the one-directional nature of the correlation, one-tailed test was used with the alpha level set at 0.05. The result showed that 42 participants were required to achieve 80% power. Severn-two children (31 girls) aged between 40 and 90 months were recruited from a preschool and a primary school representing a wide range of social economic status neighborhoods in Chong Qing, China. There were 24 children aged 4 years and younger (M = 54.08, SD = 3.99, 10 girls), 24 5-year-olds (M = 65.50, SD = 2.99, 11 girls), and 24 6 years and older (M = 81.04, SD = 5.75, 10 girls). All children were fluent in Mandarin Chinese.

Measures and Procedure

The study protocol was reviewed and approved by an overseas university's Institutional Review Board. Parents signed informed consents and children gave oral consents for participating in the study. Individual children participated in four learning tasks purposely designed for this study and three ToM tasks within 30 min in a quiet room in school with a trained experimenter. The tests were administered in Mandarin Chinese. The sequence of the learning tasks and the ToM tasks was counterbalanced. Both the four learning tasks and the three ToM tasks were administered in random order.

The learning tasks

Four learning intention stories were purposely developed for this study in a two-by-two design. They involved two levels of learning outcomes: positive and negative; and two levels of learning intentions: learning without intention and learning with a resistance intention. **Table 3** outlines the task specifications of study 2. There were no conflicts between the learning intentions and learning outcomes in the *failed learning* or *resistance to learning* tasks. The protagonists in these two stories either did not intend to learn, or resisted learning, and ended up not learning. In contrast, conflicts were presented in the other two stories. The protagonist in the *discovery learning* story discovered how to mix color green from other colors by accident. The one in the *implicit learning* story learned a song which he actually tried very hard not to learn after overhearing it. Stories used in study 2 are available in **Supplementary Material**.

The stories were presented to children with figurines, drawings, color paints, and brushes for demonstration. The experimenter read each story to children first, and then asked two control questions about the characters' knowledge state before and after the learning event. In case children answered any of the control questions incorrectly, their responses on that story were excluded from the analyses. Two task questions on the learning intention and learning outcome followed. Children scored 1 point for each correctly answered task question, making the maximum scores for both the intention judgment and the learning judgment 4 points.

ToM measures

The ToM tasks were identical to the ones in study 1.

Results

Seven children answered at least one of the knowledge control questions incorrectly. Their responses on that story were excluded from the analyses. Occasionally children answered "don't know" to the intention question or the learning question, which was treated as incorrect answer. Independent-samples Mann–Whitney U-tests showed that intention and learning judgment distributions in boys and girls did not differ significantly, standardized Mann–Whitney U ranging from −1.070 to 0.614, p ranging from 0.285 to 1.000.

Table 4 shows the descriptive statistics of study 2. **Figure 2** shows children's intention judgment across age groups in the individual learning tasks. Cochran's Q test was adopted to compare within-subject binary intention judgments. The result indicated that there were differences in children's responses across the four learning tasks on the intention question, x^2 = 59.948, df = 3, $p < 0.001$. Children performed significantly better in tasks without conflict between the learning intention and learning outcome, i.e., the *failed learning* and the *resistance to learning* stories, than those with a conflict, i.e., the *discovery learning* and the *implicit learning* stories. There were significant differences between *discovery learning* and *failed learning* intentions, McNemar's x^2 = 29.257, df = 1, $p < 0.001$, and

TABLE 3 | Task specifications of study 2.

	Learning intention	Learning outcome
Discovery learning	Negative	Yes
Failed learning	Negative	No
Implicit learning	Resistance	Yes
Resistance to learning	Resistance	No

TABLE 4 | Descriptive statistics of study 2.

	ToM	Sum of intention judgments	Sum of learning judgments
	Mean ± SD [95% CI]	Mean ± SD [95% CI]	Mean ± SD [95% CI]
4-year-old	0.92 ± 0.92 [0.52, 1.31]	1.32 ± 0.78 [0.97, 1.66]	3.46 ± 0.83 [3.11, 3.81]
5-year-old	1.96 ± 0.71 [1.65, 2.26]	2.48 ± 0.98 [2.03, 2.92]	3.55 ± 0.74 [3.22, 3.87]
6-year-old	2.05 ± 0.76 [1.69, 2.41]	2.38 ± 1.01 [1.95, 2.80]	3.63 ± 0.71 [3.32, 3.93]
Total	1.61 ± 0.95 [1.28, 1.84]	2.06 ± 1.06 [1.80, 2.32]	3.54 ± 0.76 [3.36, 3.72]

N = 70.

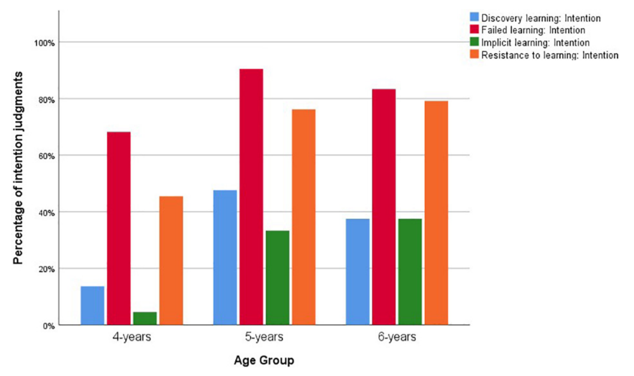

FIGURE 2 | Children's intention judgments in study 2 across age groups.

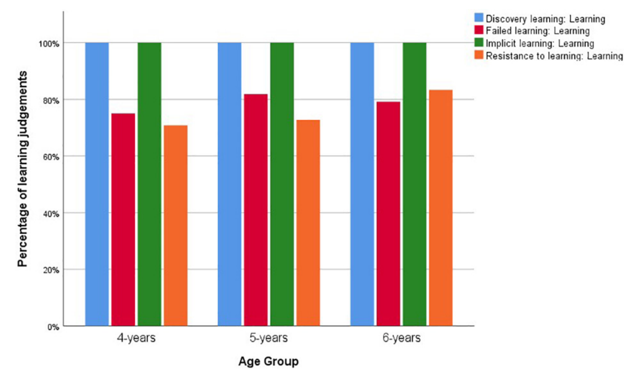

FIGURE 3 | Children's learning judgments in study 2 across age groups.

between *implicit learning* and *resistance to learning* intentions, McNemar's $x^2 = 18.27$, $df = 1$, $p < 0.001$. However, even 5- and 6-year-old children's intention judgments in the *discovery learning* and the *implicit learning* stories were not significantly different from chance level, $t(45) = -1.185$, $p = 0.242$ for the *discovery learning* story, and $t(45) = -2.002$, $p = 0.052$ for the *implicit learning* story, respectively.

ANOVA predicting intention judgment with age as between-subject factor showed that there was a significant age effect on the sum of the four intention judgments, $F(2,64) = 10.425$, $p < 0.001$, $\eta^2 = 0.246$, Cohen's $f = 0.57$. Independent-samples Kruskal–Wallis tests showed that there were significant age differences in two of the four intention judgments, with $x^2 = 6.028$, $df = 2$, $p = 0.049$ for the *implicit learning* story, and $x^2 = 9.258$, $df = 2$, $p = 0.010$ for the *resistance to learning* story.

Figure 3 shows children's learning judgments across age groups in the individual tasks. All children answered the learning questions correctly in tasks with positive learning outcomes, i.e., the *discovery learning* and the *implicit learning* stories. Although the protagonists' knowledge states were stated explicitly at the end of the stories, children's responses in the tasks with negative learning outcomes, i.e., the *failed learning* and the *resistance to learning* stories, were less than perfect. Children's performances on the four learning questions differed significantly, Cochran's *Q* test showed $x^2 = 41.838$, $df = 3$, $p < 0.001$.

ANOVA with age as between-subject factor revealed that there were significant age related differences in the ToM score, $F(2,64) = 13.931$, $p < 0.001$, $\eta^2 = 0.303$, Cohen's $f = 0.67$, with the 6-year-old children performing the best. Children's ToM was not correlated with their learning judgments, $r = 0.032$, $p = 0.807$. The sum of the four intention judgments was significantly correlated with the ToM score, $r = 0.358$, $p = 0.004$; however, the correlation was no longer significant when age was held constant, $r = 0.155$, $p = 0.232$. Liner hierarchical regression was performed to predict intention judgment with age entered in the first step and ToM entered in the second step. Age significantly predicted children's intention judgment in model 1, explaining 12.0% of the variance, $F(1,55) = 7.493$, $p = 0.008$. When ToM was entered in the regression, however, age was no longer a significant predictor. ToM was a marginally significant predictor for children's intention judgment, with a small to moderate unstandardized coefficient of 0.246, explaining extra 4.4% of the variance, $F(1,54) = 2.856$, $p = 0.097$. Regression coefficients are presented in **Table 5**.

Discussion

Study 2 found that children's understanding of learning intention improved with age. However, they did over-attribute learning intention in the discovery learning and implicit learning tasks, in which the intentions were in conflict with the learning outcomes. Even at 5 and 6 years of age, children's performances on the intention judgments in these two tasks were still at chance level. In other words, when discovery and implicit learning were successful, children did not recognize the learning was unintentional. Children's judgment of learning intention was correlated with their developing ToM with a moderate effect size. ToM marginally predicted children's intention judgment when the effect of age was accounted for.

TABLE 5 | Hierarchical linear regression predicting intention judgment in study 2.

Model		Unstandardized coefficients		Standardized coefficients	*t*	*p*	95% Confidence interval for B	
		B	SE	Beta			Lower bound	Upper bound
1	(Constant)	0.084	0.699		0.120	0.905	−1.316	1.485
	Age	0.029	0.010	0.346	2.737	0.008	0.008	0.050
2	(Constant)	0.347	0.705		0.492	0.625	−1.066	1.760
	Age	0.019	0.012	0.226	1.579	0.120	−0.005	0.043
	ToM	0.246	0.146	0.242	1.690	0.097	−0.046	0.539

N = 57.

Human actions are assumed intentional until proven otherwise (Rosset, 2008). The focus of intention understanding is not how to infer intention, but how to inhibit it. Children over-attributed learning intention to discovery and implicit learning in the current study. They seemed to assume that if somebody eventually learned something, he or she must have intended to do so. This finding was consistent with previous reports on children's intention over-attribution in case of voluntary bodily function and pretense (e.g., Lillard, 1993; Lang and Perner, 2002; Montgomery and Lightner, 2004). It was also in line with children's over-attribution of teaching intention to imitation (Frye and Ziv, 2005; Ziv et al., 2008; Jeong and Frye, 2018a).

The result provided preliminary evidence suggesting that ToM development during 4–6 years of age was associated with children's learning intention attribution. The moderate effect sized zero-order correlation between ToM understanding and children's learning intention judgments in the current study (r = 0.358) was comparable to that between ToM and teaching intention judgment reported by Jeong and Frye (2018a) (r = 0.374). Consistent with children's understanding of the intention to teach (Frye and Ziv, 2005; Ziv et al., 2008), ToM enables children to focus on the motivational mental states leading to learning rather than the behavioral outcome alone. Unlike teaching, which is intentional, intention is neither a necessary nor a sufficient condition for learning to happen. Children with more advanced ToM understanding should be better at detecting the "aha" moment in discovery learning, where the knowledge change comes as a surprise for the learner exactly because of the lack of an initial learning intention. This is the first empirical evidence according to our knowledge on the association between children's ToM development and their learning intention judgment.

Even though the learning outcomes were explicitly stated in the stories, children found it difficult to entertain the idea that learning could fail. Children's over-attribution of learning in the failed learning scenarios (*failed learning* and *resistance to learning*) replicated study 1's finding. Even more so, compared to the characters in study 1 who could perform the action without a mental representational change, no learning actions were mentioned in these scenarios in study 2. A small proportion of children still believed that the characters had learned in these stories. This finding also confirmed Sobel et al.'s (2007, study 2) result that children over-attributed learning with more rigorous research design. It is possible that this phenomenon might indicate a *Yes* bias when children are asked a yes-no question (Fritzley and Lee, 2003; Okanda and Itakura, 2008). Future studies should consider adopting forced choice format in questioning to differentiate these possibilities.

GENERAL DISCUSSION

Theory of mind is a "core human cognition" that is important because it "shapes human thoughts and learning" (Wellman, 2004, p. 2). The current study contributed to our understanding of changes in children's conceptualization of learning through highlighting the role of knowledge change and intention understanding. At the same time, the study systematically demonstrated the association between children's learning concept and their developing ToM. Small to moderate zero-order correlations were identified between children's ToM and their understanding of knowledge change and learning intention.

The current study contributed a new task to identify a shift in children's understanding that learning involves changes not only in behavior, but more importantly in knowledge state between 4 and 6 years of age. The tasks in study 1 tested children's understanding that learning to draw a symbol like the letter O requires not just the act of drawing a circle, but also acquiring the representational meaning of the symbol. The responses of the 6-year-olds showed they were beginning to see learning as a change in mental representation. The second study further examined whether 4–6-year-olds appreciate that learning does not necessarily require intention as in the instances of discovery and implicit learning. The findings showed that even the 6-year-olds seemed to over-attribute intention to learning and did not recognize that discovery and implicit learning could occur unintentionally.

The findings suggest that at school entry, 6-year-olds still face challenges in some of the learning comprehension tasks, especially those with a conflict between a learning intention and its outcome. This result is similar to Sobel and Letourneau's (2015) interview study that found that children's tendency to define learning as a process improved between 4 and 8 years. It seems that learning concept undergoes a prolonged developmental period beyond early childhood. Sobel and Letourneau further suggested that a process-based learning concept might be related to an interpretative ToM that matures during middle childhood (Carpendale and Chandler, 1996).

Both studies found correlations between learning judgments and ToM understanding. However, the correlational nature of the current study makes it impossible to infer the direction of causation. Wang et al. (2017) examined the correlation between 3- and 6-year-old children's performance on the ToM tasks and a battery of 16 teaching and learning comprehension tasks in a cross-sectional study with two samples from Hong Kong and the United States. A moderate correlation was found between the two constructs, even after controlling for age and verbal ability in both samples. Comparing competing structural equation models with either construct as predictor, they found that the model with the teaching and learning comprehension as predictor and the ToM as outcome fit the data significantly better than otherwise, indicating that earlier understanding of teaching and learning might be inductive to ToM development.

The relation between ToM development and children's understanding of teaching and learning might be bidirectional (Davis-Unger and Carlson, 2008; Bass et al., 2019). It is likely that mature mindreading ability facilitates understanding of teaching and learning. It is also possible that exposure to conflicts in perspectives and knowledge differences may enhance children's understanding that beliefs might be inconsistent with the reality (Wellman and Lagattuta, 2004; Wang et al., 2017). In light of the development of both ToM (e.g., Wang et al., 2016) and epistemological understanding (Burr and Hofer, 2002) beyond early childhood, future longitudinal research should test whether epistemological understanding links earlier mental state awareness to later metacognition knowledge.

The current findings not only enriched ToM research, but more importantly shed light on young children's metacognitive understanding of the learning. The false belief paradigm in ToM research productively demonstrates children's over-attribution of knowledge to naive others and themselves. The current research further demonstrates that young children also tend to over-attribute knowledge change and intention in their understanding of learning. These findings open up the possibility that children's initial understanding of learning may also be an important component of school readiness. According to Astington (1998), mental state understanding helps children to succeed in school through numerous ways, including increasing their representational capacity, language ability, narrative understanding and literacy, intentional learning and objective knowledge, social competence and collaborative learning, as well as in the first steps in scientific reasoning. If part of the success of formal schooling depends on both the teacher and student having some awareness of the overall point of the activity, then the change in children's understanding should be an advantage for school entry. Future research on the effect of understanding of learning on learning outcomes and school performance is warranted (Jeong and Frye, 2018a,b; Louca, 2019). Training studies focusing on improving children's mental state understanding for preparation of school entry should be fruitful.

This study has caveats. The learning tasks, especially those with conflict, may have taxed children's executive functions (Zelazo and Frye, 1997), which were not measured in the current study. Compared to Western children, Asian children develop executive functions earlier, but their ToM development is not equally advanced (Sabbagh et al., 2006; Oh and Lewis, 2008; Wang et al., 2016). By 3.5 or 4 years of age, Asian children have already developed an above-chance level of inhibitory control. However, within a specific culture, inhibitory control still correlates with ToM development (Sabbagh et al., 2006). Future studies should consider measuring children's executive function to identify the effects of both domain general cognitive ability and specific mental state understanding on children's conceptualization of learning. Replications of the current findings with diverse samples are needed. Another limitation of the current study is the lack of a linguistic ability test to examine the role of language in children's learning concept development. ToM development is highly dependent on language ability (Milligan et al., 2007). In light of the important role of abstract concept as psychological tool (Borghi et al., 2018; Fini and Borghi, 2019) in ToM development, future research is warranted to explore how children's language development facilitates metacognition and the acquisition of abstract concepts like learning.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Human Research Ethics Committee, The Education University of Hong Kong, and the Institutional Review Board, University of Pennsylvania. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

ZW collected and analyzed the data, and drafted the manuscript. DF provided critical revision to the manuscript. Both authors contributed in the study conceptualization and design.

FUNDING

The current study was partially supported by an Internal Research Grant (Ref #: RG 6/07-08) from The Education University of Hong Kong.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2020.596419/full#supplementary-material

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

ORIGINAL RESEARCH
published: 08 June 2021
doi: 10.3389/fpsyg.2021.575100

What's the Link Between Theory of Mind and Other Cognitive Abilities – A Co-twin Control Design of Neurodevelopmental Disorders

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OPEN ACCESS

Edited by:
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University of Valencia, Spain
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University of Oxford, United Kingdom

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Specialty section:
This article was submitted to Cognitive Science, a section of the journal Frontiers in Psychology

Received: *22 June 2020*
Accepted: *23 April 2021*
Published: *08 June 2021*

Citation:
Isaksson J, Neufeld J and Bölte S (2021) What's the Link Between Theory of Mind and Other Cognitive Abilities – A Co-twin Control Design of Neurodevelopmental Disorders. Front. Psychol. 12:575100. doi: 10.3389/fpsyg.2021.575100

Theory of mind (ToM), or the ability to attribute mental states to oneself and others, is a core element of social cognition (SC). Even though its importance for social functioning in general, and neurodevelopmental disorders (NDDs), in particular, is well established, the links between ToM and other cognitive functions are not. Especially the familial underpinnings of such links remain unclear. Using a co-twin control design, we examined $N = 311$ twins (mean age $M = 17.19$ years, 47% females) diagnosed with autism spectrum disorder (ASD), attention-deficit/hyperactivity disorder (ADHD), other NDDs, or typically developing individuals. We used the Reading the Mind in the Eyes Test to operationalize ToM, the Fragmented Pictures Test for central coherence (CC), the Tower Test for executive functioning (EF), and the general ability index in the Wechsler Intelligence Scales for IQ. In the linear regressions, weak CC and a lower IQ were associated with a reduced ToM ability across pairs. Female sex and higher age were robustly associated with increased ToM ability, whereas EF was not associated with ToM. In the within-pair analyses, where unmeasured familial confounders are implicitly adjusted, the associations between ToM and other cognitive functions, were attenuated and the association with CC was non-significant. The result suggests that familial factors shared by the twins, such as genetic and shared environment, influence the association between CC, IQ, and ToM. Future studies need to include a larger sample of monozygotic twins, who are genetically identical, in order to draw more firm conclusions regarding the influence of familial factors, and to differentiate between shared environmental and genetic effects on the associations between cognitive functions.

Keywords: social cognition, theory of mind, central coherence, executive function, intelligence, twin study, autism, ADHD

INTRODUCTION

Social cognition (SC) is presumed to form the basis of human social interaction and communication (Happé et al., 2017). SC encompasses a wide range of interrelated processes and skills, such as social motivation, social awareness, emotion recognition, social attention, and social learning (Happé et al., 2017). Still Theory of Mind (ToM) or the ability to mentalize around one's own and others thoughts, emotions and beliefs, might constitute the core element of SC, and is commonly also referred to as cognitive empathy (Grove et al., 2014; Happé et al., 2017). Accordingly, ToM has been associated with a wide range of social functioning outcomes, including peer-popularity (Slaughter et al., 2015), social competence (Razza, 2009), and being a bully or a bully-victim (Shakoor et al., 2012). Alterations in ToM have foremost been observed among individuals with neurodevelopmental disorders (NDDs), particularly autism spectrum disorder (ASD) (Morgan et al., 2003; Callenmark et al., 2014; Baron-Cohen et al., 2015; Bölte et al., 2015; Atherton and Cross, 2018; Isaksson et al., 2019b), and to a lesser degree in attention-deficit/hyperactivity disorder (ADHD) (Baribeau et al., 2015; Mary et al., 2016) and communication and language disorders (Smit et al., 2019).

Even though the importance of SC and ToM for social functioning and NDDs is well established, its putative link to other cognitive functions, and especially the aetiological nature of their association, remains to be established. Besides being associated with IQ (Coyle et al., 2018), ToM has shown to be related to executive functioning (EF) and central coherence (CC) in general and NDD populations (Jarrold et al., 2000; Pellicano, 2010; Devine and Hughes, 2014; Pineda-Alhucema et al., 2018; Wade et al., 2018). EF refers to higher order cognitive processes involved in the control of thought and action, including planning, working memory, inhibitory control, cognitive flexibility, and set-shifting (Diamond, 2013). CC comprises the processing of information in a broader context and top-down style, whereas weak CC (WCC) results in a more detail-focused approach with a preference of local over global information (Happé and Frith, 2006). The interrelations between these cognitive functions have been increasingly studied, especially links between ToM and EF.

Theory of mind, EF, WCC, and (low) IQ are thought to re?ect underlying cognitive alterations within NDDs, although, to some degree, different cognitive functions have been associated with certain NDDs. For instance, it has been hypothesized that alterations in ToM augment the social and communication difficulties in ASD (Baron-Cohen, 2009; Mazza et al., 2017), that EF deficits contribute to core symptoms of ADHD (Alderson et al., 2007; Kasper et al., 2012) and rigid and repetitive behaviors in ASD (Demetriou et al., 2019). WCC might underlie uneven cognitive profiles in ASD such as autism related strengths and savant talents (Happé and Frith, 2006). Low IQ is the core definition of intellectual disorder (ID), and increases the symptom burden in a wide range of NDDs (Matson and Shoemaker, 2009). However, previous research on cognitive functions in NDDs has been somewhat limited to investigating single cognitive functions, e.g., ToM in ASD, not simultaneously including multiple cognitive functions or NDDs in the same models (Brunsdon et al., 2015), which may yield shortcomings given the considerable overlap between different types of NDDs (Licari et al., 2019).

ToM, EF, and CC mature throughout childhood and have been reported to intercorrelate during development in typically developing individuals (TD). EF, such as working memory, inhibition, and cognitive flexibility are correlated with ToM abilities, such as understanding false beliefs, and are usually basically established by school-age (Pineda-Alhucema et al., 2018). According to a developmental model, these systems are dependent and impairment in one function early on during development may have substantial knock-on effects on other cognitive functions (Pellicano, 2010). Consistently, ToM and EF have been found to share underlying neuroanatomical mechanisms (Wade et al., 2018). Although the degree of prediction and predictability of one cognitive function over the other is yet be determined (Pineda-Alhucema et al., 2018), there is preliminary support from longitudinal studies that both EF and CC are precursors of ToM performance in TD and individuals with ASD or ADHD (Pellicano, 2010; Devine and Hughes, 2014; Mary et al., 2016; Skorich et al., 2016; Wade et al., 2018). In line with the latter, it has also been hypothesized that ToM abilities rely on a general information processing system, including the integration of stimulus information into a coherent whole, i.e., CC, and mental flexibility, response inhibition, and working memory, i.e., EF in ASD (Pellicano, 2010). However, this notion has also been criticized and it has been argued that ToM and WCC should be seen as separate at a genetic and cognitive level, although co-occurring (Happé and Ronald, 2008; Brunsdon and Happé, 2014). Indeed, findings on the association between the different cognitive functions have ultimately rather been mixed in for example ASD populations (Pellicano et al., 2006). Thus, it remains to be elucidated if there are common underlying factors that drive alteration in these cognitive functions in NDDs.

An alternative approach to assess the putative link between ToM, EF, CC and IQ in NDDs is by examining the aetiological basis of their relations, i.e., the genetic and environmental influences on their associations, and whether these cognitive functions are influenced by similar familial factors. While previous research has mainly been conducted using a developmental approach and regressing ToM performance on CC, EF, and IQ in the general population- or clinical samples, there is a paucity of studied conducted in population-based twin samples enriched for NDDs. To the best of our knowledge, to date only one study has investigated the association between ToM, WCC, and EF in a twin-population consisting of children with ASD and TD co-twins and peers (Brunsdon et al., 2015). The authors found that children with ASD performed atypically on measures of ToM, EF, and WCC with 1/3 of ASD cases, as compared to 1/10 of the TD co-twins, having atypical performance in tasks across all three cognitive domains, a result indicating low levels of familial confounding. They did, however, compare affected twins to unaffected co-twins at a group level, rather than regressing within-pair differences in outcomes on within-pair differences in exposure, and did hence not apply a co-twin control approach.

Expanding on the study by Brundson et al. by including a broader range of NDDs and also applying a co-twin control design, our study enables more information on the aetiological basis by automatically controlling for factors shared between twins in a pair. In a previous study of our lab, we found a within-pair association between WCC in terms of reduced global visual processing and ASD diagnosis, suggesting that this relationship is not solely driven by familial factors (Neufeld et al., 2020). However, we did not investigate the association between WCC and ToM. Familial factors include genetic factors since dizygotic (DZ) twins share on average half of their genome and monozygotic (MZ) twins are genetically identical, as well as shared environmental factors (including parenting style, prenatal factors, and social environment during upbringing) in both types of twins. Familial factors may be adjusted for in a step-wise manner. First, by using a between-subject analysis, where all twins as treated as singletons, it is possible to first get an estimation of the associations investigated across the cohort. As a second step, applying within-pair analyses, adjustments are made 50% or 100% of the genome, respectively, and for all environmental exposures within the family that make the twins similar to each other. Lastly, by only including MZ twins in the within-pair analyses, all genetic factors are adjusted for as well. If ToM shares its aetiological basis with other cognitive abilities and is as such influenced by similar familial factors, the association between these abilities should be attenuated with each step. Any remaining association between ToM and other cognitive functions in the MZ co-twin design is therefore attributable to factors unique to an individual within the same family (i.e., non-shared environmental factors).

Thus, the aim of this study was to (i) investigate the putative link between ToM and other significant cognitive functions, namely CC, EF, and IQ within a sample of MZ and DZ twins enriched for twins concordant and discordant for NDDs, as well as TD control twins, and to (ii) explore if associations are driven by familial factors shared by twins (genetics and shared environment) or remain within (MZ) twin pair indicating non-shared environmental influence. The finding may provide a better understanding of common etiological pathways to altered crucial cognition functions in general and NDDs in particular.

TABLE 1 | Sample characteristics and included factors.

	Pairs concordant or discordant for NDDs *N* = 177	Typically developing pairs *N* = 134
Sex (females)	35.0%	62.7%
Age (M, SD)	15.19 (5.68)	19.84 (6.41)
Parents civil status (Married)	58.8%	58.6%
Mother's level of education		
Elementary school	5.7%	8.3%
Secondary school	56.0%	44.7%
University	38.3%	47.0%
Father's level of education		
Elementary school	10.4%	13.1%
Secondary school	60.7%	52.3%
University	28.9%	34.6%
Work/study		
Mother	89.7%	91.9%
Father	93.9%	86.8%
Zygosity (Monozygotic)	42.9%	70.1%
ASD	33.9%	0%
ADHD	41.2%	0%
Other NDDs	28.8%	0%
Theory of Mind (M, SD)[a]	69.74 (12.95)	75.40 (11.85)
Central Coherence (M, SD)[b]	70.93 (6.60)	66.46 (6.45)
Executive Function[c] (M,SD)	10.62 (2.52)	10.94 (2.18)
IQ/General cognitive abilities (M, SD)[d]	101.51 (13.04)	103.84 (12.73)

[a]Measured with Reading the Mind in the Eyes Test, % correct answers. [b]Measured with the Fragmented Pictures Test, no. of images for recognition. [c]Measured with the Tower Test, scales scores. [d]Measured with Wechsler Intelligence Scales for Children or Adults-IV. ADHD, attention-deficit/hyperactivity disorder; ASD, autism spectrum disorder; NDDs, neurodevelopmental disorders (other NDDs include e.g., communication disorders, specific learning disorders or motor disorders).

MATERIALS AND METHODS

Participants

The Roots of Autism and ADHD Twin Study Sweden (RATSS) (Bölte et al., 2014) is an ongoing study that includes twin pairs from the population-based Child and Adolescent Twin Study in Sweden (Anckarsäter et al., 2011) and the Young Adult Twins in Sweden Study (YATSS), where one or both twins have been screened positively for ASD or ADHD, as well as TD controls. Twins that are included in RATSS are comprehensively clinically phenotyped during a 2½ day visit at a clinical research unit. Zygosity is determined on a panel of 48 single nucleotide polymorphisms (Hannelius et al., 2007). In a few cases (22 pairs), where DNA results had not yet been analyzed, a 4-item zygosity questionnaire was used, and in 10 cases the zygosity was pending. From the total sample, 52 individuals were excluded due at least one of the twin missing data, 48 were excluded due to at least one twin having an intellectual disability or borderline intellectual functioning (IQ $\leq$ 75) and nine for having different sex. In the current study, N = 311 [170 MZ, 131 DZ (one triplets included), and 10 with pending zygosity] were included (46.9% females; mean age = 17.19 years, SD = 6.43, range: 8–36 years). In total, 125 had a NDD and of these 45 had two or more NDDs; 60 had a diagnosis of ASD (39 males, 21 females), 73 had a diagnosis of ADHD (50 males, 23 females), 51 other NDDs (e.g., communication disorders, specific learning disorders or motor disorders; 36 males, 15 females). Sample characteristics are summarized in **Table 1**. The study was approved by the Regional Swedish Ethical Review Board and Informed consent was obtained from all participants after the nature of the procedure had been fully explained.

Diagnostic and Behavioral Assessments

A DSM-5 consensus diagnosis of any of the included NDDs were determined by a group of clinicians using a multitude of collected data, including medical history, diagnostic interviews and by first choice standardized diagnostic tools [for more detail see Bölte et al. (2014) and Isaksson et al. (2019a,b)]. These tools include structural interviews such as the Kiddie Schedule for Affective Disorders and Schizophrenia (Kaufman et al., 1997) or the Structured Clinical Interview for DSM-IV (SCID 1) depending on the participant's age; autism-specific tools such as the Autism Diagnostic Interview—Revised (ADI-R; Rutter et al., 2003), the Autism Diagnostic Observation Schedule Second Edition (ADOS-2, modules 3 and 4, Lord et al., 2012), and the parent-report version of the Social Responsiveness Scale Second Edition (SRS-2, Constantino and Gruber, 2005); ADHD-related instruments are the Diagnostic Interview for ADHD in adults (Kooij and Francken, 2010) and the Conners Rating Scale 3rd Edition (Conners, 2008); and measure of adaptive functioning using the Adaptive Behavior Assessment System-2 (ABAS-2).

Cognitive Functions

Theory of Mind

Theory of mind, as a construct within SC, was assessed with the Swedish version of the revised Reading the Mind in the Eyes Test (Söderstrand, 2006; Zander et al., 2011). Tasks aiming to measure alterations in SC have been criticized for not being able to assess more subtle alterations given their logical structure, encouraging a more deliberate reasoning (Callenmark et al., 2014). We selected the Reading the Mind in the Eyes Test as measure of ToM, which was developed to test ToM with sufficient sensitivity in both intellectually able individuals and in adults (Baron-Cohen et al., 1997, 2001). The test builds on the finding that the eye region is a hot spot for social communication information. The participants are presented with photographs of human eye regions portraying different emotions or mental states (e.g., playful/comforting/irritated/bored) and the participants are instructed to choose one word of four alternatives that most adequately matches the eye region's expression. Reading the Mind in the Eyes Test is generally regarded as an advanced test of SC, as the participant is required to decode/attribute complex mental and emotional states, which promotes unconscious, rapid, and automatic processes (Baron-Cohen et al., 2001). The child version (14 $\leq$ years) contains 28 photos and the adult version ($\geq$15 years) 36 photos. Expected alternatives are scored "1" and unexpected "0." The number of correct answers was summed for each participant and a percentage of correct answers were calculated in order to enable merging the child and adult version. A higher score indicates a better ToM ability. The Reading the Mind in the Eyes Test has in previous literature shown diagnostic or discriminatory validity, foremost ASD vs. TD, but also ADHD vs. TD, for children and adults (Baron-Cohen et al., 2001, 2015; Losh et al., 2009; Sachse et al., 2014; Baribeau et al., 2015). The test has also shown good test–retest reliability (Hallerbäck et al., 2009), acceptable internal consistency and evidence for a single factor structure (Vellante et al., 2013).

Central Coherence

Central coherence was assessed with the Fragmented Pictures Test (Kessler et al., 1993). More specifically, the test assesses the ability to integrate elements of visual information into a meaningful whole with as little visual information as possible (global visual processing). The participants are presented fragmented drawings of 10 different objects. Each object is displayed in 10 sequential steps where each step reveals more visual information about the object (a more complete image). The participants are instructed to browse through the images keeping a steady pace, and to respond when they identified the object. The score was calculated as the sum of images needed across trials in order to identify the objects correctly, where a higher score indicates a need for more complete visual information and hence a WCC, i.e., a reduced ability for global processing. Results on the Fragmented Pictures Test have been shown to differ between individuals with autism compared to TD controls (Scheurich et al., 2010; Booth and Happé, 2018) where individuals with autism need more visual information in order to identify the object, indicating a WCC with a reduced drive to focus on the global gestalt of visual information (Happé and Frith, 2006). In this study, Cronbach's alpha was 0.93, indicating a strong reliability in terms of internal consistency of the test.

Executive Function

Executive function was measured using the Tower Test, which is a cognitive test included in the Delis Kaplan Executive Function System (D-KEFS; Delis et al., 2001). The Tower Test is composed of a series of nine items, each one more difficult than the previous, and the test measures EF such as spatial planning, inhibition of impulsive and perseverative responding, establishment, and militainment of an instructional set. The participant is shown a picture of a tower, and instructed to move disks of various sizes across three pegs until the target tower is built, using as few numbers of moves as possible. Tower planning tasks are frequently used as a measure of EF, and in particular of deficient planning, involving the execution of cognitive and/or behavioral strategies required to attain a goal (Patros et al., 2019). In this study we used the total achievement score, i.e., number of moves, converted to scaled score with a higher score indicating fewer EF problems. Discriminant validity for the Tower Test regarding especially ADHD, but also ASD, has been reported in several studies (Craig et al., 2016; Patros et al., 2019), with individuals with NDDs requiring more moves to build the tower. The test has shown moderate to high internal consistency and moderate test–retest reliability (Delis et al., 2001).

IQ

The general ability index (GAI) of the Wechsler Intelligence Scales for Children or Adults-IV (WISC-IV/WAIS-IV) was used to assess IQ. The GAI is a composite score that is based on three Verbal Comprehension (i.e., Vocabulary, Comprehension, and Similarities) and three Perceptual Reasoning (i.e., Block Design, Matrix Reasoning, and Picture Concepts) subtests. The score does not include the Working Memory or Processing Speed subtests that are included in the Full Scale IQ. The GAI provides information about higher-order thinking abilities, as compared to the Working Memory or Processing Speed tests that provide information of cognitive processing proficiency. GAI has been shown to have very high reliability (Saklofske et al., 2010). A higher GAI score indicates a higher general IQ.

Data Analyses

Associations between the study variables were first assessed using correlations (Spearman's rho for continuous variables, the point-biserial correlation coefficient between a binary and continuous variable, and the phi correlation coefficient between binary variables). As sensitivity analyses, correlations between subtests of the IQ measures and cognitive abilities, including ToM, were explored.

In the main analysis, linear regressions in a generalized estimating equations (GEE) framework were used that fully account for twin/co-twin designs and allowing both categorical and continuous data (Neuhaus and McCulloch, 2006), using the drgee package (v.1.1.10) in R (v. 3.5.1). The main analyses in the GEE were conducted in several steps. First, we estimated associations between CC, EF, and IQ as independent variables, and ToM as an outcome across pairs (i.e., twins were treated as individuals but standard errors were adjusted for twin clustering), also adjusting for age and sex, in three separate models (i.e., for CC, EF, and IQ separately). Results are presented for the whole sample and split by NDD (concordant or discordant pairs) and TD pairs. Second, we included all cognitive functions (CC, EF, and IQ), NDD diagnoses (ASD, ADHD, and other NDDs), sex and age as independent variables within the same model. Third, we repeated the analyses at step 1 and 2 within the pairs in order to also adjust for unmeasured familial confounders. In this third step, each pair is considered a separate stratum where within-pair differences in outcomes are regressed on within-pair differences in exposure, while the models implicitly adjust for shared environmental factors and at least 50% of genetic factors. Finally, we re-calculated within-pair analyses in the MZ sub-cohort, in order to investigate the robustness of results when genetic confounding was completely adjusted, and any remaining association in the MZ subpopulation must therefore be influenced by non-shared environmental factors. Two tailed tests with p values < 0.05 were considered significant.

RESULTS

Associations Between ToM and the Other Study Variables

Correlations between the study variables are presented in **Table 2**, showing that ToM ability was positively associated with EF and IQ, and negatively associated with CC. In addition, female sex and older age was positively associated with ToM, whereas ASD, ADHD and other NDDs were negatively associated with ToM. As a sensitivity analysis, exploring subtests of the IQ measures, the correlations with the cognitive abilities largely remained for the Verbal Comprehension and the Perceptual Reasoning subtests (**Supplementary Table 1**).

Between-Pair Associations Between ToM, Other Cognitive Functions and NDDs

Results for linear regressions across pairs with ToM as outcome are shown in **Table 3**. A higher CC and IQ, but not EF, were associated with a better ToM ability. In addition, female sex and higher age were also associated with a better ToM ability in the three models [ranging between $b = -4.945$ and -5.533 for sex (female sex as reference); and between $b = 0.493$ and 0.687 for age, all $p < 0.001$]. The associations between ToM and other cognitive functions were similar among twin-pairs concordant or discordant for NDDs and TD twin-pairs, see **Table 3**.

Full Model of Between-Pair Associations Between ToM, Other Cognitive Functions and NDDs

When including all cognitive functions (CC, EF, and IQ), diagnoses (ASD, ADHD, and other NDDs), sex and age in the same model as independent variables and ToM as outcome, the association with CC, IQ, female sex and increasing age remained, but the association with a diagnosis of NDD (ASD, ADHD, other NDDs) from the correlation analyses was lost, **Table 4**.

Within-Pair Associations Between ToM and Other Cognitive Functions

As shown in **Table 3**, the association between CC and ToM was lost within pairs, whereas the association between IQ and ToM remained, although weakened and lost in the MZ subset. When including all cognitive functions (CC, EF, and IQ) and NDD diagnoses (ASD, ADHD, and other NDDs) in the same model, all associations with ToM were lost within the pairs, **Table 4**.

DISCUSSION

This is the first study using a co-twin control design to investigate the familial underpinnings between ToM and other cognitive functions in a sample enriched for twins concordant and discordant for NDDs. IQ and CC were associated with ToM ability across pairs. In addition, female sex and higher age were robustly linked with ToM ability in all models. The within-pair analyses attenuated the associations between ToM and other cognitive functions, especially for CC which was then no longer significant, and to some degree also IQ. The results from the MZ within-pair analyses were non-significant, however, these findings were more ambiguous given a broad confidence interval for the estimations, possibly due to a low power. Our results suggest that familial factors shared by the twins, such as genetic background and shared environment, influence the association between CC, IQ, and ToM.

Across the sample, the overarching cognitive functions of CC, EF, and IQ were associated with ToM in the correlation analyses, with small to moderate effect sizes. Comparable associations have been reported in numerous studies. Although no previous research has explored the associations between results on the Reading the Mind in the Eyes Test and the Fragmented Picture test, scores on other tests measuring CC have been associated with Reading the Mind in the Eyes Test (Jarrold et al., 2000), as well as other tests on false belief understanding (Pellicano, 2010), in typically developed and autistic children. Associations between scores on tests assessing EF and ToM have been found

TABLE 2 | Correlations between cognitive functions, sex, age and NDDs.

	ToM	CC	EF	IQ	Sex (male)	Age	ASD	ADHD
CC	−0.389***							
EF	0.198***	−0.129*						
IQ	0.312***	−0.198***	0.283***					
Sex (male)	−0.332***	0.271***	−0.082	−0.022				
Age	0.448***	−0.605***	0.141*	0.043	−0.330***			
ASD	−0.197***	0.229***	−0.084	−0.053	0.117*	−0.141*		
ADHD	−0.229***	0.247***	−0.072	−0.027	0.171**	−0.272***	0.287***	
Other NDDs	−0.151**	0.128*	−0.127*	−0.107	0.156**	−0.178**	0.202***	0.267***

Correlations between continuous variables were calculated using Spearman's Correlation Coefficient, between a binary and continuous variable using Point-Biserial Correlation Coefficient, and between two binary variables the Phi Correlation Coefficient; ADHD, attention-deficit/hyperactivity disorder; ASD, autism spectrum disorder; CC, central coherence; EF, executive functions; GAI, general cognitive ability; NDDs, neurodevelopmental disorders (other NDDs includes e.g., communication disorders, specific learning disorders or motor disorders); ToM, theory of mind.
**p < 0.05; **p < 0.01; and ***p < 0.001.*

TABLE 3 | Results from the linear regressions with central coherence, executive function and IQ as predictors of Theory of Mind, measured with the Reading the Mind in the Eyes Test.

		Central coherence[a] b (95% CI)	Executive functions[b] b (95% CI)	IQ[c] b (95% CI)
All pairs	Between-pair[d]	−0.388** (−0.624, −0.151)	0.422 (−0.163, 1.007)	0.265*** (0.166, 0.364)
	Within-pair	−0.282 (−0.592, 0.027)	0.424 (−0.131, 0.980)	0.215* (0.016, 0.413)
	Within-pair MZ	−0.272 (−0.782, 0.239)	0.239 (−0.592, 1.070)	0.281 (−0.121, 0.682)
TD pairs	Between-pair[d]	−0.408 (−0.823, 0.007)	0.266 (−0.671, 1.203)	0.331*** (0.218, 0.444)
	Within-pair	−0.382 (−0.834, 0.071)	0.290 (−0.645, 1.227)	0.180 (−0.032, 0.391)
NDD pairs	Between-pair[d]	−0.359* (−0.674, −0.043)	0.514 (−0.232, 1.259)	0.224** (0.082, 0.366)
	Within-pair	−0.216 (−0.641, 0.209)	0.496 (−0.194, 1.186)	0.228 (−0.034, 0.490)

[a]Measured with the Fragmented Pictures Test. [b]Measured with the Tower Test. [c]Measured with the General ability index from the Wechsler Intelligence Scales for Children or Adults-IV. [d]Between-pair calculations are adjusted for sex and age. NDDs, neurodevelopmental disorders; TD, typically developing.
**p < 0.05; **p < 0.01; and ***p < 0.001.*

TABLE 4 | Results from the linear regressions with central coherence, executive function and IQ as predictors of Theory of Mind as measured with the Reading the Mind in the Eyes Test, also adjusting for diagnoses, sex and age.

	Between-pair b (95% CI)	Within-pair b (95% CI)
Central coherence[a]	−0.250 (−0.485, −0.016)*	−0.188 (−0.459. 0.082)
Executive functions[b]	0.042 (−0.435, 0.518)	0.088 (−0.445, 0.621)
IQ[c]	0.242 (0.149, 0.336)***	0.191 (−0.005, 0.388)
ASD	−2.462 (−6.537, 1.613)	−1.353 (−5.956, 3.250)
ADHD	−2.119 (−5.779, 1.542)	−0.609 (−4.846, 3.628)
Other NDDs	−0.015 (−3.522, 3.493)	0.001 (−3.629, 3.631)
Sex (male)	−4.878 (−7.296, −2.460)***	
Age	0.466 (0.224, 0.707)***	

[a]Measured with the Fragmented Pictures Test. [b]Measured with the Tower Test. [c]Measured with the General ability index from the Wechsler Intelligence Scales for Children or Adults-IV. ADHD, attention-deficit/hyperactivity disorder; ASD, autism spectrum disorder; NDDs, Neurodevelopmental disorders (other NDDs includes e.g., communication disorders, specific learning disorders or motor disorders).
**p < 0.05; **p < 0.01; and ***p < 0.001.*

in typically developed, autistic and ADHD children (Pellicano, 2010; Devine and Hughes, 2014; Pineda-Alhucema et al., 2018), and a weak association has been reported between the Tower Test and Reading the Mind in the Eyes Test (Ahmed and Miller, 2011; Stubberud, 2017). For IQ, an association has been found with ToM in general (Coyle et al., 2018), and a week association between score on the Wechsler scale and Reading the Mind in the Eyes Test specifically, in both general and NDD populations (Baker et al., 2014). In our study, the correlation with ToM was similar for the Verbal Comprehension and the Perceptual Reasoning index.

According to the developmental approach, these functions or abilities are interrelated and develop in concert with each other (Pellicano, 2010). Moreover, it has been argued that CC and EF precede ToM (Pellicano, 2010; Devine and Hughes, 2014; Mary et al., 2016; Skorich et al., 2016; Wade et al., 2018), which is why we choose to have ToM as an outcome in our study. Accordingly, the association between CC, IQ, and ToM remained in the GEE model when adjusting for sex and age, although the association with EF was lost, indicating a moderating effect of sex and age. Overall sex, and also age, was strongly associated with ToM functions across all models. This finding corroborates previous research using the Reading the Mind in the Eyes Test with females out-performing males (Baron-Cohen et al., 2001, 2015), and is in line with the Empathizing–Systemizing theory, where males are more systemizing and females more empathic, and where autism is understood as showing a more extreme variant of cognition than found on average in males (Baron-Cohen, 2002).

All included NDD diagnoses were correlated with ToM and CC. Especially ASD has been linked to ToM and WCC, where a reduced ability to represent one's own and others thoughts, emotions and beliefs, has been hypothesized to be an integral part of the social and communication difficulties underlying ASD (Baron-Cohen, 2009; Mazza et al., 2017), whereas a reduced style to integrate stimulus information into a coherent whole has been proposed to underlie autism related talents such as an eye for details (Happé and Frith, 2006). However, in the fully adjusted model across pairs, the associations between specific NDDs and ToM ability were lost. Instead, sex and age, as well as CC and IQ, were the main factors associated with ToM scores. This finding suggests that ToM ability is not uniquely associated with ASD, but rather mediated by other factors that are partly associated with ASD. Furthermore, the associations between ToM and other cognitive functions were similar among twins concordant and discordant for NDDs and TD twin-pairs, indicating that the cognitive functions do not decouple and segregate independently in families with and without NDDs. Similar findings were found by Jarrold et al. (2000) who reported a correlation between WCC and ToM ability in both children with ASD and TD when adjusting for verbal mental age.

Interestingly, neither EF nor IQ were associated with ASD or ADHD in the unadjusted correlations, which is surprising since EF difficulties have been suggested to contribute to the core symptoms of ADHD (Alderson et al., 2007; Kasper et al., 2012), as well as rigid and repetitive behavior in ASD (Demetriou et al., 2019). Furthermore, in a recent review it was concluded that foresighted planning problems, e.g., measured with the Tower Test, were present among children with ASD, as well as among children with comorbid ASD and ADHD (Craig et al., 2016). In our study we used the Tower Test as a proxy for EF, and possibly, the measure of errors of omission and commission may be more sensitive for e.g., ADHD (Craig et al., 2016). In addition, if we would have had a more homogeneous sample of ADHD cases, not obscured by comorbidity and broad age range, the result may have been different.

The associations between CC, IQ, and ToM were attenuated and lost in the within-pair analyses, a finding that demonstrates that familial factors contribute to the associations between these cognitive functions. Familial factors are those shared by family members, i.e., genes and shared environment such as parenting style, maternal conditions during pregnancy and social environment during upbringing. This attenuation was most clear in the association between ToM and CC, reducing the estimate with 27%, followed by a reduction of 19% in the estimates between IQ and ToM. Previous research has also emphasized the heritability for IQ (Plomin and Von Stumm, 2018), as well as for CC in twins with or without eating disorders (Kanakam et al., 2013), whereas heritability estimates for ToM have been modest (Hughes et al., 2005; Ronald et al., 2006). Our finding of an attenuated association within the pairs does not give support for ToM being dependent of CC, as has been suggested previously according to the developmental approach.

The results from the MZ subsample were more ambiguous, with large confidence intervals for the estimates, indicating that the statistical calculations were under-powered. A larger MZ sample would be necessary in order to draw more firm conclusions regarding the influence of familial factors, and differentiating shared environmental from genetic effects would require both larger MZ and DZ samples. Even though, to the best of our knowledge, no previous studies have explicitly explored the association between CC, EF, IQ and ToM using a co-twin control design, there are some studies conducted on siblings. Oerlemans et al. (2013) reported an interrelatedness between SC and EF task performance, but not between SC and CC performance in children with or without ASD. This interrelatedness was found between siblings, i.e., SC in probands was related to EF in their siblings and vice versa, a finding that implies similar familial underpinnings between the SC and EF domain (Oerlemans et al., 2013). This contrasts both our finding on a weak association between ToM and EF, and that shared familial underpinnings are more evident in the ToM and CC association. Our study however, differ in several aspects from Oerlemans et al. (2013), using different statistics, different tests for ToM, EF, and CC, and only the current study included other coexisting NDDs.

The present study has limitations that need to be addressed. First, although this is a reasonably sized study using deeply phenotyped twins (Bölte et al., 2014), our results require replication in even larger samples to ensure sufficient power, especially in the MZ within-pair analyses. Second, since our sample is biased toward MZ twins discordant for NDDs, we did not model quantitative contributions of A (additive genetics), C (common/shared environment), and E (unique environment), which would lead to biased estimates in the twin model fitting. A higher number of discordant pairs, however, increase the sensitivity of the within-pair models. Third, we used a single measure to define the cognitive functions. Other measurements, covering other dimensions of SC, EF, CC, and IQ, may have yielded different findings. Our study relies exclusively on psychological tests, and adding self- or parent rated questionnaires, or more psychological tests, may provide additional information about symptoms and functioning in everyday life. In addition, the Reading the Mind in the Eyes Test has been criticized for measuring emotion recognition rather than ToM ability (Oakley et al., 2016) and being dependent on the participants vocabulary (Olderbak et al., 2015). At the same time, the correlation between verbal abilities and ToM was weak in our sample, and partly adjusted for within the GAI measure. Fourth, comorbidity was common in our sample, with some individuals having more than one NDD. This reduced power in the adjusted model, but also increased the ecological validity since comorbidity is common in the general population as well (Licari et al., 2019). Fifth, our study does not allow inference regarding directionality of the reported associations since it is correlational. Future twin studies should address these gaps by using multiple tasks of cognitive functions and including a larger sample of MZ twins and applying longitudinal designs. Sixth, no correction for multiple testing was made, and if applying Bonferroni correction, based on the number of main analyses, the null hypothesis would have been rejected if $p < 0.013$. However, with this method the likelihood of type II errors is also increased, and it is argued that the best approach is to describe what has been done and why (Perneger, 1998).

To conclude, by using a sample enriched with twins concordant and discordant for NDDs we show that WCC and a lowered general cognitive functioning are associated with a reduced ToM ability, even when NDDs are taken into account. By being the first study utilizing a co-twin control design, we found that the associations between CC, IQ, and ToM were attenuated, demonstrating that familial factors contribute to the association. This finding suggests that shared genetic or environmental factors within the family explain some part of the associations between WCC, general cognitive functioning and ToM. More studies with larger sample sizes are, however, needed to further investigate the specific contributions of genes and environment on the associations. As for the developmental approach, out finding of an attenuated association within the pairs does not give support for ToM being dependent of CC, as has been suggested previously. Rather, both functions may have a common etiological background. Also, given the robust associations between female sex, age, and ToM ability, future studies need to include these factors when assessing ToM. For the future, employing different measures to assess cognitive functions, including ToM, in larger samples of MZ twins would enable us to study the developmental pathways to alterations in ToM in more depth.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because of regulations in the ethical approval and university policies, requiring among others a data sharing agreement. Requests to access the datasets should be directed to SB, sven.bolte@ki.se.

ETHICS STATEMENT

The study involving human participants was reviewed and approved by the Regional Swedish Ethical Review Board in Stockholm and informed consent was obtained from all participants or their caregivers after the nature of the procedure had been fully explained.

AUTHOR CONTRIBUTIONS

SB contributed to conception and design of the study. JI and JN performed the statistical analysis. JI wrote the first draft in collaboration with JN. All authors contributed to manuscript revision, read, and approved the submitted version.

FUNDING

This work was supported by Swedish Research Council, Vinnova, Formas, FORTE, the Swedish Brain Foundation (Hjärnfonden), Stockholm Brain Institute, Autism and Asperger Association Stockholm, Queen Silvia Jubilee Fund, Solstickan Foundation, PRIMA Child and Adult Psychiatry, the Pediatric Research Foundation at Astrid Lindgren Children's Hospital, the Swedish Foundation for Strategic Research, Jerring Foundation, the Swedish Order of Freemasons, Kempe-Carlgrenska Foundation, Sunnderdahls Handikappsfond, The Jeansson Foundation, the Innovative Medicines Initiative Joint Undertaking (grant agreement number: 115300), which comprises financial contribution from the European Union's Seventh Framework Program (FP7/2007–2013) and in-kind contributions from companies belonging to the European Federation of Pharmaceutical Industries and Associations (EU-AIMS). The Swedish Twin Registry is managed by Karolinska Institutet and receives funding through the Swedish Research Council under the grant number: 2017-00641.

ACKNOWLEDGMENTS

We would like to thank all twins and parents who have participated in this research. We would also like to thank Britt Marie Anderlid, Kerstin Andersson, Steve Berggren, Torkel Carlsson, Christina Coco, Anna Fridell, Andreas Fällman, Martin Hammar, Johanna Ingvarsson, Elzbieta Kostrzewa, Therese Lindström, Karl Lundin, Anna Lövgren, Katell Mevel, Lynnea Myers, Soheil Mahdi, Ann Nordgren, Lina Poltrago, Anna Råde, Kristiina Tammimies, Elin Vahlgren, and Eric Zander for their valuable contribution to the work presented in this study. We acknowledge the Swedish Twin Registry for access to data.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2021.575100/full#supplementary-material

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Conflict of Interest: SB in last four years acted as an author, consultant, or lecturer for Medice and Roche, and receives royalties for text books or diagnostic instruments from Huber/Hogrefe, Kohlhammer and UTB.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

ORIGINAL RESEARCH
published: 24 June 2021
doi: 10.3389/fpsyg.2021.621457

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Language Can Obscure as Well as Facilitate Apparent-Theory of Mind Performance: Part 2—The Case of Dyslexia in Adulthood

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Many studies imply causal links between linguistic competencies and Theory of Mind (ToM). But despite Dyslexia being a prime example of linguistic deficits, studies on whether it is related to ToM have been relatively unforthcoming. In the first of 2 studies ($N = 89$), independently-diagnosed dyslexic adults and non-dyslexic adults were presented with false-belief vignettes via computer, answering 4 types of question (Factual, Inference, 1st-order ToM & 2nd-order ToM). Dyslexia related to lower false-belief scores. Study 2 ($N = 93$) replicated this result with a non-computer-based variant on the false-belief task. We considered the possibility that the apparent-issue with ToM is caused by processing demands more associated to domains of cognition such as language, than to ToM itself. Addressing this possibility, study 2 additionally utilised the ToM30Q questionnaire, designed largely to circumvent issues related to language and memory. Principal-Components analysis extracted 4 factors, 2 capturing perceptual/representational ToM, and the other 2 capturing affective components related to ToM. The ToM30Q was validated via its associations to a published measure of empathy, replication of the female gender advantage over males, and for one factor from the ToM30Q there was a correlation with an existing published index of ToM. However, when we considered the performance of dyslexic and non-dyslexic participants using the ToM30Q, we found absolutely no difference between them. The contrasting findings from our 2 studies here, arguably offer the first experimental evidence with adults, that there is in fact no ToM deficit in dyslexia. Additionally, this finding raises the possibility that some other groups considered in some sense atypical, failed ToM tasks, not because they actually have a ToM deficit at all, but rather because they are asked to reveal their ToM competence through cognitive domains, such as language and memory.

Keywords: adults, dyslexia, language, theory of mind, working memory

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Specialty section:
This article was submitted to
Cognitive Science,
a section of the journal
Frontiers in Psychology

Received: *26 October 2020*
Accepted: *21 May 2021*
Published: *24 June 2021*

Citation:
Wright BC and Wright BAL (2021)
Language Can Obscure as Well as
Facilitate Apparent-Theory of Mind
Performance: Part 2—The Case of
Dyslexia in Adulthood.
Front. Psychol. 12:621457.
doi: 10.3389/fpsyg.2021.621457

INTRODUCTION

Theory of Mind (ToM) is the socio-cognitive ability to theorise about the mind as typically the cause and sometimes the target of behaviour, and the related cognitive ability to take another person's subjective perspective irrespective of whether the reasoner holds that perspective him/herself (Moran, 2013; Abdel-Hamid et al., 2019; cf. Premack and Dasser, 1991; Tompkins et al., 2013). ToM seems an important factor in social phenomena such as empathy, moral reasoning and conflict resolution (Bruneau and Saxe, 2012; Dodell-Feder et al., 2013; Gonzalez-Liencres et al., 2013). This may be partly why psychological disorders such as autism, bipolar disorder, schizophrenia, personality disorder, sensory and learning disabilities, and dementia have each been found to be associated with issues in the functioning of ToM (Gregory et al., 2002; Wolf et al., 2010; Hobson, 2014; de Vaan et al., 2018; Németh et al., 2018; Acosta et al., 2019).

Many experimental tasks for assessing ToM ultimately derive from the form of a "false-belief task" devised by Wimmer and Perner (1983). In this simple yet ingenious task, the reasoner must give a response indicating s/he understands that a person's behaviour is based on that person's subjective perception, as distinct from the reasoner's own current factual knowledge of the situation (Premack and Dasser, 1991; Lillard, 2015). Hence, such tasks tend to be termed tasks of false-belief (Wellman et al., 2001; cf. Wimmer and Perner, 1983). There are parallel profiles of ToM development across Eastern and Western cultures, however, the age at which a particular culture passes on false-belief tasks can vary by as much as 2 years (Naito, 2003). This finding was robustly confirmed in a meta-analytic comparison between 196 studies carried out in China and 155 studies carried out in the US (Liu et al., 2008). And this may impact on our ability to make precise comparisons across diverse groups when relying only on false-belief tasks.

Wellman (2018) provides an integrative account of how this "first-order" false-belief ToM ability finds its origins in more basic perceptual and social competencies, which facilitate its emergence and development during the child's first 5 years. However, "second-order" tasks demonstrate that ToM typically undergoes up to 2 more years of development before it can be said to be of similar basic maturity to ToM in adults. In second-order ToM, the reasoner contemplates the differing subjective beliefs of two protagonists in addition to his/her own current belief about a situation (Perner, 1991; Slade and Ruffman, 2005). Such higher order ToM requires appreciation and coordination of a greater number of symbolic representations and hence they highlight the importance of memory (Abell et al., 2000; Kaland et al., 2005; McKinnon and Moscovitch, 2007; Wright and Mahfoud, 2014).

The often reported finding that first- and second-order ToM are well-developed by middle childhood, could be taken to imply that adolescents and adults would perform too near ceiling for ToM tasks to be useful measures of their understandings of mind (Dodell-Feder et al., 2013). On this issue, it has been shown that if the social context of ToM reasoning is made highly relevant to situations adults might find themselves in, then second-order ToM in particular may be below ceiling even for adults (Hedden and Zhand, 2002; Keysar et al., 2003; Terwogt and Rieffe, 2003; McKinnon and Moscovitch, 2007; Im-Bolter et al., 2016). In Rutherford's (2004) task using false-belief stories, adults answered questions that involved differing beliefs of up to four protagonists (4th-order false-belief). Thus, this may have impacted on memory in addition to ToM reasoning.

Cognitive domains such as memory, executive functions and language have been confirmed to be important in ToM (Carlson and Moses, 2001; Kaland et al., 2005; Gokcen et al., 2009; Moran, 2013; Baker et al., 2014; Mary et al., 2016; Demetrious and Spanoudis, 2018). Arguably, the most important cognitive factor may be linguistic-processing (Jackson, 2001; cf. Miller, 2001; Cardillo et al., 2018; Conte et al., 2019; Bailey and Im-Bolter, 2020; Ebert, 2020; Sarmento-Henrique et al., 2020). In support of this notion, Bailey and Im-Bolter (2020) report that having epilepsy in childhood has a highly detrimental effect on ToM. Also, blind children, who tend to have an atypical language developmental trajectory in early childhood, acquire ToM some 5 years later than deaf children, who in turn acquire ToM around 2 years later than typically-developing children (Hobson, 2014; Russell et al., 1998; Peterson et al., 2000; Roch-Levecq, 2006). Given such findings regarding language and ToM in various atypical groups, we wondered about the extent to which this might generalise such that ToM performance will be impacted by any language-related developmental issue that continues into adulthood (Fahie and Symons, 2003; Kerr et al., 2003; Kaland et al., 2005; Dodell-Feder et al., 2013; Bailey and Im-Bolter, 2020).

In line with this notion, language measures taken early in childhood do tend to predict ToM performance in later childhood, much more strongly than the converse (Milligan et al., 2007). de Villiers and Pyers (2002), reported that the crucial variable for passing ToM tasks is the child's possession of more complex syntactic constructions; which have been linked to other aspects of language such as inflectional morphology, comprehension and potentially even size of vocabulary (Watson et al., 2001; Mills and Fox, 2016). Thus, notwithstanding effects of memory, language may be in some sense integral to ToM or even a prerequisite to it (cf. Astington and Jenkins, 1999; Miller, 2001; Bailey and Im-Bolter, 2020). On this language-facilitatory thesis, Bloom and German (2000) accept that if linguistic resources are in some way under-developed or compromised, this could cause failures on false-belief tasks of ToM.

However, although consistent with the idea that ToM may be predicated on language, Bloom and German's theory seems also to contemplate an alternative possible relationship: That is, language may only seem related to false-belief indexes of ToM, because we tend to test ToM using language-related protocols (e.g., syntax, vocabulary and even memory for words and spellings— Watson et al., 2001; de Villiers and Pyers, 2002; Slade and Ruffman, 2005; Mills and Fox, 2016). It may be that the more we require participants to rely on multiple symbolic representations or to have to comprehend and respond via linguistic constructions (which although perfectly grammatical may be untypical of spontaneous real world socio-cognitive interactions regarding minds), the more our participants are made to engage memory and linguistic competencies in order to tell us how they have reasoned about minds. If linguistic processes are impacted in some way, this may result in language becoming something of a barrier or obstacle to the reasoner demonstrating his/her well-developed ToM. Conversely, if we in some sense reduce the need for testing through language we might observe higher ToM performance (Bloom and German, 2000; Milligan et al., 2007; Guajardo and Cartwright, 2016).

This disadvantage (or advantage) does not have to have occurred because of atypical (or typical) linguistic development. For example, Gundel and Johnson, 2013 found that typically-developing 3 year-olds observed in their home environment demonstrate spontaneous production of sentences encapsulating ToM, even though this age group tends to fail on more formal "tests" of ToM such as via false-belief (Wellman et al., 2001; Wright and Mahfoud, 2014). Along somewhat similar lines, a deaf sub-group of children having a linguistic advantage over a second sub-group (e.g., bilingual vs. monolingual or early bilingual signers vs. late bilingual signers) tends to as a consequence demonstrate higher ToM abilities on false-belief tasks (Meristo et al., 2007).

To test between these two possibilities about ToM, one should be able to compare the ToM performance of any group experiencing significant general or specific linguistic-diversity and a second group having no such diversity. As well as allowing us to test between the linguistic-facilitatory view and the language-obscuring view of ToM, the inclusion of an appropriate language-atypical group might allow us to go even further, and test the very validity of false-belief tasks as traditionally the main tool for assessing ToM itself (Bloom and German, 2000).

On this pursuit, it is perhaps surprising to note that one salient and widely investigated developmental language disorder is conspicuous by its near-complete absence in ToM research. That disorder is dyslexia. Dyslexia is traditionally defined as a specific reading disability that is not obviously explainable by sensory impairments, general IQ or age (Jeffries and Everatt, 2004; Valdois et al., 2004; Di Filippo et al., 2008; Nandakumar and Leat, 2008; Kalyvioti and Mikropoulos, 2012). It often involves a greater deficit in spelling than in single-word reading or sentence-reading (Selikowitz, 1998; Cappelli et al., 2018). Dyslexia is also closely related to Working Memory (WM), and differences in memory can also go some way to accounting for the differing profiles of spelling (Jeffries and Everatt, 2004; Brandenbury, 2015).

As well as reading, spelling and WM, dyslexia has recently been linked to a range of other aspects of cognition. For example, it has been linked to slower speed of processing and some deficit in production and understanding of humour and pragmatics (Pickering, 2006; Nicolson and Fawcett, 2008; Abd Ghani and Gathercole, 2013; Cappelli et al., 2018; Reis et al., 2020). Although it usually emerges fairly early in childhood, dyslexia continues to pose challenges in early adulthood and beyond, although some of these may decrease slightly with age (Reis et al., 2020). For instance, Abd Ghani and Gathercole (2013) have reported that it relates to college students' tendency towards lower academic study skills, more difficulty with time management and increased anxiety about academic performance.

Granted, some evidence seems to suggest the possibility that ToM might indeed be a factor in dyslexia (Cardillo et al., 2018). Nilsson and de Lopez (2016) found that specific language impairment (SLI), which is often taken to be similar to dyslexia, is associated with a lower ToM. More direct evidence comes from Cardillo et al. (2018). They found that children having dyslexia tended to achieve lower scores on verbally-given ToM tasks than did children not having dyslexia. However, although similar results have been obtained for young adults on pragmatic reasoning tasks (Griffiths, 2007), this finding seems yet to be replicated in ToM with an adult group having dyslexia.

Summary of Aims and Predictions

It can be theorised that ToM might be affected by having dyslexia for two main reasons. First, it is an example of an aspect of language which might be regarded as atypical (Jeffries and Everatt, 2004; Cappelli et al., 2018). Second, if the view that language is a facilitator of ToM or even integral to it is correct, then linguistic deficits related to the accessing of-, representation of-, and maintenance of symbolic information, or the manipulation and moving between multiple linguistic forms (e.g., the representation of a past view whilst similarly representing a current view), may lead to genuine deficits in ToM. But in order to test the reality of this possible ToM deficit, it may be necessary to employ alternative tasks in addition to only using false-belief.

The present research therefore had three main aims which we addressed across two studies. Firstly, to provide an initial test of the language facilitating hypothesis of ToM against the language-obscuring hypothesis we considered above. This aim was approached by comparing a group having dyslexia to a group having no such diagnosis. We predicted that, because of the language and memory demands of the standard false-belief task, adults having dyslexia should perform less well both on first-order and second-order ToM questions than a comparison group not having dyslexia, and this finding should hold across two different variants on the false-belief task.

Secondly, we aimed to introduce an alternative way of approaching the issue of ToM measurement, that avoided as far as practicable, issues of memory, the need to set up and maintain multiple mental representations, and assessment of competencies known to be related to language. Such factors might distort measurement of the target ToM ability. The new tool introduced here assessed ToM not by measuring false-belief in terms of test scores, but rather by ascertaining self-reports about the extent to which the participants align with a variety of statements designed to be related to a number of known corollaries of ToM (e.g., own prior-belief, others' false-beliefs, interest in other minds...). If dyslexia really did involve a ToM deficit, we would have expected to find essentially the same results as in aim 1 (above).

Finally, we wanted our findings to speak to the possibility that variants on the standard false-belief task when applied to adults, may sometimes not necessarily accurately reflect the reasoner's true ToM competencies. Dyslexia being a case-in-point.

STUDY 1

To address our first aim we designed a study which presented diagnosed dyslexic participants and non-dyslexic participants with a series of social situations told by way of short stories (vignettes) and given via written text (Tompkins et al., 2013). The vignettes were of a form used in much ToM research (e.g., McKinnon and Moscovitch, 2007) and were structured much like the stories in the Wimmer and Perner (1983) task, apart from involving situations more relevant to adults (Hedden and Zhand, 2002; Terwogt and Rieffe, 2003).

To confirm dyslexia in the dyslexic group and also to confirm no dyslexia for the control group, we additidonally took our own indices of single word reading accuracy, spelling aloud accuracy (based on the Wechsler Objective Reading Dimensions—WORD, Rust et al., 1993), and a basic measure of WM expected to be fairly independent of linguistic ability (based on a task used by Jeffries and Everatt, 2004).

Method for Study 1

Participants

A total of 90 young adults studying at a UK university were assigned to one of two groups based on two main criteria. The first was a self-report of dyslexia. The second was having previously been diagnosed as having dyslexia. Diagnoses of the dyslexic group was made by professional dyslexia staff in the university student support service, with most participants having already reported a dyslexia diagnosis whilst in pre-HE education. This group was recruited on the basis of presence of dyslexia whilst having no other more pervasive language impairment on their support profile (i.e., no participants had been given a SLI/DLD diagnosis). Each participant in this group was also in receipt of student support on the basis of having dyslexia. This is an acceptable way of assigning participants to a dyslexia vs. non-dyslexia group (e.g., see meta-analysis of 178 studies by Reis et al., 2020). Indeed, only a single participant in the dyslexic group was removed because being < 1.5 SDs below the mean of the group not having dyslexia.

The resultant dyslexic group comprised 33 participants (*Mean* = 23.637 years, *SD* = 5.093), 22 of whom were female. The non-dyslexic group comprised 56 participants (*Mean* = 23.190 years, *SD* = 4.904), 35 of whom were female. The resultant total sample included in analyses was 89 participants.

Materials

An IBM compatible portable computer with a 2.4GHz PentiumM processor ran programs for administering the dyslexia-diagnostic tasks (i.e., reading, spelling and WM tasks) plus the critical ToM task. A second monitor was attached and responses were taken using two external devices connected to the computer. When a response was entered, the responses were immediately saved to memory.

The ToM task comprised five stories each of which outlined a particular social scenario (hereafter termed vignettes), each immediately followed by a series of eight questions in pseudo-random order (i.e., pre-randomised). The vignettes were titled Going Swimming, A Bag of Crisps, Which Shoes, Going Out and Whose Essay. The vignette "Going Out" is presented in **Appendix 1**, along with the corresponding questions and their categories. Full transcripts of the other vignettes are available from the first author upon reasonable request. The vignette "Going Out" involved a situation where all the characters' beliefs about what has happened are incorrect but one of these actually coincides with the current state of the world. In this vignette, three friends decide to take a break from dancing to have a drink. The main character buys two drinks with blackcurrant in them for his two friends, and a drink with coke in it for himself (he does not like blackcurrant). However, he inadvertently puts the wrong drink by his own place at the table. Then, whilst he is away for a moment, the second of the three friends swaps his own drink with the main character's drink. A factual question could ask about why the friends needed the drinks (answer = because they had done too much dancing). An inference question might ask which drink was bought for one of the main characters two friends (answer = we are only told that he buys three drinks but one is with coke because he does not like blackcurrant, so we can work the answer out inferentially). A first-order question might be about which drink the second friend will taste (answer = after switching the drinks, he believes he has the one with coke in front of him but actually his original belief was false so he has a different drink to that he thought). A second-order question might be about which drink the second friend thinks the first character believes he himself is about to drink (answer = only the participant and the first character have a true belief although for different reasons; and the second friend believes he has caused a false-belief in the main character but that is not actually correct).

Factual questions were about information directly intimated or explicitly stated in the vignette. Inference questions concerned deducible or social-contextual information that did not necessitate mentalizing. First-order questions concerned a character's belief/knowledge of a situation, which represented a currently untrue state of the world. Second-order questions concerned the participant's understanding of what the first character believes the second character believes about a situation (Duval et al., 2011).

The reason for using five vignettes was to help reduce possible fatigue effects by using vignettes that were very different from all the others. This also reduced possible practise/carryover effects, because we could limit the number of questions on each vignette to eight (two for each question type). The present data were collected and summarised automatically to give us the four categories of the ToM-related index (Factual, Inferential, 1st-order & 2nd-order), which meant we had not categorised according to total scores on each vignette. However, we computed a reliability estimate from a separate dataset (*N* = 68), which had been summarised according to vignette. The Cronbach's Alpha reliability estimate for this separate computer false-belief task was 0.937, which we considered high.

The reading task was a computer-presented variant of the reading scale of the Wechsler Objective Reading Dimensions also known as the WORD (Rust et al., 1993). This presented a total of 55 words one at a time, with these becoming progressively more challenging to pronounce correctly. The spelling task was a computer-presented variant of the Spelling Dimension of the same test. This presented the researcher with a total of 50 words plus examples of their uses in sentential contexts, which were read out for the participant to spell aloud. Both these tasks have been standardised with normally-developing individuals aged between 6 and 18 years, as well as individuals with reading and/or spelling issues (Rust et al., 1993). Thus, although the non-dyslexic participants might approach ceiling, these tests should still discriminate between dyslexic and non-dyslexic participants, and between the more and less proficient readers/spellers in the non-dyslexic group.

The primary reason for including the single-word-reading, spelling and WM tasks was to inform us about how participants' self-reported dyslexia status related to these aspects of cognition

(Jeffries and Everatt, 2004; Kalyvioti and Mikropoulos, 2012). The WM task was devised to be suited for testing participants down to 5 years, so that future studies might contrast adults with young children. A monitor faced the experimenter and gave instructions for what should be presented to the participant. The experimenter read aloud a short list of previously randomly selected digits without placing any greater stress on any particular digit. For each trial, the participant waited until the list was presented and the experimenter had asked for one item from that list. The request was either for the "biggest" or the "smallest" digit (determined on a pre-randomised basis). The participant was instructed to give his/her response as quickly as possible, and only the first response was taken. This task necessitates the participant keeping the list in mind (storage aspect) and making the most basic decision about the digits in the list (mental manipulation aspect).

Design

A mixed factorial design was employed, both regarding reading, spelling and WM, and also regarding the four types of question from the ToM task. In each case the DV was the relevant score (e.g., reading score). For each analysis, performance was analysed as a function of group (dyslexic vs. non-dyslexic), with this dyslexia-status variable constituting the main IV.

Procedure

Participants were tested in a laboratory setting. The second keyboard and monitor meant that the researcher could always see the screen and start/stop the computer, and the participant had a screen which could be turned off at the appropriate times. Each participant was given the spelling task first, followed by the WM task, reading task and finally the ToM task. For the spelling task, the participant's monitor was switched off. In slight variation from the procedure presented by Rust et al. (1993) the experimenter first read out a sentence that included the word to be spelt, and then stated a single word which the participant then had to spell out aloud. All responses were audio-recorded with each participant's prior consent (McKinnon and Moscovitch, 2007). This permitted responses to be verified later on without delaying the test procedure.

For the WM task, the participant's display was again switched off. After being briefed on the task, the participant was given two examples without the computer, in which the researcher used a monotone voice to say a random series of numbers plus the prompt "biggest" or "smallest." When the participant answered, the researcher verified it. The computer was then used to present two formal practise trials, with the participant prompted to give the answer as soon as s/he thought s/he knew what it was. Although these and other trials used digits selected earlier on a random basis, their identities and orders were now fixed. No participant had difficulty with practise trials. The 12 experimental trials were then given. These had an equal number of lists with three digits, four digits and five digits. After each trial, the researcher pressed a key to record whether the answer given had been that on the display; and then pressed a designated key to move to the next list of digits.

In the reading task, participants fixated a dot centrally on their display, and then the researcher pressed a designated key to replace the dot with the first to-be-read word. The participant read the word aloud and was then permitted to correct him/herself if s/he wished. Again correct responses were indicated by the experimenter pressing a designated key, followed by a second key to tell the computer to remove the current word and present the next word. A delay was built into the onset of each new word, which varied randomly between 1 and 2 s.

In the final section of the procedure, participants sat the ToM task. This task took the form of five blocks, one vignette per block, with each block followed by a series of eight questions. Participants read each vignette twice, to ensure they had correctly understood and remembered all the details (Schenkel et al., 2005; Russell et al., 2006).

For the first pass, the participant read the vignette silently to him/herself (Tompkins et al., 2013). This was intended to help reduce anxiety, particularly for participants who might be feeling more self-conscious about their reading.

Immediately upon finishing the currently displayed text on screen, the participant pressed the space bar. This removed the current screen. When ready, the participant pressed the space bar again to display the next screen of text. This was intended to help participants progress through the vignette at their own pace; whilst simultaneously permitting us to accurately measure the time needed to read each screen, without these times being distorted by the lengths of breaks each participant required before moving on. Please note, the reading-time data were analysed in detail and will be reported elsewhere, in order to avoid detracting from the main purpose of the present paper, and in order to be fully consistent with study 2, which would not require reading time data. However, we confirm that reading times were consistent with the group membership.

After an entire vignette had been read through once, the participant was given a break, the length of which was self determined. The vignette was then presented again in the same way as before, but this time the participant was asked to read each sentence out aloud. This allowed us to verify that the information was being read accurately; provided one condition ordering to be used elsewhere in comparisons of reading times for silent vs. reading aloud; and also helped ensure that participants had the entire vignette in mind before answering any ToM questions. Finally here, the fact that participants had already read the entire vignette through once, served to reduce any anxieties about reading aloud (Abd Ghani and Gathercole, 2013).

After a given vignette had been read twice, the test questions appeared on screen one at a time. Each question was requested via the participant pressing the spacebar. The participant read the question aloud and then answered it as soon as they felt able. The researcher had training and practise in efficiently pressing a designated key on the second keyboard as soon as the participant had pronounced the last word in the sentence, and then pressed a different key as soon as the participant began their answer. This allowed her to start and stop the computer's millisecond timer, respectively. Once the timer had been stopped, the researcher pressed a different key to signal whether the participant's response had been correct, according to an answer sheet containing acceptable answers, which was in front of her but conveniently placed out of sight of the participant. For reasons explained above, only the response-accuracy data are presented here. The entire procedure took around 45 min, excluding briefing and debriefing. Participants were thanked for their assistance and any questions they had at this time were answered.

Results and Discussion for Study 1

For the ToM task, participants answered a total of 40 questions across five different vignettes. The questions were classified into four different question-types, factual, inference, first-order and second-order. There were two questions of each type per vignette. Across all five vignettes, the maximum number of correct responses for each question-type was 10.

Before considering the ToM data in detail, we considered the make-up of the dyslexic and non-dyslexic groups, respectively. The first indices were the tests of reading, spelling and WM. As these tests had different maximum scores (55, 50, and 12, respectively) we converted each score into a percentage for more ready comparisons (please see **Appendix 2** for raw scores). The mean scores as percentages are given in **Table 1** according to dyslexia-status and cognitive task.

Table 1 shows the spelling test tended to be more demanding than reading, with WM slightly easier than reading. It also shows a tendency for the combined average score to be almost 10% higher for the non-dyslexic group compared to the dyslexic group. A three-way Analysis of Variance (ANOVA) with gender, dyslexia-status and cognitive-task as factors, confirmed that the difference between the three diagnostic indices was statistically significant [$F_{(2, 170)} = 54.146$, $p < 0.001$, Partial Eta$^2 = 0.389$, Obs.Power = 1.000]. Of note, the overall difference between our two groups was also significant [$F_{(1, 85)} = 58.308$, $p < 0.001$, Partial Eta$^2 = 0.407$, Obs.Power = 1.000].

There was a 12.7% difference between the dyslexic and non-dyslexic group for spelling, reducing to 8.5% for reading and a slightly lower 8.3% for WM. This profile is in line with Reis's et al. (2020) analyses which showed WM is typically less impacted than spelling and reading. However, here, the suggested two-way interaction between dyslexia-status and cognitive-task was not statistically-significant [$F_{(2, 170)} < 1$].

There was no statistically-significant overall difference according to gender as a main effect nor of gender with either dyslexia-status or cognitive task (each F < 1). The three-way interaction between gender, dyslexia-status and cognitive task was also not statistically-significant [$F_{(2, 170)} = 1.818$, $p = 0.166$, Partial Eta$^2 = 0.021$, Obs.Power = 0.376].

Having confirmed our self identified dyslexic participants did show a dyslexia profile across reading, spelling and WM (Duval et al., 2011), we move on to the ToM analyses with the knowledge that our two groups may be considered indeed dyslexic and non-dyslexic, respectively. **Table 2** summarises the mean scores obtained by the two respective groups for each of the four different types of questions on the ToM task—factual, inference, first-order and second-order.

Table 2 shows our two groups evidenced very similar performance on factual questions. So, they had each retained the information in memory well. The relatively marked difference between the groups on ToM questions (**Table 2**), would therefore seem not to have resulted from differential retention of vignettes in any straightforward way.

Average performance was lower for the dyslexic group. **Table 2** also shows a tendency for factual questions to attract the highest scores, followed by inference questions. First-order questions showed lower scores than inferential questions, with second-order questions hardest of all. This profile was interesting given that we had ensured the inference questions were of the same form as used for the first-order ToM questions around 50% of the time, and the same form as the second-order questions the rest of the time.

We analysed these trends using a three-way ANOVA, having factors of dyslexia-status, question-type and gender. The main effect of dyslexia-status was statistically significant [$F_{(1, 85)} = 22.664$, $p < 0.001$, Partial Eta$^2 = 0.210$, Obs.Power = 0.997]. The overall difference between the question-types was also statistically significant [$F_{(3, 255)} = 34.248$, $p < 0.001$, Partial Eta$^2 = 0.287$, Obs.Power = 1.000].

Paired-contrasts showed that the higher performance on factual questions compared to first-order ToM was statistically significant ($p < 0.001$). However, the slender advantage of first-order ToM compared to inference was not statistically significant ($p = 0.233$). The higher performance of first-order ToM compared to second-order ToM was statistically significant ($p = 0.001$).

The dyslexic group's profile from question-type to question-type differed significantly from that of the non-dyslexic group [two-way interaction—$F_{(3, 255)} = 3.639$, $p = 0.013$, Partial Eta$^2 = 0.041$, Obs.Power = 0.794]. From **Table 2** we observe that the difference between groups was smallest for the factual question, which did not necessitate inferential processing or thinking in terms of minds. However, as question-type required processing of the mental states of one and then more than one protagonist's subjective viewpoint, the difference between our two groups diverged.

Neither gender as a main effect nor the two-way or three-way interactions involving gender were statistically-significant. The two-way interaction between gender and question-type had an $F > 1$ but was not significant [$F_{(3, 255)} = 2.134$, $p = 0.096$, Partial Eta$^2 = 0.024$, Obs.Power = 0.540]. All remaining interactions with gender were also non-statistically-significant (each F < 1).

STUDY 2

Let us initially take the findings of Study 1 at face value. This invites the interpretation that dyslexia is related to a deficit in ToM (Abd Ghani and Gathercole, 2013; Cappelli et al., 2018; Cardillo et al., 2018). However, now consider our thesis that false-belief tasks require the reasoner to represent the social situation of the protagonist in mind over time, in addition to representing the reasoner's current understanding of the situation. This requires the ability to set up mental tokens for things in the real world; what Lillard and Kavanaugh (2014) call a symbolic representational capacity (see also Abell et al., 2000).

TABLE 1 | Summary of tests of spelling, WM, and reading as percentages (Study 1).

	Spelling	WM	Reading	Overall
Non-Dyslexic Female	86.659 (1.386)	94.762 (1.816)	92.727 (0.848)	91.383 (0.946)
Non-Dyslexic Male	82.635 (1.790)	93.254 (2.344)	93.680 (1.095)	89.856 (1.221)
Dyslexic Female	71.628 (1.749)	84.849 (2.290)	86.281 (1.069)	80.919 (1.193)
Dyslexic Male	72.364 (2.473)	86.364 (3.239)	83.140 (1.512)	80.623 (1.687)
Non-Dyslexic	84.647 (1.132)	94.008 (1.482)	93.203 (0.692)	90.619 (0.772)
Dyslexic	71.996 (1.514)	85.606 (1.983)	84.711 (0.926)	80.771 (1.033)
Female	79.143 (1.116)	89.805 (1.461)	89.504 (0.682)	86.151 (0.761)
Male	77.499 (1.526)	89.809 (1.999)	88.410 (0.993)	85.239 (1.041)
Overall	78.321 (0.945)	89.807 (1.238)	88.957 (0.578)	85.695 (0.645)

Values represent percentages. Values in Parentheses are standard errors.

TABLE 2 | Summary of ToM performance by group and gender (Study 1).

	Factual	Inference	1st-Order	2nd-Order	Overall
Non-Dyslexic Female	8.857 (0.188)	7.971 (0.225)	7.714 (0.256)	7.314 (0.254)	7.964 (0.162)
Non-Dyslexic Male	8.762 (0.243)	7.667 (0.291)	8.667 (0.331)	7.476 (0.327)	8.143 (0.209)
Dyslexic Female	8.636 (0.237)	6.682 (0.284)	6.591 (0.323)	6.227 (0.320)	7.034 (0.204)
Dyslexic Male	8.273 (0.336)	6.455 (0.402)	6.727 (0.457)	6.455 (0.452)	6.977 (0.288)
Non-Dyslexic	8.810 (0.154)	7.819 (0.184)	8.190 (0.209)	7.395 (0.207)	8.054 (0.132)
Dyslexic	8.455 (0.206)	6.568 (0.246)	6.659 (0.280)	6.341 (0.277)	7.006 (0.177)
Female	8.747 (0.151)	7.327 (0.181)	7.153 (0.206)	6.771 (0.204)	7.499 (0.130)
Male	8.517 (0.207)	7.061 (0.248)	7.697 (0.282)	6.965 (0.279)	7.560 (0.178)
Overall	8.632 (0.128)	7.194 (0.154)	7.425 (0.175)	6.868 (0.173)	7.530 (0.110)

Maximum possible value is 10. Values in Parentheses are standard errors.

Both the respective situations need to be held in memory whilst the reasoner decides which of them is required to answer the various questions on the task (Kaland et al., 2005; McKinnon and Moscovitch, 2007).

We additionally need the ability to move mentally between, and to appropriately suppress, either one of these two differing subjective perceptions/representations. For first-order ToM this is one representation on behalf of the protagonist and the other representation being of the reasoner him/herself (Leslie et al., 2004; Russell et al., 2006; Sabbagh et al., 2006; Lallier et al., 2009; Lillard and Kavanaugh, 2014). Perhaps most importantly, the appreciation of the narrative of the task and the ability to explain what is happening requires a well-developed linguistic competence, such as regarding an adequate vocabulary, for syntax or for sentence-complements (Simmons and Singleton, 2000; Miller, 2001; Ransby and Swanson, 2003; Slade and Ruffman, 2005; Moran, 2013; Cardillo et al., 2018). So, cognitive domains such as memory, attention or in particular language seem integral to ToM. However, as outlined earlier, such relationships may stem more from the nature of tasks we tend to use (false-belief performance measurements), rather than being genuine differences in ToM between the two groups (Bloom and German, 2000; Milligan et al., 2007; Guajardo and Cartwright, 2016).

For our alternative measure of ToM, we turned to a questionnaire index instead of the more experimental-task-based index such as the false-belief task used in study 1. Questionnaires have occasionally been said to be relatively unsuited for assessing ToM (Realo et al., 2003). However, here, instead of the questionnaire testing ToM directly using a score (e.g., Rutherford, 2004), we asked participants about their behaviours, feelings and dispositions towards/about themselves and other people in quite everyday situations (Chinn and Crossmann, 1995; Hales, 1995; Griffiths, 2007; Abd Ghani and Gathercole, 2013; Dodell-Feder et al., 2013). In this way, we could assess participants ToM without the need for the assessment to be confounded with memory, attention and language competencies. As this new questionnaire tool comprised 30 questions, we termed it the ToM30Q.

To assist consideration of whether the ToM30Q was valid, we considered three separate partial-validations. The first of these was against an existing written tool for indexing ToM. One of the most noted is Rutherford's (2004) ToM stories task using embedded false-belief. This task centres on stories typically involving four characters who have false beliefs about what one of the other characters believes. After reading a story, the participant considers a number of statements, each using the two-alternative forced choice response format. The participant then has to select the correct belief or factual statement from the two options. Both types of questions could ask about first-order ToM or higher order ToM, with analogous questions asked about the facts of the stories.

The Rutherford task is given in written form but it assesses ToM in a way said to be similar to the more standard false-belief task used with children (Rutherford, 2004). We expected that, if the Rutherford task is assessing the same ToM construct as our ToM30Q, we should find that a ToM factor we extract from our ToM30Q would be correlated with the Rutherford task. However, if measuring different things (e.g., ToM independent of language vs. ToM affected by language, respectively), then we would have expected such a correlation to be absent.

The second partial validation of the ToM30Q was based around the relationship between ToM and empathy (Christov-Moore et al., 2014). Decety et al. (2010) define empathy as the ability to share a wide range of emotions and feelings of others but without this stemming from direct emotional stimulation. Basically, it is the ability metaphorically to put oneself in someone else's shoes. This ability to imagine how someone else feels, is not the same as the ability to entertain a false belief, but the two competencies are generally taken to be quite closely associated (Blair, 2005; Singer, 2006).

This means that we should be able to partially validate our ToM30Q against an existing measure of empathy. The questionnaire used here was the Empathy Components Questionnaire (ECQ—Batchelder et al., 2017).

The third way of partially validating the ToM30Q was to consider whether it results in differences between certain groups of participants. For example, gender differences in ToM are quite slight during middle childhood, with the advantage tending to be for girls (Charman et al., 2002; Walker, 2005; Gardner et al., 2012; Meneghetti et al., 2012). The female advantage appears more substantial in adolescence and adulthood (Ahmed and Miller, 2011; Gardner et al., 2012; Meneghetti et al., 2012; Ibanez et al., 2013; Wacker et al., 2017), although there are some exceptions (Russell et al., 2006; Dodell-Feder et al., 2013).

Empathy, which has been previously associated to ToM, also shows up gender effects in favour of females from around 6 years of age, with the gap widening with age as for ToM (Chapman et al., 2006; Lam and Yeung, 2012).

Method for Study 2

Participants

Participants were 93 adults studying or working at a UK university. They were assigned to one of two groups based on whether they reported previously being diagnosed as having dyslexia, in the same way as for study 1 earlier. The group having dyslexia comprised 25 participants of mean age 22.798 years ($SD = 2.488$, 15 females). The non-dyslexic group comprised 67 participants of mean age 24.744 years ($SD = 5.896$, 50 females). None of the participants had taken part in study 1.

Materials

These were the ToM30Q, the Rutherford stories task, and the Empathy Components Questionnaire. The ToM30Q contained a total of 30 questions with 24 of these intended to assess a number of hypothesised aspects of ToM but without the need for a more formal experimental test. The remaining 6 questions were intended to be control questions but were worded in a way similar to that of the ToM questions. An example is Q4—"If you are talking to someone who has tattoos, does this take your attention away from what they are saying?". ToM questions asked about the extent to which the participant routinely considers other people's beliefs, reflects on their own past beliefs, tends to be able to read what someone is thinking based on looking at their eyes or interpreting the tone of their voice, are actually interested in what people are thinking, are easily distracted away from social interactions with other people, and consider it important to share one's beliefs with other people. An example is Q16—"When someone does something do you try to imagine what they were thinking that made them do it?". Other questions asked about a participant's interest in recognising other people's emotional states, the participant's own emotionality, whether the participant feels they are better or not as good as their peers at telling when someone is getting upset in different circumstances, and how much they are troubled by a friend who is upset. An example is Q13—"In a face to face conversation with friends, I am one of the last to tell when someone's mood is changing" (Maszk et al., 1999).

The questionnaire both included positively worded and negatively worded questions, with the latter being reverse coded before scoring. For each question, the participant selected one of five possible responses on a Likert-type scale accompanied by semantic differentiated descriptions (Always … Never—similar to Duval et al., 2011). The full questionnaire is available upon reasonable request.

Factor Analysis was carried out after removing the six control questions. The remaining 24 questions were used to establish whether the data were consistent with one or more factors which could be identified as ToM. This analysis used the Principal Components method. Pre PCA checks demonstrated this method was appropriate. Skew and kurtosis were within $+/-2.0$ and $+/-3.0$, respectively. Also, inspection of the correlation matrix did not suggest any multi-collinearity.

Kaiser-Meyer-Olkin measure of sampling was 0.668 (i.e., above 0.6, Kaiser, 1974; Kaiser and Rice, 1974). Bartlett's test of sphericity was statistically-significant ($p < 0.001$), indicating the overall profile of correlations in the matrix differed from 0. Lastly here, communalities between items were above 0.40 (Jolliffe, 2002; Field, 2013).

PCA with orthogonal varimax factor rotation initially produced eight factors, with eigenvalues exceeding a Kaiser's criterion of 1, explaining 44.205% of the total variance. Of these eight factors, the last four contained two items or fewer. We then reran the analysis, forcing the number of factors to four, as only the first four factors had contained three or more items. This forced-factor reduction resulted in all but one of the 24 items (Q20) loading adequately onto one of the four forced factors.

Note, factor analysis was run completely independently by both investigators; yet both followed the same procedure for factor reduction and arrived at precisely the same factor structure. Additional confidence in the analysis was further boosted by preliminary analysis of a completely separate dataset based on around 400 participants but not concerning dyslexia (paper in preparation). Thus, we consider the analysis robust enough to continue.

A summary of the four factors and the rotated component matrix is given in **Appendix 3**. Factor 1 contained eight items, factor 2 contained seven items, factor 3 contained four items and factor 4 contained four items. The two investigators and two research assistants separately reviewed each of the four factors, in order to arrive at a consensus as to the most informative label to give each one. We tried to give a label to each, that accepted at least three of the four suggested labels, with any differences in offered labels resolved by discussion. The result of this process was that the first two factors closely related to ToM, with the other two factors more tentatively related to ToM.

The consensus label for factor 1 was "Perception-based-ToM." This label was intended to capture the tendency for this factor to involve an interest in ToM via direct perception of eyes, voice or emotion (self-perception). This accepted prior links between ToM and emotion, as discussed by Harris (e.g., Harris, 1989; see also Hynes et al., 2006).

We called Factor 2 "mental-representational-ToM," drawing on a phrase introduced by Perner (1991). This was largely because, irrespective of whether the emotion or the past beliefs of others were under consideration, the labels offered indicated mental representation of own and other's ToM or of own present vs. own past ToM (Coricelli, 2005). Thus, this factor reduces to a person being routinely sensitive to or interested in setting up dual representations of minds; as theoretically required, for example, by false-belief tasks (cf. Wimmer and Perner, 1983).

Factor 3, the first of the less direct indexes of ToM, was called "prioritising-the-face." This factor seemed to revolve around an interest in being physically in the vicinity of the other person, whose subjective belief or emotional state is then interpreted by looking at the face (Harris, 1989). We called factor 4 "interest-in-others." This factor was about how affected a person considers him/herself to be by others and, or the extent to which they find it easier to read others' beliefs if the participant already had direct experience of what the other might now be going through.

Cronbach's alpha reliability analyses were applied to the four factors. Factor 1 (perception-based-ToM) had a Cronbach's alpha value of 0.763 and this value did not increase if any one of its 8 items was excluded. For factor 2 (mental-representational-ToM), Cronbach's alpha was estimated in the same way and was 0.748, based on all 7 of its items.

For factor 3 (prioritising-the-face) we observed a Cronbach's alpha estimate of 0.626, which we considered adequate. Although the reliability estimate for factor 4 (interest-in-others) was a more moderate 0.421, we included this factor in our following analyses.

The next questionnaire was the Empathy Components Questionnaire (ECQ—Batchelder et al., 2017). This had 27 items intended to assess empathy towards other people. A factor analysis was conducted using the same procedure as for the ToM30Q. This revealed a single factor, containing 19 of the 27 items. The remaining items had low factor loadings and three or fewer items. A summary of the items loading on Factor 1 plus the items that were not robust enough to form additional factors in our particular dataset, is given in **Appendix 4**. Cronbach's Alpha analysis for the ECQ resulted in a reliability estimate of 0.895. We considered this again sufficient for us to proceed to data analyses proper.

The third of our tools was the Rutherford stories task. For reasons of time, we used only one of the four stories reported by Rutherford (2004). This was the story about chocolates. This task contained a story which the participant read, plus a series of nine questions. Four of the questions were control questions, and the remaining five questions were about subjective beliefs that the characters in the story held about the location of the chocolates, or the beliefs of other characters about its location. Each question was binary in form. Additionally, the ToM and control questions had highly differing difficulties by design and were converted to weighted and unweighted scores (Rutherford, 2004), rendering one or both measures non-linear. We estimated reliability based on the more linear coding of 1 point per item. We used Cronbach's Alpha and estimated the significance level via the Freedman-Chi-Square method. Computed in this way, the estimate for the present sample was 0.561, which we considered moderate.

Design

The design included comparisons of means on the ToM30Q according to gender, and correlations between the factors of the ToM30Q and the published index of empathy (ECQ) and ToM (Rutherford stories task). These were preceded by a preliminary analysis of the Rutherford task in terms of comparison of group means, so that we could determine if scores on this task resembled either the false-belief task profile in study 1 or more closely resembled the profile of the ToM30Q in study 2.

Procedure

Participants were tested in a laboratory setting, as before. They first answered a number of demographic questions, most notedly their birth sex and current gender identity. In all cases the responses of these two indexes were identical. Participants were also asked about their previous grades at GCSE level, in English, Maths, Science and Information Technology (IT). The subject having answers from virtually all participants was Science and so this subject was used to assess any academic performance differences according to group.

After the demographic questionnaire, participants completed the Rutherford stories task, the ECQ and the ToM30Q. For the ToM30Q the questions were read by the researcher to keep issues of participants' reading speed or accuracy to a minimum. For the ECQ, the same procedure was used. However, for the Rutherford task, each participant was first given 2 min to read through the story, and then the control and ToM questions were asked by the researcher as per the above questionnaires. For this tool, the participants were permitted to re-read the story as they saw fit, if this was needed to help them answer a particular question. The ToM questions were a composite of first-order and higher order questions, permitting the calculation of a raw score plus a weighted score as reported in Rutherford (2004). Altogether, this procedure took around 45 min per participant, including briefing and debriefing.

Results and Discussion for Study 2

For the ToM30Q we calculated the average scores out of a maximum of 5, across the items of the ToM factor and also for the Emotionality factor. We did similarly for the ECQ. For the Rutherford stories task we summed the correct answers out of 5 for ToM and out of 4 for the control (non-ToM) questions. We additionally calculated the weighted scores as in Rutherford (2004).

Study 1 already showed that the self-reporting and university student support service identification of dyslexia as a diagnosis is in line with reading, spelling and WM scores. Also, in educational settings dyslexia is typically considered to be a learning disability, rather than only concerning reading difficulties (Selikowitz, 1998; Ransby and Swanson, 2003; Jeffries and Everatt, 2004; Cardillo et al., 2018). This is partly because less accurate reading, slower reading speeds or slower comprehension of what is read, can impact on learning even where the ability to read is not the primary concern of the subject (e.g., in teaching/learning mathematics—Chinn et al., 2001). Therefore, for the present study, we took a further step to look at real-life performance impacts of having dyslexia.

The first analysis here therefore considered whether the dyslexic group and non-dyslexic group showed the expected difference on GCSE science (averaged multiple/combined awards). The data were translated as follows. For the GCSE grades we scored in even numbers from A* (12 points) through to grade F or lower (0 points). For example, a grade C would have a score of 6. All 25 of the group having dyslexia were entered into this analysis. However, for the non-dyslexic group, 1 of the 68 participants did not give GCSE data and so this participant's data are excluded from this initial analysis.

The mean GCSE score for the group having dyslexia was 7.920 ($SD = 1.681$), and for the non-dyslexic group the mean was 8.720 ($SD = 1.665$). In relative percentage terms, the non-dyslexic group tended to have translated science scores around 10% higher relative to the group having dyslexia. This difference is in line with the overall difference found in study 1, for reading, spelling and WM. The difference here, corresponds to just under one grade point (roughly C+ vs. B+).

A One-way Between Subjects Analysis of Variance was carried out with GCSE_Science as the dependent variable. The independent variable was dyslexia-status as in study 1. The difference between the two groups on science scores was statistically-significant [$F_{(1, 90)} = 4.166$, $p = 0.044$, Partial Eta^2 = 0.044, Obs.Power = 0.524].

The group having dyslexia tending to have lower scores in GCSE Science (slightly less than one grade lower), is in line with research that has shown that overall, having dyslexia can impact on indexes related to academic performance (Griffiths, 2007; Abd Ghani and Gathercole, 2013; Reis et al., 2020). Thus, this first finding seems in line with the self-categorisation of the two groups as having vs. not having dyslexia.

Before turning to the ToM questionnaire data, it was considered prudent to determine whether the Rutherford stories task of ToM, distinguished between our two groups. If we are correct in our assumption that ToM tasks based around false-belief can be distorted because of their reliance on cognitive structures such as memory and language (Bloom and German, 2000), then we should find the Rutherford task intimates a ToM deficit related to dyslexia that is similar to what we found in study 1. To robustly address this question, the means for each group for control and ToM scores were calculated. These means are presented in **Table 3**, with the unweighted scores in the top half of the table and the weighted scores in the bottom half.

TABLE 3 | Summary of main effects on the 6 variables from the Rutherford task.

	Control	Theory of Mind	Total
Unweighted			
Non-Dyslexic	3.309 (0.090)	4.500 (0.099)	7.809 (0.157)
Dyslexic	2.560 (0.149)	3.800 (0.164)	6.360 (0.259)
Overall	2.934 (0.087)	4.150 (0.096)	7.084 (0.151)
Weighted			
Non-Dyslexic	5.882 (0.259)	11.500 (0.298)	17.382 (0.432)
Dyslexic	4.280 (0.427)	9.200 (0.492)	13.480 (0.712)
Overall	5.081 (0.249)	10.350 (0.288)	15.431 (0.416)

Figures in parentheses are standard errors.

Table 3 suggests that regardless of whether we used the weighted or unweighted scores or whether we took the ToM scores, the non-ToM control scores or the total score on the Rutherford task, we saw essentially the same pattern. That is to say, the Rutherford task, just like the computer-based false-belief task of study 1, suggests a consistent tendency for participants not having dyslexia to score higher.

These data were analysed using a Multivariate Analysis of Variance (MANOVA) with dyslexia status as the between-subjects factor and the six sets of scores (2 weighting calculation modes × 3 indexes from each) as the multivariate dependent variable. The multivariate main effect of group combined across all six measures shown in **Table 3**, was found to be statistically-significant [Wilks' Lambda $F_{(4, 88)} = 7.871$, $p < 0.001$, Partial Eta^2 = 0.264, Obs.Power = 0.997].

The separate analyses run for each of the six dependent variables as part of the MANOVA for the Rutherford task showed that the difference between our two groups was statistically-significant in every case [each $F_{(1, 91)} > 13.362$, $p < 0.001$, Partial Eta^2 > 0.128, Obs.Power > 0.951]. These differences were also significant for each of the weighted Rutherford scores [each $F_{(1,91)} > 15.970$, $p < 0.001$, Partial Eta^2 > 0.149, Obs.Power > 0.975]. Thus, whether we considered the Rutherford scores for ToM, the scores on the control questions or even both of these combined into a total score, we obtained essentially the same finding: If we were to take test scores as our preferred index of ToM, we might well-interpret these findings as confirming that dyslexia is linked to lower ToM performance. The key findings about dyslexia in study 1 then, are unlikely to have arisen because of our use of a computer task of false-belief ToM.

So, we have confirmed that the group-wise comparison of GCSE Science scores is in line with the dyslexic vs. the non-dyslexic groups' self-reported dyslexia status, and that according to the Rutherford task there would seem to be a deficit in ToM connected to having dyslexia. However, recall our main thesis is that a relationship of language measures to ToM does not necessarily have to have arisen because language is integral to ToM. Equally, such a data profile could arise if linguistic performance measures make it harder for a participant group to report its true ToM competence. Our ToM questionnaire index of ToM does not rely on participants having to memorise fairly substantial amounts of material and does not call for mastery of particular syntactic propositional structures through which ToM reasoning must pass (Miller, 2001; de Villiers and Pyers, 2002; Milligan et al., 2007). Therefore, if one wishes to fully confirm whether the computer-based false-belief task of study 1 and the Rutherford stories task, which do agree with one another, are revealing a reality of having dyslexia, it is important to assess ToM in a way not so reliant on language/memory. This is what our ToM questionnaire is intended to address.

Turning to the three planned partial validations of the ToM30Q. A set of Pearson's correlations was run in order to determine the strength of association between the four factors (from the ToM30Q) against each of the other main variables (Rutherford stories task, ECQ Empathy, Gender). Recall from the factor analysis of this tool, the factors were labelled F1 = Perception-based-ToM; F2 = Mental-representational-ToM; F3 = Prioritising-the-face; and F4 = Sensitivity-to-others. This correlational analysis included all four factors of the ToM30Q so that we could assess whether the factors of the ToM30Q were correlated with each other. This analysis was run first with all participants included and then with only the non-dyslexic group. The results were no different in terms of statistical significance. We therefore present only the analysis with all participants included. The pairwise correlations are summarised in **Table 4**.

Table 4 shows that the 4 ToM factors from the ToM30Q were significantly correlated with our measure of empathy (the ECQ). Empathy has generally been taken to form part of the basis of ToM (Dodell-Feder et al., 2013), and so the present finding of a strong association was as anticipated.

There was also a statistically-significant association between gender and the first three factors of the ToM30Q. That correlation was negative, indicating that the gender that had been coded as 1 (i.e., females) tended to have higher factor 4 scores than the gender coded as 2 (i.e., males), although it approached but did not reach statistical significance. These significant associations are again in line with findings from previous studies as regards gender and ToM in children and adults (Walker, 2005).

However, things seemed somewhat less clear for our third partial validation which was against the Rutherford stories task, intended to test for the actual application of ToM reasoning via a direct ToM score. The Rutherford ToM task was not reliably correlated with factor 1 (perception-based-ToM), factor 2 (mental-representational-ToM), nor with factor 4 (sensitivity-towards-others). However, Rutherford ToM score was correlated with factor 3 (prioritising-the-face).

Rutherford ToM was not correlated with overall empathy (via the ECQ) or with gender. This latter finding suggests that, on this occasion, the Rutherford task may not have been as good a measure of ToM as we had hoped; possibly due to us relying on only one of its stories.

That said, the finding that the Rutherford stories task was correlated with Factor 3 of the ToM30Q (prioritising-the-face), suggests that in our sample, the Rutherford story we selected was more sensitive to thinking about the facial expressions likely exhibited by the four protagonists in the story than to their hypothesised mental states.

To test the robustness of the Rutherford task and the ToM30Q as predictors of our independent index of empathy (ECQ) in the context of each other, a linear regression was carried out. This used the step-wise method in order to establish the variables most critical to predicting empathy score. We selected the backward stepping method to allow us to see how the variables are removed from the initial model (the simultaneous entry model) to settle on those variables contained in the most stable model.

This analysis produced five models, with the Rutherford ToM index the first to be removed (step 2). The final model had a multiple correlation coefficient of 0.763 [$F_{(3, 89)} = 41.299$, $p < 0.001$]; and accounted for 58.2% of the variability in the empathy index ($R^2 = 0.582$). **Table 5** shows that our final model contained the first three factors from the ToM30Q. This is further confirmation that the ToM30Q indexes phenomena that are related to empathy.

We can now turn to the important issue of whether the ToM30Q gives findings on dyslexia that bolster the findings from study 1 and the Rutherford task of study 2, regarding differential ToM as a function of having dyslexia. **Table 6** summarises mean scores for the factors of the ToM30Q, according to gender and dyslexia status. The trends summarised in the table were analysed using a three-way mixed-model ANOVA with ToM30Q score as the dependent variable. The within-subjects factor was ToM30Q component, with four levels corresponding to our four factors from the ToM30Q. The two between-subjects factors were dyslexia status (dyslexia vs. non-dyslexia) and gender (females vs. males).

Table 6 suggests scores tended to differ according to ToM30Q factor (Duval et al., 2011). The overall difference was statistically-significant [$F_{(3, 267)} = 20.171$, $p < 0.001$, Partial Eta$^2 = 0.185$, Obs.Power = 1.000].

Table 6 additionally reconfirmed the tendency for females to have higher scores on the ToM30Q than did males (see also earlier r value for gender in **Table 4**), with this difference again significant [$F_{(1, 89)} = 14.492$, $p < 0.001$, Partial Eta$^2 = 0.140$, Obs.Power = 0.964].

However, the very slender difference between dyslexic and non-dyslexic group was not statistically-significant [$F_{(1, 89)} = 1.944$, $p = 0.167$, Partial Eta$^2 = 0.021$, Obs.Power = 0.281]. None of the two-way or three-way interactions were statistically-significant [Gender × ToM category—$F_{(3, 267)} = 1.071$, $p = 0.362$, Partial Eta$^2 = 0.012$, Obs.Power = 0.289; Gender × Dyslexia Status—$F_{(1, 89)} = 1.494$, $p = 0.225$, Partial Eta$^2 = 0.017$, Obs.Power = 0.227; Dyslexia Status × ToM Category—$F_{(1, 89)} < 1$; Gender × Dyslexia Status × ToM Category—$F_{(3, 267)} = 1.616$, $p = 0.186$, Partial Eta$^2 = 0.018$, Obs.Power = 0.423].

This analysis reconfirmed the gender association with the ToM factor in the above correlational analyses, as well as being in line with the oft-reported finding of higher ToM in girls beyond childhood (Ahmed and Miller, 2011; Gardner et al., 2012; Wacker et al., 2017). However, importantly and in stark contrast to our Rutherford task and our computer-based false-belief tasks (study 1), the ToM30Q (present study) did not support the contention

TABLE 4 | Correlations between ECQ, Rutherford ToM, and ToM30Q four factors.

	Empathy	Ruth ToM	F1	F2	F3	F4	Gender	Ruth CTRL
Empathy	–	0.056 (0.296)	0.573 (<0.001)	0.561 (<0.001)	0.506 (<0.001)	0.223 (0.016)	−0.390 (<0.001)	0.051 (0.313)
Ruth ToM		–	−0.143 (0.085)	−0.032 (0.380)	0.330 (0.001)	−0.024 (0.410)	−0.111 (0.144)	0.458 (<0.001)
F1			–	0.378 (<0.001)	0.152 (0.073)	0.165 (0.057)	−0.192 (0.033)	−0.020 (0.425)
F2				–	0.294 (0.002)	0.196 (0.030)	−0.343 (<0.001)	−0.035 (0.369)
F3					–	0.237 (0.011)	−0.314 (0.001)	0.203 (0.025)
F4						–	−0.095 (0.183)	−0.251 (0.008)
Gender							–	−0.154 (0.070)
Ruth CTRL								–

ToM, Theory of Mind. F1–F4 are factors from the ToM30Q. F1, Perceptual-based-ToM; F2, Mental-representational-ToM; F3, Prioritising-the-face; F4, Sensitivity to others; Ruth, Rutherford stories task; CTRL, control questions. Values in parentheses are significance levels for each respective pairwise correlation.

TABLE 5 | Summary of final model (5) of stepwise regression onto ECQ.

Variable name	Unstandardized beta	Standardised beta	Partials	*t*	*p*-Value
F1	0.391	0.404	0.501	5.457	<0.001
F2	0.279	0.304	0.388	3.969	<0.001
F3	0.328	0.355	0.464	4.941	<0.001

F1, Perceptual-based-ToM; F2, Mental-representational-ToM; F3, Prioritising-the-face; F4, Sensitivity to others; ECQ, Empathy Components Questionnaire. Variables excluded from this model were Rutherford ToM, Rutherford control questions, Gender, and F4 from the ToMQ30. Only F1–F3 of the ToM30Q predicted empathy (DV = ECQ).

that there exist differences in ToM according to dyslexia, neither on its own as a main effect nor in interaction with one or both of the other independent variables analysed here (Gender and ToM category).

GENERAL DISCUSSION

We found in study 1, that dyslexic participants performed less well on false-belief ToM questions; and that this finding was replicated with a different false-belief task (Rutherford stories task) in study 2. However, with the new ToM30Q we introduced as the main focus of study 2, we greatly reduced the reliance in particular on memory and language for working out test answers. Our findings now showed that persons having dyslexia do not in fact have any deficit at all in ToM. Below we consider these and our other findings in terms of lessons from dyslexia to ToM.

In our first study we found that the participant group previously diagnosed as having dyslexia scored lower on a false-belief task than did a non-dyslexic group. Similar findings have been reported for other neurological impairments (e.g., Tompkins et al., 2008; Sandoz et al., 2014; Ho et al., 2018; Bailey and Im-Bolter, 2020). However, this is one of the first such findings regarding ToM in adults having dyslexia.

Moran (2013) raised the possibility that ToM may function quite independently from general cognition in adults. This meant it may be possible to assess ToM whilst limiting the influence of cognitive factors known to be an issue in certain groups such as persons having dyslexia. We used this approach in study 2, in order to arrive at a new measure for ToM that was more spontaneous than in study 1. We largely avoided the need to test participants directly and relied as little as practicable on cognitive abilities such as language and memory in the ToM reasoning process. This allowed us to assess ToM as it is subjectively reflected or applied in the individual's actual real-life experiences. This pursuit was in line with the observation from many theorists, which is that ToM in real life settings may be effortless, automatic and rarely needing to become verbally explicated (Brüne and Brüne-Cohrs, 2006; Burman, 2008; Mills and Fox, 2016).

From the ToM30Q data in study 2, we extracted four factors, two of which could be termed ToM. These two ToM factors, perception-based-ToM (factor 1) and mental-representational-ToM (factor 2) exhibited lower ToM30Q scores than the remaining two factors which seemed to be more about attitudes to minds more than to the importance of reading minds (see Perner, 1991 for first distinctions of this kind).

Of these two further factors, prioritising-the-face (factor 3) seemed to be about being more interested in mental states if the mental states to be appreciated, can be partly gleaned by looking at a person's face. Note, the distinction between this factor and factor 1, is that factor 1 uses one's own emotions to assist the discerning of others mental states, unlike factor 3 which seems to require direct perception of the face itself (i.e., a perceptual cue—Wright and Dowker, 2002).

The final factor of sensitivity-towards-others (factor 4), seemed to be about being comfortable with the need to read minds during social interaction. Thus, this factor was not so much about ToM, as it was about sensitivity to the need or the potential advantages of mindreading to social interaction.

Our two ToM factors bear some resemblance to a category of ToM quite recently termed cognitive ToM; and our remaining two factors seem to resemble a second proposed category termed

TABLE 6 | Summary of ToM30Q factors by gender and Dyslexia Status.

	F1	F2	F3	F4	Overall
Non-Dyslexic Female	3.106 (0.079)	3.295 (0.081)	3.650 (0.080)	3.417 (0.084)	3.367 (0.051)
Non-Dyslexic Male	2.870 (0.110)	2.919 (0.113)	3.359 (0.111)	3.467 (0.118)	3.154 (0.071)
Dyslexic Female	2.858 (0.136)	3.286 (0.140)	3.550 (0.138)	3.717 (0.146)	3.353 (0.088)
Dyslexic Male	2.738 (0.167)	2.814 (0.171)	3.025 (0.169)	3.175 (0.178)	2.938 (0.108)
Non-Dyslexic	2.988 (0.068)	3.107 (0.069)	3.504 (0.068)	3.442 (0.072)	3.344 (0.045)
Dyslexic	2.798 (0.108)	3.050 (0.111)	3.288 (0.109)	3.446 (0.115)	3.251 (0.070)
Female	2.982 (0.079)	3.290 (0.081)	3.600 (0.080)	3.567 (0.084)	3.360 (0.044)
Male	2.804 (0.100)	2.867 (0.103)	3.192 (0.101)	3.321 (0.107)	3.145 (0.070)
Overall	2.893 (0.064)	3.079 (0.065)	3.396 (0.064)	3.444 (0.068)	3.203 (0.041)

ToM, Theory of Mind. F1–F4 are factors from the ToM30Q. F1, Perceptual-based-ToM; F2, Mental-representational-ToM; F3, Prioritising-the-face; F4, Sensitivity to others. Values in parentheses are standard errors.

effective ToM (Brothers and Ring, 1992). In our study 2, individuals were found to score lower on the ToM factors (factors 1 & 2) than on the attitudinal factors (factors 3 & 4). This finding seems to imply that thinking in terms of mental states is in some sense more demanding than responding to other people's in terms of positive/negative effect (Maszk et al., 1999; Duval et al., 2011).

The ToM30Q revealed the expected effects regarding correlations with empathy (Blair, 2005; Chapman et al., 2006; Singer, 2006; Lam and Yeung, 2012; Christov-Moore et al., 2014). Unlike in study 1, we observed the expected relationship to gender (Ahmed and Miller, 2011; Gardner et al., 2012; Meneghetti et al., 2012; Ibanez et al., 2013; Wacker et al., 2017). Also as anticipated, we observed a difference in profile between the ToM30Q and a second task that measured false-belief (Rutherford, 2004). The ToM30Q also showed some degree of independence between the four factors we extracted (Moran, 2013). Despite the relative success of our multiple partial validations, the ToM30Q revealed absolutely no evidence of any difference between persons having dyslexia vs. those not having dyslexia. This null result occurred both for the ToM factor and the emotionality factor. The contrast between the false-belief tasks and our ToM30Q can be seen most clearly in **Figure 1**. This shows no difference in ToM on the ToM30Q but a relatively robust difference on both false-belief tasks (one used with each sample).

Our findings from the ToM30Q are in line with findings from a group of African-American children assessed via a composite of three measures of ToM, which included false-belief. There were no differences between the ToM of children of low vs. high socio-economic class, there was no suggestion of differences compared to studies of the majority ethnic group (e.g., middle class White children), and no indication that basic linguistic skills (e.g., dialect differences, vocabulary differences) were associated to ToM (Longobardi et al., 2016).

The present findings are also in line with recent research concerning ADHD, which is often said to be strongly associated with dyslexia (Abdel-Hamid et al., 2019). So, we are in the position where we would have reported an apparent-dyslexia disadvantage when we use a false-belief task of ToM (computer-based false-belief task and also Rutherford stories task). However, we find not even a hint of a dyslexia disadvantage when we assess ToM in a way that greatly reduces reliance on language; despite the performance on cognitive and performance tests supporting the greater difficulties our dyslexic groups are expected to have (Moran, 2013). What this says to us is that lower performance on a false-belief ToM task does not necessarily prove lower understanding of others' minds (Bloom and German, 2000; Sandoz et al., 2014).

We draw on two additional studies in support of our view. First, McKinnon and Moscovitch (2007) found that older adults did worse on a ToM task and also on a non-ToM task, as compared to younger adults. But rather than concluding that we lose the ability to understand beliefs, intentions etc. as we mature in age, McKinnon and Moscovitch accepted the far more reasonable conclusion that computational processes that happen to be called on as part of ToM reasoning, and not necessarily ToM understanding itself, are what decline in older adults (e.g., manipulating symbolic representations in WM). Second, Marschark et al. (2000) found that when a narrative task is used instead of a false-belief task of ToM, with ToM calculated by scoring the spontaneous use of mental state attributions from the recordings, deaf children (often considered to have a ToM deficit when false-belief tasks are used—e.g., Russell et al., 1998), now do not show any ToM deficit at all, as compared to hearing children matched for age (see also Courtin, 2000; Meristo et al., 2007; Bailey and Im-Bolter, 2020).

As confirmed by taking our two studies together, it is possible to infer reasons why certain groups might appear to have a ToM deficit, when in fact they do not have any such deficit. Our explanation is in line with that of Longobardi et al. (2016) who concluded that there is a distinction between having ToM and demonstrating it via false-belief tasks. We could liken this difference to one of ToM competence vs. ToM performance. It is our view that our findings with the ToM30Q, may carry implications about the ecological validity of relying too heavily on any one particular ToM task (e.g., the standard false-belief task) when we are carrying out research that might have far-reaching implications to a particular atypical group, should the findings indicate a deficit. For example, there may be implications

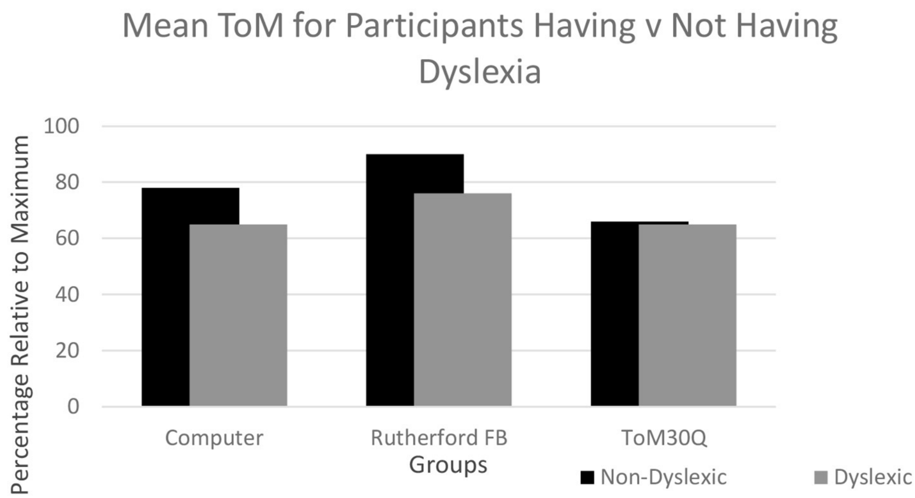

FIGURE 1 | Summary According to Task and Dyslexia Status: There was a difference between ToM for participants having dyslexia vs. those not having dyslexia for the computer false-belief task and the Rutherford false-belief task. However, when the total on the ToM30Q was used, this showed no difference between the two groups. FB refers to false-belief tasks. ToM30Q includes all 4 factors.

to strategies teachers might use to educate certain child groups, or even implications to the potential lowering of academic expectations of those groups (Simmons and Singleton, 2000; Jeffries and Everatt, 2004; Abd Ghani and Gathercole, 2013; Demetrious and Spanoudis, 2018; Bailey and Im-Bolter, 2020).

Atypicalities concerned, might include deafness, schizophrenia and potentially even autism (Gregory et al., 2002; Meristo et al., 2007; Wolf et al., 2010; Hobson, 2014; de Vaan et al., 2018; Németh et al., 2018; Acosta et al., 2019). Our thesis that ToM might be assessed without the need to actually "test" participants on false-belief tasks, does not automatically exclude the thesis that language assists the setting up of mental tokens for things in the external world and hence may be related to ToM for that reason (Astington and Jenkins, 1999; de Villiers and Pyers, 2002; Mills and Fox, 2016). Rather, it may be that language assists ToM in some respects but is an obstacle to accurately assessing ToM in certain contexts (Milligan et al., 2007; Guajardo and Cartwright, 2016). For example, language at the symbolic level may aid the setting up and maintenance of mental representations of the contents of others' minds, and hence may help make ToM an enduring ability of long-term social benefit, rather than merely a transient ability. One way of conceptualising this position is to argue that ToM may be a predictor of complex linguistic discourse skills or a mediator between basic language (e.g., production of mental state words or size of vocabulary) and spontaneous use of social narrative language (Mills and Fox, 2016; Kim, 2020). Indeed, ToM may even be predictive of written compositions (Kim, 2020). Testing all possible relationships was beyond the scope of the present paper, but we do hope to provide evidence on this in the near future.

It is also important to be aware that we are not at all advocating the abandonment of false-belief tasks. Rather, we are advocating the use of false-belief tasks alongside other tasks less reliant on memorising and linguistically (symbolically) processing multiple representations in mind. It is by using the contrast between two rather different tasks satisfying our criterion of language-diversity, and by using these tasks with the same participants (i.e., in study 2) that we have been able to establish exactly why it might seem that persons having dyslexia may have an apparent-ToM deficit, when in fact there is no such ToM deficit in dyslexia at all. Any apparent deficit in ToM in dyslexia would seem due to language-related issues rather than ToM-related issues.

Perhaps now is a good time to re-explore the possibility of ToM deficits in several atypical groups with a more diverse set of ToM tasks than used thus far. One atypical group difficult to adequately assess using variants on the standard false-belief tasks is in blindness (Roch-Levecq, 2006). It has proved highly problematic to design a physical ToM task for this group, and this may be why findings suggest that there may be a greater delay in acquiring ToM for blind children than for any other group, possibly including children having ASD (e.g., see Peterson et al., 2000). According to Hobson (2014) there are good reasons why this finding might in fact be correct. One example Hobson discusses is that low birth weight can lead both to blindness and ASD de Vaan et al. (2018). The ToM30Q, on the other hand, would be as relevant to assessing ToM in blind participants as it is to sighted participants; and hence it promises to more definitively answer this question.

Indeed, the ToM30Q even raises the possibility of assessing young children who fail the standard false-belief task, for example by asking their main caregiver to answer the questions on the ToM30Q on behalf of their child. This carries the further benefit that it can be used even in the current Covid-19 climate, because testing can be done on a pseudo face-to-face basis via platforms such as Zoom or MS-Teams, by using only the audio channel on such a platform, or even less directly by using platforms such as Qualtrics.

Finally, we acknowledge potential issues with our studies that should be borne in mind alongside our very positive findings. One is that we relied on slightly < 100 participants in each of our two studies. However, many other studies have produced meaningful findings with similar or smaller sample sizes than here (Astington and Jenkins, 1999; Meristo et al., 2007; Mills and Fox, 2016; Bailey and Im-Bolter, 2020). Another potential issue is that our factor analysis of the ToM30Q in study 2 might be considered less robust for reasons of sample size. Although this will of course be true, we believe it might actually render our three partial validations all the more persuasive. A third potential issue is that the reliability estimate for study 2 was quite low compared to in study 1. This may have been due to us needing to rely on only one of the four stories from the Rutherford task we used as part of study 2.

CONCLUSIONS

Dyslexia initially was found to be associated with lower ToM performance as indexed by a computer-based and a non-computer-based false-belief task. However, we then in some sense controlled for language, performance issues and other cognitive issues that could affect performance on experimental tasks but which might not be integral to ToM itself. Our resultant task, based around extraction of at least two ToM factors from a 30 item questionnaire about what reasoners feel is important in their interactions with others, showed that any difference in ToM performance between a dyslexic and non-dyslexic group completely vanished.

All of the four factors on the ToM30Q (two relating to cognitive ToM and two more attuned to attitude to presence of other minds) were quite valid and reliable. For example, we replicated previously reported profiles by gender and associations with the ECQ questionnaire on empathy. We also found partial validation in terms of the factor we called prioritising-the-face (the first of the two attitudinal/effective factors—factor 3), when the comparator for our ToM30Q was the Rutherford stories task.

Despite our very encouraging findings regarding dyslexia in this research, we would of course concede that ours is an initial exploratory study. It is therefore necessary to further confirm the utility of the ToM30Q with wider studies with other participant groups and also a variety of socio-cognitive phenomena. We are in the process of providing such studies. However, our present conclusion regarding dyslexia, that experimental tasks of ToM such as the false-belief task may tend to confound cognitive domains such as language with the ability to think in terms of minds itself, does seem plausible on our present findings. Dyslexia does not involve a deficit in ToM, but over-reliance on memory and verbal reporting and false-belief tasks may make it seem so.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Department of Life Sciences Research Ethics Committee, Brunel University. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

The authors each contributed to planning and data analysis of the research, and writing up of the manuscript.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2021.621457/full#supplementary-material

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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ORIGINAL RESEARCH
published: 02 May 2022
doi: 10.3389/fpsyg.2022.682889

The Relationship Among Mentalization, Mindfulness, Working Memory, and Schizotypal Personality Traits in the General Population

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Individuals with high schizotypal traits are less able to observe, describe, and monitor inner feelings, thoughts, and experiences, commonly referred to as mindfulness and mentalization. High schizotypy is also associated with impaired working memory (WM). However, the relationship among mindfulness, mentalization, WM, and schizotypal traits is unknown. Three hundred individuals from the community (mean age: 38.0 years, *SD* = 10.5; 49.3% women) completed questionnaires examining schizotypal traits, mindfulness, and mentalization and performed working memory tasks. Results revealed that mentalization was a general predictor of schizotypal traits, including unusual experiences, cognitive disorganization, introverted anhedonia, and impulsive nonconformity, when the effect of mindfulness and working memory was controlled. We also found a positive correlation between mindfulness and mentalization. Low mindfulness and mentalization performances were associated with high schizotypy. However, poor working memory was only weakly linked to cognitive disorganization and introverted anhedonia. These findings suggest that weak mentalization is a core feature of schizotypy independent of mindfulness and working memory.

Keywords: mindfulness, mentalization, working memory, schizotypy, theory of mind

Edited by:
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Specialty section:
This article was submitted to Cognitive Science, a section of the journal Frontiers in Psychology

Received: *19 March 2021*
Accepted: *12 April 2022*
Published: *02 May 2022*

Citation:
Török E and Kéri S (2022) The Relationship Among Mentalization, Mindfulness, Working Memory, and Schizotypal Personality Traits in the General Population. Front. Psychol. 13:682889. doi: 10.3389/fpsyg.2022.682889

INTRODUCTION

Currently, the dimensional approach to mental illness receives special attention. A typical example is the odd and eccentric nature of schizotypal personality, which exhibits some similarities with schizophrenia-spectrum disorders (Raine et al., 1994; Mason et al., 2005; Nelson et al., 2013; Ettinger et al., 2014; Cohen et al., 2015). People with high levels of schizotypal traits are characterized by unusual experiences (illusions and perceptual distortions), bizarre beliefs, loosened associations, less conventional social behavior, and isolation. First, unusual experiences, also known as the cognitive-perceptual dimension of schizotypy, refer to anomalous perceptual experiences, overvalued and unusual thoughts, and suspiciousness. In schizophrenia patients, these traits turn into the symptoms of frank hallucinations and delusions. Second, introverted anhedonia, also termed the interpersonal dimension of schizotypy, involves decreased interest in pleasurable social activity, diminished feelings, and reduced volition. These schizotypal traits are reminiscent of the negative symptoms of schizophrenia, including blunted affect, social withdrawal, avolition, and alogia. Third, individuals with disorganized schizotypy display derailed thinking, loosened associations, and eccentric behavior, which are milder variants of incoherent thinking and grossly disorganized behavior in schizophrenia. Finally, eccentric and odd behavior often pairs with impulsive nonconformity in schizotypy: weak attunement to social conventions, poor impulse control, and deficient emotion regulation (Raine et al., 1994; Mason et al., 2005; Rosell et al., 2014).

Adaptive personality functioning is founded on the human ability to build an integrated and nuanced internal model of the social world, experience and regulate thoughts, feelings, and impulses, and understand self-other interactions in terms of mental states and intentions. As seen from the above-described features of schizotypy, one can assume a marked alteration of social cognitive functions in individuals with high schizotypy. Dating back to fundamental psychoanalytic theories of personality and mind, two leading concepts in contemporary psychology aim to characterize the experience and regulation of mental states and their differentiation from the external world: mentalization and mindfulness (Klein, 1946; Bion, 1962; Fonagy et al., 2002; Choi-Kain and Gunderson, 2008; Kernberg, 2011). Although these concepts share several features, there also are multiple distinctive features.

Mentalization refers to the interpretation of other- and self-related behavior in terms of mental states (intentions, beliefs, and desires; Dennett, 1987; Fletcher et al., 1995; Fonagy et al., 1997, 2002, 2016; Bateman and Fonagy, 2010). Most scholars accept the view that mentalization is not a unitary construct: it can be automatic (preconscious) or controlled (conscious), self-focused and other-centered, driven by internal or external features of self and others, and cognitive or affective (Fonagy and Luyten, 2009). In addition to understanding the social world and setting the boundary between external reality and the inner world (i.e., psychic equivalence and pretend modes), mentalization is critical in reflective self-representation, emotional awareness, and affective regulation. From a developmental perspective, there is a strong link between attachment to important others and mentalization, a foundation of stable self-identity (Main, 1991; Fonagy et al., 2002; Karterud and Kongerslev, 2019). This relationship between mentalization and developmental attachment can explain why mentalization is socially and interpersonally context-dependent and denote the relationship between two persons.

Mindfulness, which derives from Buddhist meditative tradition and is widely accepted and popularized in Western psychology, also embraces self-observation (Kabat-Zinn, 1996; Falkenstrom, 2003; Bishop et al., 2004; Chi et al., 2018). However, in contrast to reflective mentalization on past experiences, individuals practicing mindfulness focus their attention on the present moment without any cognitive effort and preoccupation to readily observe and accept percepts, thoughts, and feelings as they appear and vanish. Mindfulness is conscious and explicit, related to the self (inner experiences of thoughts, feelings, images, and bodily sensations) and sometimes external events (sounds and sights). Thus, the main difference between mentalization and mindfulness is that the latter does not deal with other individuals' inner states and emotions (Choi-Kain and Gunderson, 2008; Falkenström et al., 2014; Marszal and Górska, 2015). Moreover, explicit mentalization requires intensive cognitive elaboration to maintain, understand, and verbalize inner mental states, referring to past experiences and future perspectives, going beyond the mere moment-by-moment observation and attention of mindfulness. However, empirical evidence shows that scores on scales measuring mentalization and mindfulness share considerable variance (Falkenström et al., 2014; Marszal and Górska, 2015). Mindfulness is a foundation so as to consciously contain internal representations as a starting point of mature mentalization. Marszal and Górska (2015) emphasized that Kernberg (2011) had compared mindfulness with containment, which is essential for the regulation of aggressive and threatening feelings related to the self and others. In other words, the primary purpose of mindfulness is the acceptance of emotions without acting them out in the external world. Mature mentalization serving emotion regulation is possible only if there is an appropriate containing mindfulness function for intensive and ambivalent emotions (Kernberg, 2011). Overall, mindfulness facilitates the acceptance of experiences without prejudice and action, and indirectly affects self-regulation as a gateway to genuine mentalization (Fossati et al., 2012).

Altered mentalization and mindfulness may contribute to schizotypy and schizophrenia-spectrum disorders *via* dysfunctional attentive appreciation, experience, and metacognitive reflection on mental states (Lysaker et al., 2021). In patients with schizophrenia, impaired mentalization substantially contributes to social dysfunctions, and its neurocognitive bases may provide new insight into the development of innovative psychotherapeutic and pharmacological methods (Dimopoulou et al., 2017). Moreover, mentalization is markedly impaired even in patients with first-episode psychosis; in unaffected relatives of schizophrenia patients and individuals with ultra-high risk for psychosis, mentalization performance is intermediate between first-episode psychosis and healthy individuals (Bora and Pantelis, 2013).

Several studies attempted to characterize the association between mentalization and schizotypy, but the results remained controversial (Langdon and Coltheart, 1999; Henry et al., 2008; Morrison et al., 2013; Acosta et al., 2019). Initial evidence suggested a selective mentalization deficit in high schizotypal individuals from the general population that might contribute to psychotic-like traits, forming a continuum with clinically diagnosed schizophrenia (Langdon and Coltheart, 1999). Others emphasized that the mentalization deficit was not related to a specific schizotypal trait (Morrison et al., 2013). Furthermore, some findings indicated only a weak association between unusual experiences and mentalization without a global impairment of mentalization in people with high schizotypy (Pickup, 2006). Therefore, the intuitive assumption that general schizotypy is associated with less efficient mentalization has been challenged (Jahshan and Sergi, 2007; Fernyhough et al., 2008; Barragan et al., 2011; Kallai et al., 2019; Wastler and Lenzenweger, 2019).

Attempts to separately investigate the specific link between negative and positive schizotypy and mentalization yielded mixed results without a generally accepted conclusion (Pickup, 2006; Fernyhough et al., 2008; Henry et al., 2008; Barragan et al., 2011; Gooding and Pflum, 2011). Moreover, some studies indicated over-mentalizing in positive schizotypy, leading to an exaggerated attribution of mental states to others, which may form the basis of overvalued ideas, referential thinking, and delusional inferences (Fyfe et al., 2008; Wastler and Lenzenweger, 2019). Mentalization would be strongly linked to cognitive disorganization because lack of concentration and social anxiety constitute cognitive disorganization. Furthermore, social rejection affects cognitive disorganization more than unusual experiences and introvertive anhedonia (Premkumar and Kumari, 2022). Thus, mentalization declines when there is a high level of social anxiety (Ballespí et al., 2021).

In contrast to mentalization, the literature provides little information on the relationship between schizotypy and mindfulness. Bronchain and Chabrol (2020) used a network theory approach to explore the relationship between dispositional mindfulness and schizotypy. The findings indicated a strong relationship between weakened mindfulness (decreased capacity to describe inner experiences, acting with awareness, and nonjudgment) and interpersonal schizotypy. According to the authors, alterations in mindfulness may lead to a diminished capacity to experience emotions and dysfunctional self-agency in schizotypy (Bronchain and Chabrol, 2020). From another point of view, mindfulness meditation does not enhance schizotypal traits in general: individuals who regularly practice mindfulness meditation exhibited reduced suspiciousness, low social anxiety, but they also displayed enhanced magical thinking (Antonova et al., 2016). Higher dispositional mindfulness may turn positive schizotypy into creativity and leads to lower suspicion (Mcdonald et al., 2021). Surprisingly, one study found intact dispositional mindfulness in schizophrenia (López-Del-Hoyo et al., 2019).

To our knowledge, no attempts were made to investigate the relationship among mentalization, mindfulness, and dimensions of schizotypy (unusual experiences, cognitive disorganization, introverted anhedonia, and impulsive nonconformity) in the same population. Therefore, the latent interaction between mentalization and mindfulness concerning schizotypy is unknown. An additional potential confounding factor in such analyses is working memory (WM), which refers to a short-term and limited capacity system that serves the retaining of behaviorally relevant information. There is some empirical evidence for the association between worse WM and higher schizotypy (Ettinger et al., 2015; Siddi et al., 2017). Working memory deficits are associated with positive and negative schizotypy and may contribute to dysfunctional psychosocial adaptation (Ettinger et al., 2015). As a general impairment in top-down attentional control, working memory deficits may be related to the weakened maintenance, control, and manipulation of internal representations implicated in mindfulness and mentalization. Although the traditional view suggests an inverse relationship between task-oriented problem solving (working memory) and introspective reflection on intentions and feelings (mentalization), demanding social cognition simultaneously involves both mentalization and working memory at the behavioral and neuronal level (Meyer and Lieberman, 2012). In patients with schizophrenia, abnormal activation of lateral prefrontal areas, which are canonical regions engaged for working memory, correlated with impaired Theory of Mind (ToM) performance (Pu et al., 2016). Therefore, working memory may be critical in the relationship between mentalization and schizotypal traits: dysfunctional mentalization may result from a lessened capacity to actively retain information in individuals with high schizotypy (Kocsis-Bogar et al., 2017).

Therefore, we presumed the following hypothesis: (i) high schizotypal traits are associated with poor mentalization and mindfulness; (ii) there is a significant correlation between mentalization and mindfulness; and (iii) working memory impairment can explain a significant amount of variance in schizotypy, mentalization, and mindfulness.

MATERIALS AND METHODS

Procedure

We recruited the participants from the general population *via* social media advertisement and random digit dialing. In those who decided to visit the laboratory (participation rate of all people invited as: 63%), we first registered the essential demographic characteristics and administered a clinical interview for mental disorders. Second, the participants completed three questionnaires (schizotypy, mentalization, and dispositional mindfulness) and a set of working memory tests (digit span, letter-number sequencing, and arithmetic). The authors and qualified research assistants personally administered the scales and working memory tests in the laboratory. We used the standard and validated Hungarian version of the scales and tests (Balázs et al., 1998; Rózsa et al., 2006; Simor et al., 2013; Kocsis-Bogár et al., 2016; Fekete et al., 2019).

Participants

We assessed 300 non-clinical individuals (152 men, 148 women; all Caucasian; 72% urban population; and 18% suffering from chronic illness), aged 18–70 years. The average age was 38.0 years ($SD = 10.5$). The average duration of education was 11.2 years ($SD = 4.6$). We used digital social media advertisement and random digit dialing—recruited postal survey to obtain a representative sample for age, gender, education, income, rural and urban geography, and perceived health (all Cramer values of $V < 0.1$; Shaver et al., 2019). Following a detailed description of the study, we obtained written informed consent from the participants. The study was reviewed and approved by the National Medical Research Council (ETT-TUKEB 18814, Budapest, Hungary). We performed all procedures according to the relevant guidelines, regulations, and the Declaration of Helsinki.

Mini International Neuropsychiatric Interview 7.0

The mini international neuropsychiatric interview 7.0 (MINI 7.0) is a brief and structured clinical interview for the 17 most common disorders defined in the Diagnostic and Statistical Manual of Mental Disorders-5 (DSM-5; American Psychiatric Association, 2013; Sheehan, 2015). The administration time is 15–20 min. The MINI 7.0 is validated against the DSM-5-CV (Structured Clinical Interview for DSM-5 Disorders—Clinician Version) in Hungarian (First et al., 2016).

Oxford-Liverpool Inventory of Feelings and Experiences, Short Version

The Oxford-liverpool inventory of feelings and experiences, short version (sO-LIFE) consists of 43 dichotomous items (yes—no responses) measuring the four dimensions of schizotypal traits: Unusual Experiences (unusual perceptual experiences and non-ordinary beliefs; 12 items), Cognitive Disorganization (loosening of associations, lessened ability to focus attention, and social anxiety; 11 items), Impulsive Nonconformity (impulsivity and weak adherence to social norms; 10 items), and Introvertive Anhedonia (reduced ability to experience pleasure and decreased motivation to participate in social activities; 10 items; Mason et al., 2005; Mason and Claridge, 2006; Kocsis-Bogár et al., 2016). Participants with high scores exhibit pronounced schizotypy. The internal consistency of Unusual Experiences and Cognitive Disorganization dimensions were good ($\alpha > 0.8$). In the case of Impulsive Nonconformity and Introvertive Anhedonia, we observed acceptable alpha-values ($0.85 > \alpha > 0.65$).

Mentalization Questionnaire

The mentalization questionnaire (MZQ) is a 15-item self-report questionnaire. The items focus on self-reflection (e.g., "Most of the time it is better not to feel anything."), emotional awareness (e.g., "Often I do not even know what is happening inside of me."), psychic equivalence mode (e.g., "If I expect to be criticized or offended, my fear increases more and more."), and affect regulation (e.g., "Often I cannot control my feelings."). Each item is rated on a 0- to 4-point scale (0 – totally disagree; 4 – totally agree; range of full-scale score: 0–60). Individuals with weak mentalization achieve high scores (Hausberg et al., 2012; Fekete et al., 2019).

Mindful Attention Awareness Scale

The mindful attention awareness scale (MAAS) is a self-report questionnaire consisting of 15 items to measure dispositional mindfulness, which refers to openness, receptiveness, and attention to the present moment (sample items: "I could be experiencing some emotion and not be conscious of it until sometime later."; "I break or spill things because of carelessness, not paying attention, or thinking of something else."; and "It seems I am 'running on automatic', without much awareness of what I am doing."; Brown and Ryan, 2003; Simor et al., 2013). Participants rate how frequently they experience an item (1 – almost always; 6 – never). High scores reflect effective mindfulness (range: 15–90). The MAAS has good psychometric properties (internal consistency: $\alpha > 0.85$; intra-class correlation for test–retest scores: 0.84).

Working Memory Index

We used the Wechsler Adult Intelligence Scale-III (WAIS-III) WM index consisting of three tests (Wechsler, 1997; Lange, 2011). The Digit Span test, assessing verbal short-term memory and attention, consists of two parts. In the digits forward condition, participants repeat a previously exposed series of numbers. In the digits reversed condition, participants say the digits back in reverse order. In the Letter-Number Sequencing test, participants repeat letters and numbers with the letters in alphabetical order and the numbers in numerical order. Finally, the Arithmetic test comprises mental arithmetic questions (e.g., "If Jo has 12 buns, he then eats three and gives four away how many does he have left?").

Data Analysis

We used STATISTICA 13.5 (TIBCO, Palo Alto) and G*power 3.1.9.2 (UCLA, Institute for Digital Research and Education, Statistical Consulting). In the descriptive statistics, we calculated means, SDs, range, kurtosis, and skewness. Raw data were examined for normal distribution with Kolmogorov–Smirnov tests. First, bivariate correlations were conducted (Pearson's product–moment correlation coefficients) between sO-LIFE, MZQ, MAAS, and WAIS-III-WM scores. The significance level was Bonferroni-corrected [correlation analysis: $p < 0.001$ (0.05/49); regression analysis: $p < 0.003$ (0.05/15)]. Second, multiple regression analyses were performed, controlled for age and gender, for the four dimensions of sO-LIFE schizotypy (Unusual Experiences, Cognitive Disorganization, Introverted Anhedonia, and Impulsive Nonconformity). First, we proposed that mindfulness is the starting point of mentalization; therefore, it was the first predictor. Next, we added working memory to the model to control the non-specific effect of active maintenance of information. Finally, mentalization was incorporated into the regression model to test the covariance and predictive power controlled for mindfulness and working memory. Therefore, in the first step, MAAS (mindfulness) was entered as a predictor of the schizotypy dimension, followed by WAIS-III-WM (working memory) and MZQ (mentalization). To obtain a statistical power of 80%, we enrolled 300 individuals. The level of statistical significance was $\alpha < 0.05$.

RESULTS

Descriptive Statistics and Correlation Analysis

Means, SDs, and ranges for schizotypal traits, mindfulness, mentalization, and working memory scores are depicted in **Table 1**. High Unusual Experiences, Cognitive Disorganization, and Introverted Anhedonia were associated with low mentalization and mindfulness abilities (ps < 0.001, **Table 2**). Individuals with less effective mindfulness also exhibited a lower capacity to mentalize ($r = -0.58$, $p < 0.001$, **Table 2**). Cognitive Disorganization, Introverted Anhedonia, and mentalization weakly and negatively correlated with working memory ($p < 0.05$), whereas we found a more pronounced association between mindfulness and working memory ($p < 0.001$, **Table 2**).

TABLE 1 | Descriptive data for schizotypal personality traits, mindfulness, mentalization, and working memory (WM).

	Mean	Standard deviation	Range
sO-LIFE			
Unusual experiences	2.9	2.0	0–9
Cognitive disorganization	2.8	1.9	0–9
Introverted anhedonia	3.6	2.6	0–12
Impulsive nonconformity	2.2	1.7	0–8
MAAS	52.6	14.7	15–90
MZQ	25.3	13.6	0–55
WAIS-III WM	103.1	10.4	85–134

sO-LIFE, oxford-liverpool inventory of feelings and experiences, short version; MAAS, mindful attention awareness scale; MZQ, mentalization questionnaire; and WAIS-III WM, Wechsler adult intelligence scale-III (WAIS-III) working memory index.

TABLE 2 | Correlations between schizotypal traits, mindfulness, mentalization, and WM ($N = 300$).

	1	2	3	4	5	6	7
1. Unusual experiences		0.50***	0.41***	0.25***	0.38***	−0.22***	−0.11
2. Cognitive disorganization	0.50***		0.34***	0.23***	0.40***	−0.32***	−0.15*
3. Introverted anhedonia	0.41***	0.34***		−0.14*	0.32***	−0.25***	−0.13*
4. Impulsive nonconformity	0.25***	0.23***	−0.14*		0.22***	−0.05	0.04
5. MZQ	0.38***	0.40***	0.32***	0.22***		−0.58***	−0.18**
6. MAAS	−0.22***	−0.32***	−0.25***	−0.05	−0.58***		0.40***
7. WAIS-III WM	−0.11	−0.15*	−0.13*	0.04	−0.18**	0.40***	

*sO-LIFE, oxford-liverpool inventory of feelings and experiences, short version; MAAS, mindful attention awareness scale; MZQ, mentalization questionnaire; and WAIS-III WM, Wechsler adult intelligence scale-III (WAIS-III) working memory index. *p<0.05; **p<0.01; ***a<0.001 (***=Bonferroni-corrected threshold).*

Predictors of Total sO-LIFE Scores

In the first step of the analysis, mindfulness significantly predicted the total sO-LIFE score ($R^2 = 0.10$, $\beta = -0.32$, $SE = 0.05$, $p < 0.001$). We then added the working memory index to the model, which resulted in no significant changes ($R^2 = 0.10$; working memory: $\beta = -0.02$, $SE = 0.06$, $p = 0.80$; mindfulness: $\beta = -0.32$, $SE = 0.06$, $p < 0.001$). In the final step of the analysis, we included mentalization in the model, which appeared as the sole significant predictor of the total sO-LIFE score ($R^2 = 0.25$; working memory: $\beta = -0.05$, $SE = 0.05$, $p = 0.40$; mindfulness: $\beta = -0.03$, $SE = 0.07$, $p = 0.61$; and mentalization: $\beta = 0.47$, $SE = 0.06$, $p < 0.001$).

Predictors of Unusual Experiences

In the first regression model, we found that mindfulness significantly predicted the Unusual Experiences ($R^2 = 0.06$, $\beta = -0.22$, $SE = 0.06$, $p < 0.01$, not significant after correction for multiple comparisons). When the working memory index was added to the model, we did not observe significant changes ($R^2 = 0.06$; working memory: $\beta = -0.03$, $SE = 0.06$, $p = 0.58$; mindfulness: $\beta = -0.21$, $SE = 0.06$, $p < 0.01$). In the final model, mentalization was included, and it emerged as the sole significant predictor of Unusual Experiences ($R^2 = 0.15$; working memory: $\beta = -0.06$, $SE = -0.06$, $p = 0.33$; mindfulness: $\beta = -0.01$, $SE = 0.01$, $p = 0.84$; and mentalization: $\beta = 0.36$, $SE = 0.07$, $p < 0.001$).

Predictors of Cognitive Disorganization

In the first regression model, we found that mindfulness was a significant predictor Cognitive Disorganization ($R^2 = 0.11$, $\beta = -0.3$, $SE = 0.05$, $p < 0.001$). In the second step of the model, working memory and mindfulness were both included. However, the combination of these measures did not reveal significant differences as compared to the first regression model ($R^2 = 0.12$; working memory: $\beta = -0.03$, $SE = 0.06$, $p = 0.59$; and mindfulness: $\beta = -0.30$, $SE = 0.06$, $p < 0.001$). In the final model, including mindfulness, working memory, and mentalization, only mentalization was a significant predictor of Cognitive Disorganization ($R^2 = 0.18$; working memory: $\beta = -0.05$, $SE = 0.06$, $p = 0.37$; mindfulness: $\beta = -0.11$, $SE = 0.07$, $p = 0.13$; and mentalization: $\beta = 0.36$, $SE = 0.07$, $p < 0.001$).

Predictors of Introverted Anhedonia

Similar to the case of Unusual Experiences and Cognitive Disorganization, mindfulness significantly predicted Introverted Anhedonia ($R^2 = 0.06$, $\beta = -0.25$, $SE = 0.07$, $p < 0.001$). The addition of working memory to the model did not reveal a significant predictive effect of working memory ($R^2 = 0.07$; working memory: $\beta = -0.04$, $SE = 0.07$, $p = 0.59$; mindfulness: $\beta = -0.23$, $SE = 0.06$, $p < 0.001$). In the final model, when mentalization was added to the regression model, the sole significant predictor was mentalization ($R^2 = 0.11$; working memory: $\beta = -0.06$, $SE = 0.06$, $p = 0.33$; mindfulness: $\beta = -0.07$, $SE = 0.07$, $p = 0.35$; and mentalization: $\beta = 0.27$, $SE = 0.07$, $p < 0.001$).

Predictors of Impulsive Nonconformity

In contrast to other schizotypy dimensions, Impulsive Nonconformity was not predicted by mindfulness and working memory (only mindfulness included in the model: $R^2 = 0.03$, $\beta = 0.05$, $SE = 0.06$, $p = 0.43$; both working memory and mindfulness included in the model: $R^2 = 0.04$; working memory: $\beta = 0.06$, $SE = 0.06$, $p = 0.36$; and mindfulness: $\beta = -0.07$, $SE = 0.06$, $p = 0.27$). However, the final model, including mindfulness, working memory, and mentalization, indicated a significant predictive effect of mentalization ($R^2 = 0.08$; working memory $\beta = 0.04$, $SE = 0.06$, $p = 0.50$; mindfulness: $\beta = 0.10$, $SE = 0.07$, $p = 0.17$; and mentalization $\beta = 0.28$, $SE = 0.07$, $p < 0.001$).

DISCUSSION

Our main conclusion is that mentalization is a significant and common predictor of all schizotypal traits, including unusual experiences, cognitive disorganization, introverted anhedonia, and impulsive nonconformity. Furthermore, in line with our prior assumption, we found a significant correlation between mindfulness and mentalization, and low mindfulness and mentalization abilities were both associated with high levels of schizotypal features. However, in the regression analyses, mindfulness was not retained as a significant predictor of schizotypal traits when mentalization was added to the analysis because of the high covariance of mindfulness and mentalization.

Contrary to our hypothesis, working memory did not play a critical role in schizotypy: it yielded a weak correlation with cognitive disorganization and introverted anhedonia without significant predictive power. This is a counterintuitive finding because extensive research from schizophrenia and schizotypal personality disorder revealed impaired working memory (Moustafa et al., 2021). Meta-analytic evidence suggests a similarly impaired working memory in individuals at high clinical risk for psychosis (Zheng et al., 2018). However, the correlation between symptoms and working memory is less clear. The situation is even more dubious in non-clinical populations. Some studies demonstrated an association between letter-number sequencing and spatial working memory performances and schizotypy (Park et al., 1995; Matheson and Langdon, 2008). However, others did not find a link between schizotypy and verbal working memory (Lenzenweger and Gold, 2000). Remarkably, Louise et al. (2015) failed to detect a significant correlation between schizotypal traits and working memory: only a trend appeared between cognitive disorganization, impulsive nonconformity, and spatial span backward scores. The magnitude of correlation was like our results. However, more specific measures, such as inhibitory latency and cognitive flexibility on the Color-Word Interference Test, exhibited a more straightforward association with schizotypal traits, suggesting that future studies should use advanced testing strategies beyond conventional neuropsychological procedures (Louise et al., 2015).

In contrast to the weak association between schizotypal traits and working memory, we documented that mindfulness was associated with working memory. Indeed, several studies demonstrated that mindfulness training strengthens attention and working memory (Jha et al., 2019). Furthermore, working memory is crucially implicated in emotion regulation and decision making, so mindfulness training and improved working memory may be beneficial to cope with maladaptive schizotypal features, depression, and anxiety (Barkus, 2020).

The significant relationship between mentalization, mindfulness, and schizotypal personality traits is in line with the evidence from patients with various personality disorders (Fossati et al., 2012). Specifically, mindfulness predicted the overall number of personality disorder criteria in borderline and histrionic types. Deficient mindfulness might be the common denominator of several personality disorders (Fossati et al., 2012): it implies essential emotional awareness, a foundation of higher-level mentalization, and conscious reflection on mental states, which is a critical issue in borderline and schizotypal conditions (Marszal and Górska, 2015). Previous studies indicated that the regulative function of mindfulness and mentalization play a critical role in borderline personality organization (Marszal and Górska, 2015), and our results extend this model to schizotypy. Despite the symptom-level overlap, a notable difference between borderline personality and schizotypy may be the developmental disturbance of emotion regulation in individuals with borderline features, extending to interpersonal relationships, attachment, and identity coherence (Van Riel et al., 2017).

Since the pioneering hypothesis of Frith (1992), impaired mentalization has become an extensively documented phenomenon in psychosis-spectrum disorders, including individuals with a high clinical risk of schizophrenia, and in first-degree relatives of schizophrenia patients (Brüne, 2005; Debbané et al., 2016; Armando et al., 2019). However, much less is known about mindfulness. New evidence suggests that mindfulness has a predictive value in the physical health, psychological well-being, and end environmental quality of life of patients with schizophrenia-spectrum disorders (Bergmann et al., 2021). Although, as a supplementary treatment, mindfulness therapy is moderately effective in the clinical management of negative symptoms, depression, and social functions in schizophrenia (Khoury et al., 2013; Jansen et al., 2020), there is a surprising lack of studies exploring the characteristics of state- and trait-level mindfulness in schizophrenia patients. Nevertheless, mindfulness seems to be less helpful in reducing distress associated with frightening psychotic experiences (Strauss et al., 2015). It must be underlined that the relationship of mentalization, mindfulness, and working memory has not been investigated in clinically defined schizophrenia-spectrum disorders, and, therefore, our results cannot be generalized to clinical conditions.

As a stable foundation of mentalization, mindfulness opens a gate to mental states (Goodman, 2014). Consequently, mindfulness can enhance mentalization (Allen, 2013), a fundamental principle of Mentalizing Imagery Therapy. A case series recently showed that mental imagery and mindfulness focusing on attachment and interpersonal challenges could enhance mentalization and ameliorate depression and anxiety (Jain and Fonagy, 2020). These results are consistent with our cross-sectional data, demonstrating a positive relationship between mindfulness and mentalization. Moreover, according to Jain and Fonagy (2020), there is a causal link between mindfulness and mentalization: individuals can improve their mentalization skills by enhancing mindfulness.

Although our results suggest a straightforward relationship between mindfulness, mentalization, and schizotypy, we must consider several limitations. First, neither mindfulness nor mentalization is a unitary phenomenon. For example, the MZQ score can be subdivided into self-reflection, emotional awareness, psychic equivalence, and emotion regulation (Hausberg et al., 2012). However, the factor structure of MZQ is not consistent (Paridaens, 2017; Song and Choi, 2017), and our sample size was too small to increase the number of variables and separately investigate the predictive power of different mentalization types. Therefore, like other studies, we decided to include the total MZQ score as a single measure (Ballespi et al., 2018; Hayden et al., 2018; Probst et al., 2018). Future studies with larger samples may also investigate multiple facets of mindfulness (i.e., observing, describing, acting with awareness, non-judgmental, and non-reactive) and its relationship with schizotypy (Baer et al., 2006) by combining questionnaire data with results from structured interviews and real-life observations.

The relationship between working memory, mindfulness, mentalization, and schizotypy also requires additional studies using a more comprehensive array of tests. The WAIS-III working memory index taps on verbal and arithmetic functions (Lange, 2011), and it has not been elucidated how visual working memory is related to mindfulness, mentalization, and schizotypy. Based on the mechanism of Mentalizing Imagery Therapy (Jain and Fonagy, 2020), visual working memory may be more closely related to mindfulness and mentalization because visual working memory and mental imagery share the same cognitive and neuronal representations (Kosslyn et al., 2001).

In conclusion, we demonstrated that all schizotypy dimensions are associated with low levels of mindfulness and mentalization in the general population. As measured with the MAAS and MZQ, mindfulness and mentalization are highly interrelated, and mentalization is a better predictor of schizotypy than mindfulness. These results pose the possibility that therapeutic interventions focusing on both mentalization and mindfulness may be more effective than approaches targeting only one of them. Future studies are warranted to elucidate the relationship between schizotypy and different components of mindfulness and mentalization.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

SK designed the study, coordinated data collection, and wrote the first draft of the paper. ET reviewed the relevant literature, performed the revision, and extension of the manuscript. ET and SK analyzed the data, reviewed, and edited the final version of the paper, which was approved by all authors. All authors contributed to the article and approved the submitted version.

FUNDING

The study was supported by the BME-Biotechnology FIKP grant of EMMI (BME FIKP-BIO) and the National Research, Development, and Innovation Office (NKFI/OTKA K 128599).

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frontiers | Frontiers in Psychology

TYPE Mini Review
PUBLISHED 26 October 2022
DOI 10.3389/fpsyg.2022.600699

Check for updates

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Cognitive Science, a section of the journal Frontiers in Psychology

RECEIVED 30 August 2020
ACCEPTED 16 September 2022
PUBLISHED 26 October 2022

CITATION
O'Grady AM and Nag S (2022) "Where's Wally?" Identifying theory of mind in school-based social skills interventions.
Front. Psychol. 13:600699.
doi: 10.3389/fpsyg.2022.600699

"Where's Wally?" Identifying theory of mind in school-based social skills interventions

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This mini configurative review links theory of mind (ToM) research with school-based social skills interventions to reframe theoretical understanding of ToM ability based on a conceptual mapping exercise. The review's aim was to bridge areas of psychology and education concerned with social cognition. Research questions included: how do dependent variables (DVs) in interventions designed to enhance child social-cognitive skills map onto ToM constructs empirically validated within psychology? In which ways do these mappings reframe conceptualization of ToM ability? Thirty-one studies (conducted from 2012 to 2019) on social-cognitive skill with typically-developing children ages 3–11 were included as opposed to explicit ToM trainings in light of an identified performance plateau on ToM tasks in children. Intervention DVs mapped onto the following ToM constructs in at least 87% of studies: "Representation of Others and/or Self," "Knowledge/Awareness of Mental States," "Attributions/Explanations of Mental States," "Social Competence," "Predicting Behavior," and "Understanding Complex Social Situations." The absence of false-belief understanding as an intervention DV indicated a lack of direct training in ToM ability. A hierarchy to further organize the review's ToM framework constructs as either skills or competences within the construct of 'Representation of Others and/or Self' is proposed. Implications for the conceptualization of ToM and social-cognitive research as well as educational practice are discussed, namely how school social skill interventions conceptualize skill along a continuum in contrast to the common artificial dichotomous assessment of ToM skill (i.e., presence or lack), yet the development of ToM can nevertheless be supported by the school environment.

KEYWORDS

social skill, social cognition, intervention, configurative review, theory of mind (ToM), conceptual mapping, children, theoretical framework

Introduction

Navigating the social-cognitive world of the developing child

"Where's Wally?" (Handford, 1987) is a series of UK puzzle books wherein children must find Wally hidden amidst Escher-like crowds, often well-camouflaged amongst red-herring objects, matched to his iconic peppermint-striped shirt and bobble-hat. Finding Wally may not call for complex social-cognitive processing, but it does involve vaguely systematic pattern-seeking echoed in the purpose of this preliminary configurative review. Sifting through a myriad of constructs (often used interchangeably) to define and organize skills pertinent to a child's ability to represent others' mental states is not without difficulty. However, such theoretical reflection on the development of mentalizing ability instigated by Premack and Woodruff (1978) and further discussed by Wellman (2018) is a necessary step to adequately characterize a child's understanding of mind and unite relevant research fields.

In 2012 Henry Wellman was awarded the G. Stanley Hall Award by the American Psychological Association for his contributions to developmental psychology, signaling an agreement across the field of the importance of further researching (a) the mechanisms of social development, and (b) how children come to acquire the sophisticated ability of ascribing mental states to others (i.e., theory of mind; ToM). Ten years on, it is of interest to consider how the field has evolved to define ToM within the larger context of research on social-cognitive development and within education. On a similar timescale since Wellman's award, the past decade has seen an important increase in school-based programs to train social-cognitive skills as part of a curricular focus on social-emotional learning (SEL). The present study aims to reconsider the definition of ToM through a conceptual mapping exercise of social skill outcome variables in SEL intervention studies onto construct categories of ToM ability previously identified in the literature. This study is the first to the researchers' knowledge to reframe the definition of ToM based on conceptual trends across the psychology and education research fields that have acted in parallel in their focus on developing social cognition.

Social cognition encompasses diverse abilities tied to navigating social situations such as attributing internal states, decoding social and emotional cues, and forming impressions (Fiske and Macrae, 2012; Carlston, 2013; Fiske, 2013; Verhaeghen and Hertzog, 2014). The construct of ToM has roots in philosophy, but ToM as a term in empirical research can be traced back to Premack and Woodruff (1978). ToM encompasses the understanding that others have thoughts and desires separate from our own, as well as the abilities to make inferences about others' internal experiences, to predict and interpret their behavior. ToM as such can be said to serve as a foundation to social interaction and has been linked to various aspects of social cognition including self-regulation (Korucu et al., 2017), executive function (Qu et al., 2015; Duh et al., 2016; Jones et al., 2018; Wilson et al., 2018), acquiring greater insight into internal states of the self and others (Peterson et al., 2012; Hofmann et al., 2016), and interpersonal skills that support peer relationships and effective social interaction (Slaughter et al., 2015).

Considering ToM in relation to social cognition to further clarify its definition as a construct today is a task that calls for a complex and multi-layered conceptual framework. Byom and Mutlu (2013) provide a "working definition" of ToM by flagging three components synthesized from ToM measures including "shared world knowledge," "perceiving social cues," and "interpreting actions," but do not provide further comment as to how to organize the ToM-related social-cognitive skills they identify across different research fields. The components proposed by Byom and Mutlu (2013) also raise the difficulty in defining ToM if constructs are treated at the same conceptual level, whether a ToM ability or a ToM cognition (Butterfill and Apperly, 2013), whether skill, competence, or domain.

Schaafsma et al. (2015) call for a "programmatic revision of ToM" (p. 67) that distinguishes psychological processes constituting ToM from associated concepts. Social neuroscience researchers have proposed a two-component model informed by the type of tasks used to assess ToM: the *social-cognitive,* wherein mental states are inferred *via* explicit verbal reasoning, and the *social-perceptual,* wherein mental states are inferred based on non-verbal cues (Tager-Flusberg and Sullivan, 2000; Meinhardt-Injac et al., 2018, 2020). Meinhardt-Injac et al. (2020) found that the social-cognitive ToM component aligned with general cognitive development in participants aged 11–25, whereas the social-perceptual component presented age-related performance shifts. However, the two-component model is less clear for defining ToM from a developmental perspective and when considering social-cognitive skill in an applied setting: the school environment.

The present study

This study is the first to map outcome variables from school-based social-cognitive skill interventions to an *a priori* ToM framework to identify theoretical overlap across research fields concerned with social-cognitive development and reframe conceptualization of ToM ability. This approach can be described as a "framework synthesis framed by dimensions explicitly linked to particular perspectives" (Gough et al., 2012, p. 3). This study can be further characterized as a configurative review in its goal of synthesizing trends across a specific field and type of study to address research questions concerned with theoretical and methodological trends. The undertaken conceptual mapping exercise involved an inferential process that did not assume an intervention's intent to enhance ToM. Instead, the review's authors interpreted how school intervention outcome variables mapped onto ToM constructs. Conceptual mapping exercises have proved useful in the field of SEL (e.g., Wigelsworth et al., n.d.), most recently to identify core components of SEL by focusing on both pedagogical practice and the content of SEL intervention programs (Wigelsworth et al., 2022).

Theory of mind trainings do not usually adopt previously validated programs, opting for experimentally-developed protocols instead (e.g., Gola, 2012; Bianco et al., 2016; Lecce and Bianco, 2019). The intent of the current review was, however, to explore research on social-cognitive skill development in real-world settings and as such, did not focus on ToM trainings. The current review also did not focus on studies with populations that already had demonstrable or diagnosed adjustment problems, similar to Durlak et al.'s (2011) approach for their meta-analysis of school-based universal SEL interventions. The following research questions were addressed in the present review:

1. How do dependent variables chosen in school-based interventions designed to enhance child social-cognitive skills map onto ToM constructs empirically validated within psychology?
2. In which ways do these mappings reframe current conceptualization of ToM ability?

Materials and methods

Search methods used for review and article screening

Twelve databases in the fields of psychology, education, and linguistics were searched for social-cognitive skills interventions conducted from 2012 to March 2019. The search returned 10,458 records that were then uploaded to Rayyan QCRI, a systematic review web-based application. An initial pre-screening of titles and abstracts reduced the number of records to 141 based on the following inclusion criteria: (a) intervention is school-based, (b) study population includes typically developing children ages 3–11, and (c) full article is available and written in English. Screening of full texts for quality, the presence of a previously validated or CASEL-approved social skills program (Collaborative for Academic, Social, and Emotional Learning [CASEL], 2013; McLeod et al., 2017), and inclusion of social-cognitive skill DVs resulted in a final selection of 31 articles for this configurative review (*see* **Table 1**), marked with an asterisk in list of references. The first author and a research assistant read 20% (n = 27) of pre-screened articles, assigning a quality rating along a scale ranging from "1" (low quality) to "4," (high quality), to establish inter-rater reliability. A Cohen's kappa was calculated, $k = 0.703$ [95% CI (0.435, 0.971); $p < 0.0005$] that indicated moderate to good agreement (Altman, 1999; McHugh, 2012).

Generating an *a priori* theory of mind framework to define child mind representation ability

Meta-analyses of studies conducted with children since 2012 were searched as well as seminal literature to select recent ToM framework constructs either explicitly cited or synthesized from study definitions of ToM. A brief report on a conceptual mapping exercise conducted for the Education Endowment Foundation SPECTRUM Database of non-academic skill assessment was also consulted (Wigelsworth et al., n.d.). The seven constructs to define ToM ability and respective sources from the research literature (meta-analyses are italicized) were as follows:[1]

1. Attributions/explanations of mental states (Wellman et al., 1996; Bosacki and Astington, 1999; Peterson et al., 2012; Hutchins et al., 2014; Wellman, 2014; Rakoczy, 2017; Wellman and Lind, 2020).
2. False-belief understanding (Wellman et al., 2001; Wellman and Liu, 2004; Shahaeian et al., 2011; Wellman, 2012, 2014; Hutchins et al., 2014; *Slaughter et al., 2015; Hofmann et al., 2016*; Wellman and Lind, 2020).
3. Knowledge/awareness of mental states (Flavell, 2004; Wellman and Liu, 2004; Hutchins et al., 2014; Tahiroglu et al., 2014; Wellman, 2014; *Slaughter et al., 2015; Hofmann et al., 2016*; Wellman and Lind, 2020).
4. Predicting behavior (Peterson et al., 2012; Hutchins et al., 2014; Wellman, 2014; *Slaughter et al., 2015*; Wellman and Lind, 2020).
5. Representation of others and/or self (Wellman et al., 1996; Carpendale and Lewis, 2004; Hutchins et al., 2014; Wellman, 2014; *Slaughter et al., 2015*; Wellman and Lind, 2020).
6. Social competence (Rose-Krasnor, 1997; Bosacki and Astington, 1999; Liddle and Nettle, 2006; Hughes, 2011; Peterson et al., 2012; Wellman, 2014; *Slaughter et al., 2015*; Wellman and Lind, 2020).
7. Understanding complex social situations (Baron-Cohen et al., 1999; Bosacki and Astington, 1999; Peterson et al., 2012; Hutchins et al., 2014; Wellman, 2014; *Hofmann et al., 2016*; Wellman and Lind, 2020).

1 Constructs are listed alphabetically.

TABLE 1 Summary of interventions included in review grouped by study design including: Number of participants, child participant age band, social skills program selected for intervention, and intervention-targeted social-cognitive areas[a].

Study [Country]	(n)[b]	Child age band (Years)/UK school year	Social skills program	Social-cognitive domain targeted by intervention program[c]				
				RS	RDM	S-A	S-M	SA
2 × 2 Mixed model design								
Ohl et al. (2013) [UK]	385	7 to 8/Year 3	Year 3 Pyramid Intervention	x		x	x	x
Between-subjects design								
Ashdown and Bernard (2012) [Australia]	103	4 to 7/Reception – Year 2	You Can Do It! Early Childhood Education Program (YCDI)	x	x	x	x	x
Graham et al. (2015) [USA]	64	8 to 11/Years 4 – 6	Best Foot Forward	x		x	x	x
Kourmousi et al. (2018) [Greece]	2439	7 to 9/Years 3 – 4	Steps for Life	x	x	x	x	x
Cluster-randomized trial (CRT)								
Crean and Johnson (2013) [USA]	779	8 to 11/Years 4 – 6	Providing Alternative Thinking Strategies (PATHS)	x		x	x	x
DiPerna et al. (2018) [USA]	700	6 to 7/Year 2	Social Skills Improvement System Classwide Intervention Program (SSIS-CIP)	x	x	x	x	x
Interrupted time-series								
Whitcomb and Merrell (2012) [USA]	88	6 to 7/Year 2	Strong Start	x		x	x	x
Longitudinal study								
Leadbeater et al. (2016) [Canada]	2477	6 to 10/Years 2 – 5	The WITS Program (Walk Away, Ignore, Talk it Out, Seek Help)	x	x		x	x
Nested cohort								
Myles-Pallister et al. (2014) [Australia]	683	8 to 10/Years 4 – 5	Aussie Optimism Positive Thinking Skills Program (AO-PTS)	x		x	x	x
Sequential cohort-control								
Fraser et al. (2014) [USA]	688	8 to 9/Year 4	Making Choices (MC) Program	x	x	x	x	x
Quasi-experiment								
Carvalho et al. (2017) [Portugal]	474	8 to 10/Years 4 – 5	MindUp	x		x	x	x
Coelho and Sousa (2017) [Portugal]	982	10 to 12/Year 6 – 7	Positive Attitude Program	x	x	x	x	x
El Hassan and Mouganie (2014) [Lebanon]	80	7 to 9/Years 2 – 4	Social Decision-Making Skills Curriculum (SDSC)	x	x	x	x	x
Finne and Svartdal (2017) [Norway]	399	11 to 14/Years 7 – 9	Social Perception Training	x	x	x	x	x
Gol-Guven (2017) [Turkey]	397	5:06 to 9:07/Years 2 – 5	Lions Quest Program: Skills for Growing	x	x	x	x	x
Goossens et al. (2012) [The Netherlands]	1223	5 to 11/Years 1, 4 and 6	Providing Alternative Thinking Strategies (PATHS)	x		x	x	x
Hoglund et al. (2012) [Canada]	432	6 to 7/Year 2	Walk away, Ignore it, Talk it out and Seek help (WITS)	x			x	x
Koposov et al. (2014) [Russia]	391	10 to 11/Year 6	Aggression Replacement Training (ART)	x	x	x	x	x
Pereira and Marques-Pinto (2017) [Portugal]	98	9 to 13/Years 6 – 9	Experiencing Emotions		x	x	x	x

(Continued)

TABLE 1 (Continued)

Study [Country]	(n)[b]	Child age band (Years)/UK school year	Social skills program	Social-cognitive comain targeted by intervention program[c]				
				RS	RDM	S-A	S-M	SA
Raimundo et al. (2013) [Portugal]	334	9 to 10/Year 5	Slowly but Steadily	x	x	x	x	x
Schonert-Reichl et al. (2012) [Canada]	613	8 to 12/Years 5 – 8	Roots of Empathy (ROE)	x		x	x	x
Wang and Goldberg (2017) [USA]	88	7 to 9/Year 4	Bullying Literature Project (BLP)-Moral Disengagement (MD)	x	x	x	x	x
Wu et al. (2016) [China]	214	8 to 10/Years 4 – 5	Let's Be Friends (Adapted from the 'Making Choices Program')	x	x	x	x	x
Randomized controlled trial (RCT)								
Daunic et al. (2012) [USA]	1296	7 – 12/Years 3 – 7	Tools for Getting Along (TFGA)	x	x	x	x	x
DiPerna et al. (2016) [USA]	755	6 to 7/Year 2	Social Skills Improvement System-Classwide Intervention Program (SSIS-CIP)	x			x	x
Graves et al. (2017) [USA]	61	5 to 8/Years 1 – 3	Strong Start	x		x	x	x
Havighurst et al. (2015) [Australia]	408	4 to 9/Reception – Year 4	Child Component: materials drawn from 'Exploring Together' and 'Fast Track child group' School Component: Providing Alternative Thinking Strategies (PATHS) or Professional Learning Package (PLP)	x		x	x	x
Humphrey et al. (2016) [UK]	4516	7 to 9/Years 3 – 4	Providing Alternative Thinking Strategies (PATHS)	x		x	x	x
Low et al. (2015) [USA]	7400	5 to 8/Years 1 – 3	Second Step	x	x	x	x	x
Muratori et al. (2016) [Italy]	184	7 to 8/Year 3	Coping Power	x	x	x	x	x
Schonert-Reichl et al. (2015) [Canada]	99	9 to 11/Years 5 – 6	MindUP British Columbia (BC) Ministry of Education Social Responsibility Program	x	x	x	x	x

[a] Based on the Collaborative for Academic, Social, and Emotional Learning (CASEL) framework to define SEL (Collaborative for Academic, Social, and Emotional Learning [CASEL], 2005).
[b] The total number of participants at times includes teachers, school staff and parents who participated in the study in addition to child participants.
[c] RS, relationship skills; RDM, responsible decision-making; S-A, self-awareness; S-M, self-management; SA: social awareness.

Conceptual mapping of social-cognitive skills intervention dependent variables to a seven-construct theory of mind framework

Dependent variables (DVs) were extracted from included articles, recorded verbatim, and then mapped onto the ToM framework. Conceptual mapping revealed that over 87% of outcome variables included in school-based social skill interventions mapped onto all ToM constructs included in the framework, except for false-belief understanding. ToM was not explicitly cited as a DV across analyzed interventions. Overall, recurrent DVs were abilities that could be extrapolated to involve ToM ability as they pertained to social problem-solving skills and the awareness of internal states. **Supplementary Table 1** presents results of the mapping exercise with child-related outcome variables grouped thematically within each of the seven constructs of the ToM framework.

Discussion

Main trends from conceptual mapping exercise

School-based social skill intervention programs targeted at least three key social-emotional learning areas, namely "Relationship Skills," "Self-Management," and "Social Awareness." To address the first research question, the conceptual mapping exercise revealed that intervention DVs mapped onto the following ToM constructs in at least 87% of studies: "Representation of Others and/or Self," "Knowledge/Awareness of Mental States," "Attributions/Explanations of Mental States," "Social Competence," "Predicting Behavior," and "Understanding Complex Social Situations." No school intervention DV mapped onto the "False-Belief Understanding" construct.

One emergent theme across DVs was a focus on child engagement with and potential behavioral impact on external referents, whether concerning behavior with peers and teachers (e.g., aggression) or within the classroom environment (e.g., on-task behavior). DVs focused on either reducing or promoting behaviors for social harmony, or self-cognition to then improve interpersonal relationships; both rely on the fundamental ability to represent others and the self (i.e., ToM). However, ToM was neither explicitly mentioned nor directly assessed across school social skill interventions despite their focus on representing others' internal states and promoting social decision-making and/or problem-solving skill.

The absence of both ToM as a DV and of intervention DVs that mapped onto the ToM framework construct of false-belief understanding can be explained by theoretical and practical considerations. Although ToM is linked to social-cognitive skill, interventions included in this review focused on a broader scope of social-cognitive development rather than explicit ToM training. The predominant study age band (6–12 years) has also been identified as a performance plateau for traditional ToM tasks (Wellman, 2014) and consequently would have offered little insight for researchers assessing program impact. This potential age-based measure gap is of concern given that ToM continues to develop through middle childhood and adolescence (Wellman et al., 2011; Peterson and Wellman, 2018), developmental periods wherein individual differences in social cognition can persist into later social development (Dunn, 2000; Steinberg, 2005; Fuhrmann et al., 2015).

False-belief understanding is often used as a measure of ToM ability and as such, the lack of false-belief understanding as a DV is not surprising given the absence of ToM as an explicit outcome in included studies. Although a useful acquisition milestone for ToM development well-established in the literature (e.g., Happé et al., 2017), levels of false-belief understanding were not assessed in school-based intervention studies concerned with social-cognitive skill. As such, we encounter a limit to this review's effort to unify research in psychology with that in education. One possible explanation is that school-based social-cognitive interventions are concerned with real-world interaction and train students using situations likely to be encountered. False-belief measures may be too specific and removed from this applied classroom setting to be relevant. Another explanation could be that school-based interventions conceptualize social-cognitive skill along a continuum, and often false-belief measures only allow for an "artificial" dichotomous assessment of skill (i.e., presence or lack) as raised by Liszkowski (2013, p. 105).

Reframing theory of mind: Toward a comprehensive conceptual model

To answer the review's second research question on how to reframe ToM ability, one main trend from the mapping exercise was the centrality of emotion awareness and regulation in social skill interventions. This was not surprising given that emotion understanding has been understood as a specific form of ToM (Ready et al., 2017), although the place of emotion as it relates to core ToM constructs is often subsumed within a broader ability to represent internal states. A category of *social emotions* that develops during puberty (Burnett et al., 2011) has been identified to characterize emotional states that incur the representation of others' mental states (e.g., embarrassment, guilt). Such social emotions provide a theoretical bridge between emotion representation, social cognition more broadly, and ToM—often more concerned with the representation of non-affective states.

Furthermore, ToM has been linked to prosocial behavior (Caputi et al., 2012; Imuta et al., 2016), affective sensitivity (Contreras-Huerta et al., 2020) and perspective-taking (Tamnes et al., 2018) that all pertain to interpersonal interaction. The representation of an "other's" mind can be said to be incomplete should emotional or affective states not be considered part of ToM ability. In effect, even while a theoretical difference is made within the literature between the ability to represent the thoughts, beliefs and desires of an "other" (i.e., cognitive ToM), and the ability to understand emotional states and preferences (i.e., affective ToM) (e.g., Sebastian et al., 2012), equal weight is not necessarily given in child development research. A nuanced framework for ToM ability could apprehend both cognitive and affective states within the broader construct of representing others and/or the self, in itself part of social cognition.

A further theoretical bridge between social skills and cognitive ability linked by ToM arises when considering another DV common to interventions analyzed here: social problem-solving skills. Social problem-solving skills emphasize the strategic component of ToM ability at times lost in research (Sher et al., 2014), as well as the adaptive and flexible thinking involved in how ToM is used in real-life social situations (Liszkowski, 2013). Given these trends, we propose the inductively identified ToM framework constructs be subsumed under one key framework construct—that of "Representation of Others and/or Self"—and organized as a skill or competence (*see* **Figure 1**). "Skill" is understood as a learned ability, "competence" as a repertoire of skills as compared to a level of performance ability in a given area, and "domain" as a field of mastery (American Psychological Association, 2022). We find the level of distinction between skill and competence necessary in the adapted framework as its absence is one source of confusion in organizing pertinent constructs for both ToM and social-cognitive development, as raised previously.

Limitations of this study

The choice to look for ToM within a school setting while excluding ToM training studies may have skewed the search and findings from the conceptual mapping exercise in that it presents a specific analytic lens: a focus on universal social skill interventions. The review and mapping exercise present a novel effort to highlight how core constructs to define ToM within the psychological field are captured in social skill intervention outcomes, but do not speak to all efforts undertaken within schools to promote mentalizing ability. Inclusion criteria restricted interventions to a specific population, setting, and timeframe; this account of included interventions and choice of DV to assess social-cognitive skills is in no way exhaustive of all trends within this field. There was also an inherent difficulty during analysis to categorically bound ToM framework constructs, resulting in many mapping overlaps for the same DVs.

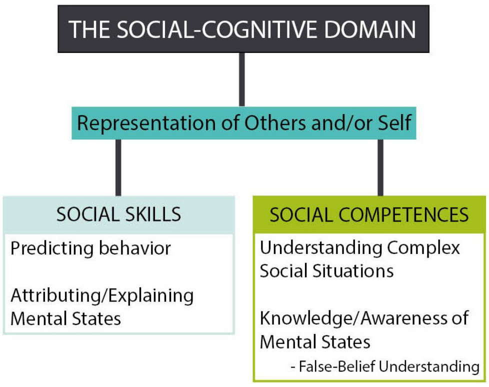

FIGURE 1
Proposed conceptual organization of the review's core theory of mind (ToM) framework constructs based on mapping exercise of school-based social skills intervention outcomes onto the ToM framework. For reference, the seven constructs part of the original ToM framework used in the review's mapping exercise included: (1) Attribution/explanation of mental states; (2) False-belief understanding; (3) Knowledge/awareness of mental states; (4) Predicting behavior; (5) Representation of others and/or self; (6) Social competence; (7) Understanding complex social situations. Constructs are listed in alphabetical order.

Conclusion and future directions

Social-cognitive research acknowledges the complexity and multi-faceted nature of its empirical focus with a vast repertory of constructs, but there is an arguable lack of unity. Amongst the review's 31 studies, there were no overwhelmingly recurrent DVs or common social skill programs. Construct operationalization greatly varied even in instances wherein the same DV was adopted. This review does not call for uniformity in developmental social-cognitive research, but rather attempts to synthesize in its aim of identifying shared theoretical trends based on a mapping exercise of social skills intervention outcomes to a ToM framework. Meaningful overlap between the majority of ToM constructs and school intervention outcomes was found, but a cohesive organization was strained by their variety and inter-relatedness. Nevertheless, the review proposes a novel organization of core ToM constructs (empirically established) to be grouped under a main construct of "Representation of Others/the Self" (in itself part of the social-cognitive domain), and further categorized as either skills or competences that we hope can prove useful for future research.

The lack of traditionally understood ToM and related milestone-construct of false-belief understanding as explicit DVs potentially points to an empirical shift in school-based interventions away from framing ToM as a skill that can be enhanced. However, the development of ToM understanding characterized as a "progression of conceptual achievements" (Wellman, 2018, p. 375) can be readily supported by learning within the school environment. Given ToM is tied to a majority of skills targeted by social-cognitive interventions, it does seem strange that ToM is not directly considered as enhancing mind-representing ability that would then logically impact on social-cognitive development. This is not necessarily problematic. Even within the context of developing ToM ability, researchers have advanced that direct training in mental-state concepts may not be the type of learning that best supports passing the ToM litmus test of the false-belief task, and that improved performance hinges on pragmatic language ability instead (Helming et al., 2014, 2016; Westra and Carruthers, 2017).

In fact, Wellman (2012) notes that much of ToM research is not necessarily developmental and calls for studies that capture a sequential progression of ability acquisition (e.g., microgenetic studies). Now in 2022 "social skill" is empty as an umbrella term to describe ToM, but the body of intervention research on social-cognitive development conducted since Wellman's award has the potential to paint a cohesive picture of ToM as a set of skills and competences that can be systematically developed as seen here in the context of school-based programmes. Coupled with an effort to safeguard against jingle-jangle fallacies, further conceptual refinement of ToM will allow for convergence across social-cognitive research areas to consistently reflect ToM's status as an ability crucial to development that can be enhanced for all children, as easy to spot as Wally's red-and-white stripes.

Author contributions

AO'G completed the initial search of databases for the review, screened articles for quality along with research assistants, extracted and analyzed the data, and drafted the main body of the manuscript. SN screened articles in cases of conflict between AO'G and research assistants, and provided feedback as well as edited the manuscript. Both the authors contributed to the article and approved the submitted version.

Acknowledgments

We would like to thank Katherine Tredinnick and Hannah Simmons for their valuable research assistance in screening and data extraction of articles included in this review.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.600699/full#supplementary-material

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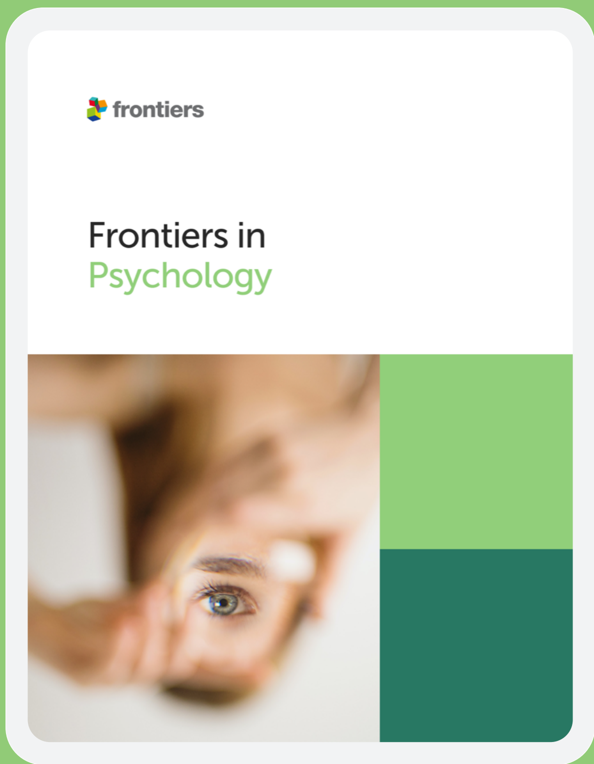

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