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## Executive function predicts theory of mind but not social verbal communication in school-aged children with autism spectrum disorder



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### ABSTRACT

**Background:** The association between Executive Function (EF) and Theory of Mind (ToM) in autism spectrum disorder (ASD) has been mainly investigated using false belief tasks, whilst less is known about the EF effect on other ToM facets. Furthermore, the role EF plays in social communication in ASD is mainly assessed using parent-report EF ratings rather than direct assessment.

**Aims:** The aim of this study was to shed more light on the effect of performance-based EF measures on ToM and social communication in middle childhood in ASD relative to neurotypical controls.

**Methods and procedures:** Cross-sectional data were collected from 64 matched, school-aged children with and without ASD (8–12 years old), tested on measures of EF (*inhibition, working memory, cognitive flexibility*), ToM mental state/emotion recognition and social verbal communication.

**Outcomes and results:** Significant group differences were observed only in selective EF skills (*inhibition & cognitive flexibility*) and social verbal communication. EF working memory contributed to the explained variance of ToM but not social verbal communication in middle childhood.

**Conclusions and implications:** These findings suggest that EF and ToM are still associated in middle childhood and EF may be a crucial predictor of ToM across childhood in ASD. Implications are discussed regarding the social-cognitive impairment relationship in ASD.

### What this paper adds?

The association between EF and ToM in middle childhood in ASD has been mainly investigated using false belief tasks, whilst less is known about the EF effect on other ToM facets such as mental state/emotion recognition. We found that strong correlations between EF and ToM mental state/emotion recognition are still significant in middle childhood (8–12 years) (over and above age and IQ), which highlights the importance of following the developmental pathway of the interrelation between EF and various ToM facets beyond the preschool period in ASD as well. Such information may help identify the contribution of long-term EF effects on the

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functional outcomes of children with ASD, and have important theoretical implications for current conceptualisations of the development of both domains. The significant EF-ToM relation in middle childhood suggests that both abilities are possibly linked across development and these data could provide a solid ground for future longitudinal studies aiming to identify the underlying mechanisms linking EF and ToM in ASD.

## 1. Introduction

Autism spectrum disorder (ASD) is a multifaceted neurodevelopmental disorder defined by impaired verbal and nonverbal communication, social interactions, and repetitive/restricted behaviours and interests (Diagnostic and Statistical Manual of Mental Disorder—DSM-5, [American Psychiatric Association APA, 2013](#)). Several ASD samples have also been reported to experience deficits in multiple neuropsychological functions, such as Executive Function (EF) and Theory of Mind (ToM) ([Losh, Martin, Klusek, Hogan-Brown, & Sideris, 2012](#); [Robinson, Goddard, Dritschel, Wisley, & Howlin, 2009](#)). ToM is multifaceted and refers to the ability to infer beliefs, intents, desires and emotions ([Korkmaz, 2011](#)), in order to explain or predict behaviour ([Wimmer & Perner, 1983](#)). EF refers to a set of future-oriented and goal-directed cognitive skills that are crucial for problem solving and social behaviour ([Anderson, 1998](#)). Several studies have reported strong associations and that the emergence of ToM is dependent on EF ([Best, Miller, & Jones, 2009](#); [Carlson, Moses, & Claxton, 2004](#); [Devine & Hughes, 2014](#); [Hughes & Ensor, 2007](#)). As children continue to develop both EF and ToM during middle childhood and adolescence ([Davidson, Amso, Anderson, & Diamond, 2006](#); [Devine & Hughes, 2013](#); [Huizinga, Dolan, & van der Molen, 2006](#)), there is a vast body of research indicating that ToM abilities remain associated with EF during middle childhood in typical development ([Bock, Gallaway, & Hund, 2015](#); [Im-Bolter, Agostino, & Owens-Jaffray, 2016](#); [Lagattuta, Sayfan, & Harvey, 2014](#)).

Within the autism spectrum, growing evidence of significant EF deficits across development in aspects such as cognitive flexibility (the ability to switch between thinking about two different concepts; [Hill, 2004](#); [Verté, Geurts, Roeyers, Oosterlaan, & Sergeant, 2005](#)), working memory (the ability to store and manipulate information; [Alloway, Gathercole, Kirkwood, & Elliott, 2009](#); [Geurts, Verte, Oosterlaan, Roeyers, & Sergeant, 2004](#)), inhibition (the ability to inhibit irrelevant information; [Christ, Holt, White, & Green, 2007](#); [Happé, Booth, Charlton, & Hughes, 2006](#)) and planning (constant monitoring and (re)-evaluation of sequential actions in order to achieve a goal; [Kimhi, Kugelmas, Agam Ben Artzi, Ben Moshe, & Bauminger-Zviely, 2014](#); [Verté et al., 2005](#)) have been reported in middle childhood and adolescence. Thus one of the competing theories trying to explain the ASD symptomatology, namely the Executive Dysfunction theory, has suggested that disruptions in EF may likely contribute to impairments in ToM and broader social cognition for children with ASD (see for a review, [Hill, 2004](#); [Russell, 1997](#)). Theoretically, ToM and EF could be associated only in early childhood when both abilities emerge ([Moses, 2001](#)). Evidence of EF-ToM associations later in development though, for example middle childhood (e.g. [Austin, Groppe, & Elsner, 2014](#); [Bock et al., 2015](#); [Im-Bolter et al., 2016](#)), suggests that both abilities may be linked across the lifespan as they share overlapping tasks demands and cognitive competencies ([Bock et al., 2015](#)). However, less is known about the association between EF and ToM in ASD. Examining such relations in ASD could provide a better understanding of the nature of these links.

While executive dysfunction is widely studied in ASD (e.g. [Demetriou et al., 2017](#)), research examining the association between EF and ASD behavioural symptoms (i.e. social communication difficulties and repetitive/restricted behaviours) is limited ([Leung, Vogan, Powell, Anagnostou, & Taylor, 2016](#)). Some findings suggest that EF disruptions may associate with repetitive/restrictive behaviours (e.g., [D’Cruz et al., 2013](#); [Miller, Ragazzino, Cook, Sweeney, & Mosconi, 2015](#); [Mosconi et al., 2009](#); [Reed, Watts, & Truzoli, 2013](#); [Yerys et al., 2009](#)), whereas social communication deficits are most commonly associated with social cognition aspects in ASD (e.g., [Ames & White, 2011](#); [Lerner, Hutchins, & Prelock, 2011](#); [Nagar Shimoni, Weizman, Yoran, & Raviv, 2012](#)). Taking this evidence together, it seems that the role EF plays in social communication in ASD is not fully understood yet. The present study focused on determining whether these abilities are associated in middle childhood in ASD.

### 1.1. EF and ToM in ASD

Research has indicated that impairments in EF and ToM are associated within ASD (e.g., [Demetriou et al., 2017](#)). Regarding the preschool period, evidence from Pellicano’s cross sectional (2007) and longitudinal (2010) studies has shown that EF skills (i.e. planning, cognitive flexibility, and inhibition) of young children with ASD (4–7 years) were significantly correlated with and contributed to the development of ToM, even after partialling out the effects of chronological age, verbal, and non-verbal ability. More recently, [Kimhi et al. \(2014\)](#) found that ToM and two EF aspects (cognitive flexibility and planning) were significantly associated in young children (5 years) with ASD. These findings indicate that, similar to typical development, there is a strong association between EF and the ToM acquisition/expression in young children with ASD.

Converging evidence from the investigation of the EF-ToM relationship beyond the preschool period in ASD has shown that ToM performance was significantly correlated with EF aspects (e.g. inhibition, planning, and working memory) in children and adolescents (5–14 years) with ASD ([Joseph & Tager-Flusberg, 2004](#)). A subsequent longitudinal study of the same authors ([Tager-Flusberg & Joseph, 2005](#)) revealed that EF was still associated to ToM after one year in children and adolescents with ASD (5–14 years). Both these studies however did not use a control group (of typical development) and thus clear conclusions about whether children’s performance was consistent with their age or ability could not be drawn. Finally, [Ozonoff, Pennington, and Rogers \(1991\)](#) also reported significant correlations between selective EF aspects (planning, cognitive flexibility, and working memory) and ToM abilities in children and young adults (8–20 years) with ASD. It should be noted at this point that the aforementioned studies have addressed mainly false belief (understanding that one’s belief/representation about the world can contrast with reality) tasks to

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