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# Connections between executive function and pragmatic skills in Finnish 5–10-year-old children on the autism spectrum and control children

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## Abstract

This study explored the performance of children on the autism spectrum (AS) and control children in executive function (EF) tasks and the relationship between EF and pragmatic skills using clinically available measures. 15 Finnish children on the AS (mean age 7;8 years) and 15 control children (mean age 7;7 years) participated in this study. We examined EF domains of working memory (verbal working memory) and inhibitory control of attention (selective auditory and visual attention) using the neuropsychological assessment battery NEPSY-II. Pragmatic skills were assessed by using the Pragma Test and Pragmatic Composite score of the Children's Communication Checklist-2 (CCC-2). According to the results, the control group performed better in verbal working memory and selective auditory attention subtests, but no between-group difference was observed in selective visual attention. In the control group, verbal working memory was positively associated with the Pragmatic Composite score of the CCC-2. No statistically significant associations were observed in the AS group. Our findings indicate that many, but not all, children on the AS have domain-specific EF difficulties. Our findings also suggest that verbal working memory has a stronger relationship with pragmatic skills in the control group than in the AS group. Clinical implications are discussed.

KEYWORDS: Autism spectrum, executive function, inhibitory control, pragmatics, working memory

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## Introduction

Executive function (EF) can be broadly defined as the regulation of goal-directed, higher-order cognitive processes that are needed to manage thinking and behaviour (Demetriou et al., 2018; Diamond, 2013). Skills such as working memory, selective attention, inhibitory control, planning and cognitive flexibility are often included in the definition of EF (Diamond, 2013; Miyake et al., 2000). EF skills are suggested to underlie social function (Beauchamp & Anderson, 2010) and to be the basis for the ability to engage in decision making, problem solving and reasoning (Diamond, 2013; O'Hearn et al., 2008), which are needed in everyday life, including in social situations which require complex pragmatic processing of language.

Navigating social situations successfully requires pragmatic ability which refers to the skills of using and interpreting spoken language and other expressive means in different contexts and adapting to contextually demanding social situations (e.g. Gibbs & Colston, 2012; Loukusa, 2021). Pragmatic abilities affect how a person communicates and behaves in different social situations, which has implications on how others respond (see e.g. Loukusa et al., 2018). Pragmatic abilities include skills such as the ability to initiate conversation and to respond with contingent and relevant information as well as to produce and understand contextually situated utterances (e.g. Levinson, 1983; Loukusa, 2021; Matthews et al., 2018). Prior research has shown that children on the autism spectrum (AS)<sup>1</sup> tend to interpret contextually demanding social situations differently than control children (e.g. Loukusa et al., 2018; Mäkinen et al., 2014; Norbury & Bishop, 2002). Children on the AS also differ from control children in context-situated use of language, recognition of others' feelings and making inferences from, for instance, metaphors, receiving lower scores on tasks measuring these abilities (e.g. Dennis et al., 2001; Loukusa et al., 2018). Research has further shown that difficulty with pragmatic tasks increases for children on the AS as the intentionality and inferencing loads increase (Angeleri et al., 2016; Dennis et al., 2001; Loukusa et al., 2007, 2018).

It is argued that EF skills, such as working memory, are essential for the management of thinking and behaviour (Barendse et al., 2013; Matthews et al., 2018). The examination of the relationship between EF and pragmatic skills is informative given that pragmatic skills concern the ability to interact as well as use spoken language and other expressive means in a context-sensitive manner (Levinson, 1983; Loukusa, 2021), at times in a context of other simultaneous competing stimuli. Clinically, it is also an important question whether by strengthening EF skills it would be possible to support pragmatic skills, or vice versa (see Friedman & Sterling, 2019). One relevant theoretical model to conceptualize this relationship is the Hierarchical Competing Systems Model (HCSM, Marcovitch & Zelazo, 2009). This model argues that there are two hierarchical systems, a habit and a representational system, which compete in guiding one's goal-directed behavior. The habit system uses information based on one's previous experiences whereas the representational system involves the conscious language-guided reflection of behavior. According to the model, the representational system can override the habit system, which would lead an individual to engage in conscious reflection of behaviour rather than be influenced by perceptual information (Marcovitch & Zelazo, 2009, see also Friedman & Sterling, 2019).

The relationship between different domains of EF and pragmatic skills has received some attention in previous research (e.g. Blain-Brière et al., 2014; Cardillo et al., 2021; Friedman & Sterling, 2019; Parola et al., 2020). However, the investigations of the relationship are challenged by the lack of consensus on what constitutes EF and which measures are best to use (Matthews et al., 2018). More research is needed to better understand the relationship, particularly with regard to the heterogeneous group of individuals on the AS with reported challenges both in EF and pragmatic skills (see e.g. Christoforou et al., 2023; Friedman & Sterling, 2019; Loukusa, 2021 for reviews).

### Executive functioning in autism spectrum

Many prior studies based on direct clinician-administered tests and indirect caregiver-, teacher- or self-reports have found children on the AS and adolescents having difficulties with EFs (Cardillo et al., 2021; Corbett et al., 2009; Demetriou et al., 2018; Ellis Weismer et al., 2018; Filipe et al., 2020; Joseph et al., 2005; see Christoforou et al., 2023 and Friedman & Sterling, 2019 for reviews). Studies have however reported mixed findings concerning different EF domains (Bölte et al., 2011; Hill, 2004; Schmitz et al., 2006; White et al., 2017; Yang et al., 2009), suggesting that EF difficulties are not global, but rather domain-specific, in autism (O'Hearn et al., 2008). In this article, we focus on working memory (measured as verbal working memory) and inhibitory control of attention (measured as selective auditory and visual attention), which are two core EF domains (Demetriou et al., 2018; Diamond, 2013; Hill, 2004; O'Hearn et al., 2008).

*Working memory* is used for integrating information from different sources (O'Hearn et al., 2008). Previous findings on working memory of individuals on the AS have been inconsistent (see Habib et al., 2019 and Christoforou et al., 2023 for reviews). While some studies have not found differences between children on the AS and typically developing children and adults (e.g. Faja & Dawson, 2014; Ozonoff & Strayer, 2001), other studies have found children, adolescents, and adults on the AS having working memory difficulties particularly in tasks that require cognitive flexibility and complex information processing (e.g. Barendse et al., 2013; Hill, 2004; Habib et al., 2019; Joseph et al., 2005; Kercood et al., 2014; Narzisi et al., 2013; Wang et al., 2017). Prior studies using clinical direct assessments of verbal working memory have also indicated that the immediate verbal recall of complex material, such as sentences, can be considerably difficult for children and adolescents on the AS (e.g. Minshew & Goldstein, 2001; Narzisi et al., 2013).

*Inhibitory control* is another key EF domain (e.g. Demetriou et al., 2018; Diamond, 2013; Hill, 2004). Inhibitory control of attention refers to the ability to selectively attend to a chosen target and suppress attention to another (Diamond, 2013; Friedman & Sterling, 2019). Inhibitory control of attention is interesting to study in the context of AS since distinctive sensory experiences and interests are common in individuals on the AS (American Psychiatric Association, 2013), reportedly influencing an individual's attentional focus and the ability to engage in or shift between activities (e.g. Buckle et al., 2021; Murray et al., 2005; Phung et al., 2021). The findings on inhibitory control in children and adults on the AS are however mixed (see e.g. Christoforou et al., 2023; Friedman & Sterling, 2019; Hill, 2004; O'Hearn et al., 2008; Russo et al., 2007). In the current study, we examine selective visual and auditory attention as measures of inhibitory control of attention which involves

discriminating relevant information from information that is not relevant at a given moment (Diamond, 2013). As regards to selective visual attention, prior studies have shown that children and adults on the AS often excel in tasks requiring visual search by having shorter reaction times as compared to control groups (Hessels et al., 2014; Jarrold et al., 2005; Joseph et al., 2009; Remington et al., 2009). Clinical selective visual attention tasks have shown no differences in the performance of children on the AS and control children (Barron-Linnankoski et al., 2015; Hooper et al., 2006; Narzisi et al., 2013), some studies suggesting that individuals on the AS have an increased capacity for visual perception (e.g. Remington et al., 2009).

Research also suggests enhanced auditory selective attention capacity in children and adults on the AS (Haesen et al., 2011; Remington & Fairnie, 2017). Increased susceptibility to auditory distraction in individuals on the AS could result in either increased or reduced performance in a task, depending on the task itself (Remington & Fairnie, 2017). Previous studies using clinical selective auditory attention tasks have often found children on the AS having lower scores as compared to control children (Barron-Linnankoski et al., 2015; Hooper et al., 2006; Narzisi et al., 2013).

#### Associations between executive function and pragmatic skills

Multiple studies argue for associations between EF and pragmatic skills. For instance, in typically developing children, better inhibitory control has been found associated with a decrease in talkativeness and assertiveness in a semi-structured conversation (Blain-Brière et al., 2014; see also Matthews et al., 2018) whereas better working memory skills have been found associated with the ability to produce contingent answers and clear utterances (Blain-Brière et al., 2014).

Evidence for associations between these skills exist also in children on the AS, yet the findings are mixed (see Friedman & Sterling, 2019, for a review). Evidence has been found for higher caregiver-reported EF abilities across all domains associated with lower levels of caregiver-reported social pragmatic difficulties (Pervasive Developmental Disorders Behavior Inventory; Cohen & Sudhalter, 2005) in children on the AS (Howard et al., 2023). Also, a study by Filipe et al. (2020) found that a composite measure of caregiver-reported EF skills was associated with clinician-assessed pragmatic skills (Pragmatic Protocol; Prutting & Kittchner, 1987). On the other hand, in a study by Cardillo et al. (2021), a composite measure of clinician-assessed EF skills was found associated with clinician-assessed pragmatic skills (assessed as the ability to understand metaphors and produce correct inferences) only in typically developing children but not in children on the AS.

The variation in findings may be due to methodological reasons since composite measures of EF skills do not show how specific EF domains may or may not be associated with pragmatic skills (Toplak et al., 2013). Further, the use of clinician-administered direct assessments or indirect caregiver- or teacher-reports can tap different levels of functioning of an individual and result in different findings (Toplak et al., 2013).

Domain-specific investigations on working memory have found both clinician-assessed and caregiver- and teacher-reported skills associated with caregiver-reported (Children's Communication Checklist; Bishop, 1998) and clinician-assessed (Comprehensive Assessment of Spoken Language, Pragmatic Judgement subtest; Carrow-Woolfolk, 1999) pragmatic skills

(Akbar et al., 2013; Baixauli-Fortea et al., 2019; Razavi et al., 2019). These findings provide evidence for the connections between working memory and pragmatic ability (see also Friedman & Sterling, 2019). For the other EF domain of interest in the current study, inhibitory control, the findings are more mixed. Razavi et al. (2019) have found caregiver-reported inhibitory control associated with caregiver-reported pragmatic skills (Children's Communication Checklist; Bishop, 1998), whereas contrary to these findings, Akbar et al. (2013) reported finding no associations between caregiver- and teacher-reported nor clinician-assessed inhibitory control skills and clinician-assessed pragmatic skills (Comprehensive Assessment of Spoken Language, Pragmatic Judgement subtest; Carrow-Woolfolk, 1999).

Also the directionality of these associations is not clear (see Friedman & Sterling, 2019). Previously, associations between language and EF have been interpreted in the light of children using language skills in the service of EF (e.g. Joseph et al., 2005). The study by Akbar et al. (2013) also suggests that clinician-assessed pragmatic skills predict clinician-assessed and teacher-reported working memory skills. However, training studies with adolescents on the AS have shown that improvement in pragmatic ability does not necessarily result in improvement in EF skills (see Gabbatore et al., 2022), although contrasting findings have also been reported (see Friedman & Sterling, 2019, for a review). Examining different directionality, Baixauli-Fortea et al. (2019) reported that despite observed associations, clinician-assessed working memory did not predict caregiver-reported pragmatic skills. Similarly, the study by Cardillo et al. (2021) found composite measure of clinician-assessed EF skills not predicting clinician-assessed pragmatic skills.

To better understand these associations or lack thereof, research using domain-specific EF measures and both direct and indirect measures of pragmatic skills is needed. It can also be considered important to examine the associations between these skills separately in children on the AS and typically developing children. Hypothesized in the light of the HCSM model (Marcovitch & Zelazo, 2009), it may be that children on the AS, with distinctive sensory experiences and increased susceptibility to sensory distraction, rely on the use of the experience-based habit system more than typically developing children who may instead use the conscious language-guided reflection (see also e.g. Joseph et al., 2005).

### The current study

In this study, we examine:

1. Do children on the AS differ from control children in the clinician-assessed EF domains of working memory (verbal working memory) and inhibitory control of attention (selective auditory and visual attention)?
2. Are EF and pragmatic skills associated in children on the AS and control children, as measured by
  - a the clinician-administered Pragma Test?
  - b caregiver-reported Pragmatic Composite score of the Children Communication Checklist (CCC-2)?

## Materials and methods

### Participants

In total 30 five to ten-year-old children (15 children on the AS and 15 control children) participated in the study. All participants were Finnish-speaking, had normal hearing and lived

in the Northern Ostrobothnia region of Finland. One female on the AS was excluded from the otherwise male-dominated sample due to known sex differences in EF skills (Bölte et al., 2011; Demetriou et al., 2018; White et al., 2017). The remaining participants in both groups consisted of males only. Participation in the study was voluntary and based on informed consent. The study was approved by the Ethical Committee of the Northern Ostrobothnia Hospital District.

The children in the AS group (mean age 7;8 years, range 5;1–10;7 years) originally participated in a larger Finnish clinical study (see Loukusa et al., 2014; Mäkinen et al., 2014). They were recruited from the Clinic of Child Psychiatry or Child Neurology at the Oulu University Hospital where they had been diagnosed earlier by child psychiatrists or child neurologists in multiprofessional collaboration based on the Autism Diagnostic Interview Revised (ADI-R; Lord et al., 1995), the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000), and other clinical information using the ICD-10 (World Health Organization, 1993) diagnostic criteria. Study inclusion criteria for the AS group required a child to be a native Finnish speaker and to not show signs of significant difficulties with cognitive functioning. The children on the AS had been previously assessed for cognitive functioning by clinical psychologists using the Finnish versions of the age-appropriate Wechsler Intelligence Scales (e.g. Wechsler, 2010). The information regarding children's Intelligence Quotients (IQs) were collected with parental permissions. Such information was available for 12 out of the 15 participants in the AS group. The Full-Scale Intelligence Quotients (IQs) ( $Mdn = 96.50$ ,  $IQR = 31.00$ ), Verbal Scale IQs ( $Mdn = 90.50$ ,  $IQR = 37.75$ ), and Performance Scale IQs ( $Mdn = 90.50$ ,  $IQR = 27.50$ ), were within typical range. For the three participants with missing information, it was evident from psychologists' written reports that these children's cognitive functioning was within a typical range since no significant difficulties with cognitive functioning were mentioned in the reports.

The children in the control group (mean age 7;7 years, range 5;2–10;0 years) were recruited from municipal day care centers or mainstream schools. There were no between-group differences according to participant age (see Table 1). A parent-reported questionnaire about the child's developmental history (e.g. early language development, familial risk of language delays and attendance in speech language therapy) was used to verify the control children's typical development. Study inclusion criteria for the control group required a child to be a native Finnish speaker, not to have a history of language delay, any neurological or language disorder diagnosis nor prior or current attendance to speech language therapy. However, functional single speech sound error did not prevent a child participating. Our study design did not include the clinical assessment of cognitive functioning of the control group. Our control group represents a population of children without developmental concerns. In Finland, children go through regular free-of-charge health clinic appointments to assess the development of children. Specific data on socioeconomic status was not available for the current study. All Finnish citizens have an equal right to free basic education, health care and social security.

### Measures and procedure

Data on children's receptive language and pragmatic skills are presented as participant background information in Table 1. These are presented as background information since

Table 1. Background information and test scores by groups and group comparisons (Mann Whitney U test).

	Autism spectrum group (n = 15)			Control group (n = 15)			U statistic	P value	Effect size <sup>e</sup>
	Mean (SD)	Mdn (IQR)	Range	Mean (SD)	Mdn (IQR)	Range			
Age <sup>a</sup>	91.87 (19.35)	93.00 (33.00)	61–127	90.53 (17.31)	92.00 (29.00)	62–120	116.0	0.902	0.04
TTFC-2 <sup>b</sup>	96.33 (13.23)	97.00 (11.00)	75–132	112.93 (9.15)	116.00 (13.00)	97–127	28.50	<0.001	0.65
Pragma test total <sup>c</sup>	20.99 (14.35)	19.20 (20.20)	–4.80– 43.65	49.03 (7.83)	47.20 (11.56)	36– 61.67	6.00	<0.001	0.81
Pragmatic composite <sup>d</sup>	26.33 (5.62)	27.00 (7.00)	16–38	60.20 (8.24)	63.00 (10.00)	41.00– 70.00	0.00	<0.001	0.85

<sup>a</sup>Age in months.

<sup>b</sup>TTFC-2 = Token Test for Children 2. Reported as standardised scores based on the norm data collected in the United States (McGhee et al., 2007).

<sup>c</sup>t scores computed for the current study only.

<sup>d</sup>Summed scaled scores of the Children's Communication Checklist 2 (CCC-2) scales Coherence, Inappropriate initiation, Stereotyped language, Use of Context and Non-verbal communication. Transformation of the raw scores into scaled scores based on the CCC-2 manual (Bishop, 2015).

<sup>e</sup>Effect size calculated using  $r = Z/\sqrt{N}$ .

these data are previously reported in Loukusa et al. (2014, 2018) with partially overlapping samples. The Token Test for Children-2 (TTFC-2, McGhee et al., 2007) was used to assess children's comprehension of spoken instructions. The TTFC-2 has been translated (with forward and back translation) into Finnish for research purposes. Since the TTFC-2 has not been standardized in Finland, we converted the children's raw scores into standardised scores based on the norm data collected in the United States (McGhee et al., 2007). The TTFC-2 standard scores have a mean of 100 and standard deviation of 15. Although the control group was assessed to have better skills in comprehending spoken instructions (control group mean performance "above average"), neither of the groups showed difficulties in their performance (AS group mean performance "average"; McGhee et al., 2007). There was however individual variation between the participants (see Table 1).

Pragmatic skills were explored using assessment tools commonly used in clinical practice in Finland: the Pragma Test (Loukusa, 2019; see also e.g. Gabbatore et al., 2021; Loukusa et al., 2018) and the Finnish version of the Children's Communication Checklist-2 (CCC-2, Bishop, 2015). The Pragma test is a Finnish clinician-administered assessment method for comprehension of social and pragmatic language. The Pragma Test includes tasks that measure *Contextual inference—not implying Theory of Mind*, *Contextual inference—implying Theory of Mind*, *Relevant language use, depending on the communicative context*, *Emotion recognition*, and *Understanding of False Beliefs*. The tasks consist of short scenarios that are presented verbally to children with the support of pictures and plastic characters to minimize memory load. For the current study, the Pragma Test total raw scores were transformed into t scores. The control group was assessed to have better pragmatic skills as measured with the Pragma Test (see Table 1).

The CCC-2 is a caregiver-reported measure of the children's everyday social communication skills (Bishop, 2015). The CCC-2 consists of 70 items originally divided into ten subscales that measure language structure, vocabulary and discourse (*Speech, Syntax, Semantic and Coherence*), pragmatics (*Inappropriate initiation, Stereotyped language, Use of context and Nonverbal communication*) as well as *Social relations* and *Interests*. The caregivers are asked to score the items on a four-point scale (less than once a week [or never], at least once a week, but not every day, once or twice a day, and several times [more than twice] a day [or always]). We transformed the scores into scaled scores according to the CCC-2 manual (Bishop, 2015). Although not included as part of the CCC-2 manual, the Pragmatic Composite (PC) has been calculated in multiple studies (see e.g. Geurts & Embrechts, 2008; Helland et al., 2014). The PC gives a general impression of the pragmatic skills as assessed by caregivers. The PC is calculated by summing the scaled scores of the subscales *Coherence, Inappropriate initiation, Stereotyped language, Use of context and Nonverbal communication*. *Coherence* is commonly included in the PC due to its coverage of aspects of both structural language and pragmatics (e.g. Helland et al., 2014). Since the PC is based on the scaled scores, higher score represents the skills of a child. The AS group showed more pragmatic difficulties as measured by the PC (see Table 1).

Verbal working memory as well as selective auditory and visual attention were assessed using the Finnish version of the NEPSY-II (Korkman et al., 2008) that is a comprehensive neuropsychological assessment battery widely used in clinical practice and research. Verbal working memory was assessed using either the Sentence Repetition or Word List Interference subtest, depending on the age of the participating children. Sentence Repetition (for three to six-year-old children) assesses the ability to recall and repeat increasingly complex and long sentences. In this subtest, the child listens to a series of sentences and is asked to recall each sentence immediately after its presentation. Word List Interference (seven to 16-year-old children) assesses verbal working memory, repetition, and word recall after interference. In this subtest, two series of words are presented to the child and he or she is asked to repeat each sequence following its presentation. Then, the child is asked to recall each series in order of their presentation. Verbal working memory (instead of visuospatial working memory) was assessed since it was the only working memory subtest available in the NEPSY-II.

Selective auditory attention was assessed using the Auditory Attention Response Set A that was suitable for the age group of the current study. This subtest measures selective auditory attention and a child's ability to sustain it (vigilance). In this subtest, the child listens to a series of audio-recorded words and touches an appropriate circle when hearing a target word. In addition to correct responses, commission errors were recorded. Commission errors represent non-targets that were reacted to although they were supposed to be ignored. The total raw score is calculated by subtracting the number of commission errors from the total correct score. Selective auditory attention data was available for 10 or 11 individuals in the AS group (depending on the score type examined) due to technology or examiner related errors.

Selective visual attention was assessed using the Visual Attention subtest, which measures selective visual attention and a child's ability to sustain it (vigilance). In this subtest, the child is presented with a paper containing both target and distractor stimuli and asked to

select only the items that match with the target stimuli. The total raw score is calculated by subtracting the number of selected incorrect targets from the selected correct targets.

Scaled scores were calculated for each participant for each subtest using the NEPSY-II manual. A scaled score of  $\geq 8$  represents an “average” or “above average” performance, a scaled score of 6 or 7 “slightly below average”, and a scaled score of 5 or below “significantly below average” performance (see Korkman et al., 2008). For the Auditory Attention Response Set A and Visual Attention subtests, performance percentiles were further examined. The Sentence Repetition subtest does not include additional correct or incorrect answer scores, hence verbal working memory was not examined further based on percentiles. Percentile transformations were conducted according to the Finnish NEPSY-II manual (Korkman et al., 2008).

Children were assessed individually in a quiet room at children’s schools, preschools or at the premises of the University of Oulu. Each assessment session was video recorded which enabled offline coding procedures.

### Statistical analyses

Statistical analyses were carried out using nonparametric tests due to the small sample size and non-normal distribution of variables. To examine between-group differences in EF, Mann Whitney  $U$  tests were conducted for the NEPSY-II subtests. Fisher’s Exact Tests using Bonferroni-corrected post hoc pairwise  $Z$  tests were used to further examine between-group differences in the NEPSY-II Auditory and Visual Attention correct (total correct, correct targets) and incorrect (commission errors, incorrect targets) performance percentiles. Within-group associations between EF and pragmatic skills were examined using Spearman correlation coefficients. Due to missing data, the sample sizes varied between 10 and 15. A correlation of 0.5 was considered large, 0.3 medium and 0.1 small (Cohen, 1988). All statistical tests were two-tailed.

Effect sizes were estimated using  $r = Z/\sqrt{N}$  for Mann-Whitney  $U$  tests and Cramer’s  $V$  ( $\phi_c$ ) for Fisher’s Exact Tests. For both  $r$  and  $\phi_c$ , an effect size above 0.5 could be considered as a large, above 0.3 as a medium and above 0.1 as a small effect (Cohen, 1988).

## Results

### Performance and between-group differences in executive function skills

In working memory, the performance of the AS group varied from “significantly below average” to “average” performance whereas the performance of the control group varied from “slightly below average” to “above average” performance (see Figure 1). In auditory attention, the performance of the AS group varied from “significantly below average” to “average” performance whereas the performance of the control group varied from “average” to “above average” performance. The variance was high in the AS group particularly as regards selective auditory attention. In visual attention, the performance of the AS group varied from “significantly below average” to “average” performance whereas the performance of the control group varied from “below average” to “above average” performance.

The control group was assessed to have better skills in verbal working memory ( $U = 52.00$ ,  $p = 0.011$ ,  $r = 0.46$ , see Figure 1(a)) and selective auditory attention ( $U = 20.00$ ,

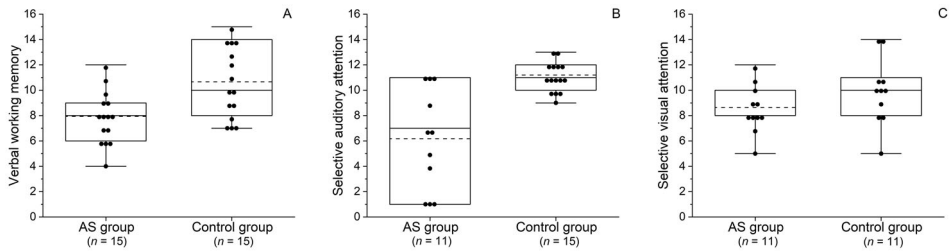


Figure 1. NEPSY-II Sentence Repetition or Word List Interference (verbal working memory, 1(A)), Auditory Attention and Response Set A (selective auditory attention, 1(B)), and Visual Attention (selective visual attention, 1(C)) subtest scaled scores in the autism spectrum (AS) and control group. Dots represent individual participants. Solid lines in the middle represent the group medians and dashed lines group means.

$p = <0.001$ ,  $r = 0.65$ , see Figure 1(B)) than the AS group. The effect sizes were medium and large, respectively. The variance was high in the AS group particularly regarding auditory attention (see Figure 1(B)). No between-group differences were observed in selective visual attention skills ( $U = 39.00$ ,  $p = 0.171$ ,  $r = 0.31$ , see Figure 1(C)). The effect size was small.

We further examined whether the groups differed in the distributions of the NEPSY-II Auditory Attention and Response Set A correct and incorrect answer percentiles (see Table 2). The groups differed statistically in the distribution of the correct answer (total correct) percentiles ( $\chi^2(5, N = 25) = 10.672$ ,  $p = 0.006$ ,  $\phi_c = 0.697$ ) and incorrect answer (commission errors) percentiles ( $\chi^2(4, N = 25) = 7.090$ ,  $p = 0.016$ ,  $\phi_c = 0.573$ ). The effect sizes were large. With regard to the correct answer percentiles, the analyses showed that more children in the AS group scored in the 2–5 percentile compared to children in the control group. With regard to the incorrect answer percentiles, the analyses showed that more children in the AS group scored in the 6–10 percentile compared to children in the control group. The analyses of the NEPSY-II Visual Attention percentiles showed that the groups did not differ statistically in the distribution of correct answer (correct targets) percentiles ( $\chi^2(6, N = 30) = 7.452$ ,  $p = 0.099$ ,  $\phi_c = 0.510$ ) or incorrect answer (incorrect targets) percentiles ( $\chi^2(5, N = 30) = 4.652$ ,  $p = 0.470$ ,  $\phi_c = 0.389$ ). The effect sizes were large and medium, respectively.

#### Within-group associations between executive function and pragmatic skills

In the control group, there was a large positive correlation between verbal working memory and the Pragmatic Composite score of the CCC-2 (see Table 3). That is, the better the verbal working memory skills, the better the overall pragmatic skills of a child as reported by the caregivers. No other statistically significant associations were observed in the control group. No statistically significant associations were observed in the AS group.

## Discussion

This study examined the differences between children on the AS and control children in the EF domains of working memory and inhibitory control of attention. We further explored the within-group associations between these EF skills and pragmatic skills.

Table 2. NEPSY-II selective auditory and visual attention subtest performance percentiles in the autism spectrum and control group.

Percentiles <sup>d</sup>	Autism spectrum group				Control group											
	Selective auditory attention <sup>a</sup> (n = 10) <sup>c</sup>		Selective visual attention <sup>b</sup> (n = 15)		Selective auditory attention (n = 15)		Selective visual attention (n = 15)									
<2	Total correct	0%	Commission errors	0%	Correct targets	6.7%	Incorrect targets	13.3%	Total correct	0%	Commission errors	0%	Correct targets	0%	Incorrect targets	6.7%
2-5	Total correct	30.0%	Commission errors	0%	Correct targets	6.7%	Incorrect targets	0%	Total correct	0%	Commission errors	0%	Correct targets	0%	Incorrect targets	0%
6-10	Total correct	10.0%	Commission errors	40.0%	Correct targets	0%	Incorrect targets	13.3%	Total correct	0%	Commission errors	6.7%	Correct targets	6.7%	Incorrect targets	13.3%
11-25	Total correct	20.0%	Commission errors	60.0%	Correct targets	33.3%	Incorrect targets	40.0%	Total correct	0%	Commission errors	46.7%	Correct targets	6.7%	Incorrect targets	20.0%
26-50	Total correct	10.0%	Commission errors	0%	Correct targets	20.0%	Incorrect targets	6.7%	Total correct	26.7%	Commission errors	20.0%	Correct targets	20.0%	Incorrect targets	33.3%
51-75	Total correct	20.0%	Commission errors	0%	Correct targets	13.3%	Incorrect targets	20.0%	Total correct	33.3%	Commission errors	20.0%	Correct targets	40.0%	Incorrect targets	13.3%
>75	Total correct	10.0%	Commission errors	0%	Correct targets	20.0%	Incorrect targets	6.7%	Total correct	40.0%	Commission errors	6.7%	Correct targets	26.7%	Incorrect targets	13.3%

<sup>a</sup>NEPSY-II Auditory Attention Response Set A subtest.

<sup>b</sup>NEPSY-II Visual Attention subtest.

<sup>c</sup>Autism spectrum group n = 10 due to technical issues in recording the total correct and commission error data.

<sup>d</sup>Percentiles represent the percentage of values below which the other scores of the distribution fall.

Table 3. Associations between pragmatic skills and verbal working memory, selective auditory attention and selective visual attention in the autism spectrum and control group.

	Autism spectrum group						Control group					
	Pragma test total <sup>a</sup>			Pragmatic composite <sup>b</sup>			Pragma test total			Pragmatic composite		
	$r_s$	$p$	$n$	$r_s$	$p$	$n$	$r_s$	$p$	$n$	$r_s$	$p$	$n$
Verbal working memory <sup>c</sup>	.103	.714	15	.174	.535	15	.245	.378	15	<b>.622</b>	<b>.013</b>	15
Selective auditory attention <sup>d</sup>	-0.223	.510	11	-0.099	.773	11	.084	.766	15	.262	.345	15
Selective visual attention <sup>e</sup>	.145	.671	11	-0.412	.208	11	.278	.407	11	.110	.748	11

Note.  $r_s$  = Spearman correlation coefficient.

<sup>a</sup>Pragma test total  $t$  score.

<sup>b</sup>Pragmatic composite score of the CCC-2.

<sup>c</sup>NEPSY-II Sentence Repetition or World List Interference subtest.

<sup>d</sup>NEPSY-II Auditory Attention Response Set A subtest.

<sup>e</sup>NEPSY-II Visual Attention subtest.

First, the EF performances of the AS and control group had differences and similarities depending on the specific EF domain examined. On a group level, the control children were found to have higher verbal working memory skills as compared to the AS group, providing evidence toward domain-specific EF difficulties in some children on the AS (e.g. Christoforou et al., 2023; Friedman & Sterling, 2019). Some previous studies on working memory in individuals on the AS have yielded mixed findings (e.g. Christoforou et al., 2023; Habib et al., 2019), possibly due to the different types of working memory measured (visuospatial, verbal) and the different methods used (Kercood et al., 2014). Our findings are however in line with the previous NEPSY-II validation study by Narzisi et al. (2013) as well as other prior studies finding working memory difficulties in children, adolescents and adults on the AS (e.g. Habib et al., 2019; Kercood et al., 2014; Wang et al., 2017). Our findings therefore lend support to the idea that verbal recall of material, such as sentences, can pose difficulties for some children on the AS (Minshew & Goldstein, 2001; Narzisi et al., 2013). This might relate to how children on the AS recall information: their cognition is reportedly rooted “in the here-and-now” and children on the AS may benefit from immediate memory cues (e.g. Bowler et al., 2008), which could have implications for pragmatic skills.

The control children were also found to have better skills in selective auditory attention, supporting previous studies (Barron-Linnankoski et al., 2015; Hooper et al., 2006; Narzisi et al., 2013). Difficulties of children on the AS in these tasks could reflect challenges in sustaining and shifting attention in tasks with high cognitive load. Lower scores in these tasks could also possibly reflect a narrow attention tunnel and difficulties in engaging in or shifting between activities (Buckle et al., 2021; Murray et al., 2005; Phung et al., 2021). There have been also findings on increased susceptibility to auditory distraction in individuals on the AS (Remington & Fairnie, 2017), which could be reflected in the tendency of the AS group to respond to non-targets. This could also suggest an impulsive responding style, possibly relevant for pragmatic communication.

Contrary to the findings on verbal working memory and selective auditory attention, we did not find between-group differences in selective visual attention. This is in line with prior evidence reporting strong performance in individuals on the AS in visual search tasks (e.g. Barron-Linnankoski et al., 2015; Remington et al., 2009; see Christoforou et al., 2023 for a review).

It is important to note that while our study observed the AS group, on a group level, scoring lower in the verbal working memory and selective auditory attention tasks, 9 out of 15 participants in verbal working memory and 4 out of 11 participants in selective auditory attention had an “average” performance. Therefore, our study does not suggest that all children on the AS have domain-specific EF difficulties even in verbal working memory or selective auditory attention, highlighting the importance of understanding variation between individuals on the AS.

Regarding associations between the EF and pragmatic skills, we found that in the control group, verbal working memory was positively associated with pragmatic skills whereas no associations were found in the AS group. Previously, Cardillo et al. (2021) did not find associations in children on the AS between clinician-assessed EF skills and pragmatic skills either. Also, the study by Gabbatore et al. (2022) showed that improvements in pragmatic skills do not necessarily improve EF skills, suggesting the specificity of these constructs (see Bosco et al., 2018). Our findings however contradict with some other studies reporting associations in children on the AS between pragmatic skills and a composite EF measure (Filipe

et al., 2020), specific domains of working memory (Akbar et al., 2013; Howard et al., 2023; Razavi et al., 2019) and inhibitory control of attention (Howard et al., 2023; Razavi et al., 2019). These studies that have found associations are mostly based on indirect parent- or teacher-reported EF skills, except for the study by Akbar et al. (2013) which used both direct and indirect measures.

Overall, our findings support the notions of complex relationships between EF and pragmatic skills (e.g. Cardillo et al., 2021). Our findings further suggest that the connections between EF skills and pragmatic skills can be different in the AS and control group. Our study design does not allow for the evaluation of directionality of these associations. However, in light of the HCSM model (Marcovitch & Zelazo, 2009), it could be that the observed association between verbal working memory and pragmatic skills in the control group tells us about the more conscious language-guided task orientation (using the representational system) of the control group in solving the working memory task (see also Akbar et al., 2013; Joseph et al., 2005). For the AS group, their task orientation may have been more perception-based (using the habit system) and less dependent on conscious reflection of language. The fact that we used a *verbal* working memory measure, could have had an impact as to why we did not observe similar association between inhibitory control and pragmatic skills in the control group (that is, language-guided reflection was presumably less relevant for the inhibitory control task). These hypotheses merit further research, including the examination of directionality and the effect of age, since the HCSM model proposes that the use of the representational system increases by age (Marcovitch & Zelazo, 2009).

Given the variation in findings between different studies, it is likely that methodological differences play a role. For instance, clinician-administered tests and caregiver-reports may measure considerably different levels of functioning (Toplak et al., 2013). Caregiver-reported EF and pragmatic skills focus more on the “broad” management of daily situations and evaluate how a child applies a skill in different settings, whereas clinician-assessed pragmatic skills zoom in on how efficiently a child uses the skill in isolation (see e.g. Toplak et al., 2013). The use of complementary measures of both EF and pragmatic skills can be therefore recommended in future studies for a comprehensive understanding of these skills (see also Christoforou et al., 2023; Gabbatore et al., 2023). Our study utilised assessment methods that were available and commonly used in clinical practice in Finland given our aim of increasing knowledge based on clinically easily accessible tools.

The current study has also limitations that merit discussion. First, the small sample size and the considerable variance in the performance of the AS group should be carefully considered when making generalisations based on our findings. Whereas some prior studies have utilised a similar sample size (e.g. Filipe et al., 2020), larger samples that also include female participants would be useful and would also allow to examine gender differences. Our clinical sample was male-dominated and did not enable the examination of the role of sex. Therefore, the findings of our study should be taken as suggestive when considering the population of children on the AS. Second, the EF skills were examined as part of a larger data collection procedure, and the measures were narrowed down in order to create a comfortable, “autism-friendly” data collection procedure with a reasonable duration. However, the assessment of EF using additional methods (caregiver- and teacher-assessments, e.g. Behavior Rating Inventory of Executive Functioning [BRIEF], Gioia et al., 2000) would be interesting both in terms of exploring potential between-group differences as

well as the associations with pragmatic skills. It is also important to note that we only measured verbal working memory and our findings on working memory do not necessarily reflect spatial working memory. Also, NEPSY-II involves the use of two different working memory tasks depending on participants' age, which means that not all the children completed the same tasks. However, there was no between-group age difference which indicates that the working memory tasks were distributed evenly between the groups. The findings of our study should however be interpreted in the light of the measures used. Third, we measured the ability to comprehend spoken instructions using the TTFC-2 as an index of language ability and neither the AS nor control group showed difficulties. However, the control group had a higher performance as compared to the AS group, which may have some effect on the findings on verbal working memory. Fourth, the current study focused on pragmatic skills whereas theory of mind, the ability to attribute mental states to oneself and others, is a closely related construct (see Cardillo et al., 2021) that merits a separate examination (e.g. Bosco et al., 2018). Future studies would also benefit from cultural comparisons. Cultural differences may be evident particularly in the parent-, teacher- and self-reported measures reflecting cultural understanding of appropriate EF and pragmatic skills (see e.g. Gabbatore et al., 2023). Cultural comparisons could significantly inform clinical practice and therefore deserve more consideration in the future research.

There is a clear clinical relevance in understanding the EF skills of individuals on the AS and the relationship between EF and pragmatic skills. A thorough assessment of these skills using a variety of direct and indirect measures provides a comprehensive profile of a child's strengths. Our findings suggest that clinicians should be aware that EF and pragmatic skills in children on the AS may not have a straightforward relationship. Therefore, it is important to encourage clinicians to consider both EF and pragmatic skills in their own right to provide comprehensive support for a child to navigate social situations.

## Note

1. We use terminology that is reportedly preferred by people on the autism spectrum (see e.g. Bury et al., 2023).

## Ethical considerations

The study was approved by the Ethical Committee of the Northern Ostrobothnia Hospital District.

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## Consent to participate

Participation in the study was voluntary and based on parental written informed consent.

## Authors' contributions

KD: conceptualization, formal analysis, investigation, methodology, visualization, funding acquisition, writing—original draft, writing—review and editing; LM: conceptualization, data curation, investigation, methodology, writing—original draft, writing—review and editing; IG: conceptualization, funding acquisition, writing—review and editing; EL: funding acquisition; writing—review and editing; HE: resources, writing—review and editing; SL: conceptualization, data curation, investigation, methodology, funding acquisition, project administration, supervision, writing—review and editing.

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## Data availability statement

Data is not available due to ethical reasons. The participants of this study did not give a consent for their data to be publicly available.

## REFERENCES

- Akbar, M., Loomis, R., & Paul, R. (2013). The interplay of language on executive functions in children with ASD. *Research in Autism Spectrum Disorders*, 7(3), 494–501. <https://doi.org/10.1016/j.rasd.2012.09.001>
- American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). American Psychiatric Association. <https://doi.org/10.1176/appi.books.9780890425596>
- Angeleri, R., Gabbatore, I., Bosco, F. M., Sacco, K., & Colle, L. (2016). Pragmatic abilities in children and adolescents with autism spectrum disorder: A study with the ABaCo battery. *Minerva Psichiatrica*, 57(3), 93–103.
- Baixauli-Fortea, I., Miranda Casas, A., Berenguer-Forner, C., Colomer-Diago, C., & Roselló-Miranda, B. (2019). Pragmatic competence of children with autism spectrum disorder. Impact of theory of mind, verbal working memory, ADHD symptoms, and structural language. *Applied Neuropsychology. Child*, 8(2), 101–112. <https://doi.org/10.1080/21622965.2017.1392861>
- Barendse, E. M., Hendriks, M. P., Jansen, J. F., Backes, W. H., Hofman, P. A., Thoonen, G., Kessels, R. P., & Aldenkamp, A. P. (2013). Working memory deficits in high-functioning adolescents with autism spectrum disorders: Neuropsychological and neuroimaging correlates. *Journal of Neurodevelopmental Disorders*, 5(1), 14. <https://doi.org/10.1186/1866-1955-5-14>
- Barron-Linnankoski, S., Reinval, O., Lahervuori, A., Voutilainen, A., Lahti-Nuutila, P., & Korkman, M. (2015). Neurocognitive performance of children with higher functioning autism spectrum disorders on the NEPSY-II. *Child Neuropsychology: A Journal on Normal and Abnormal Development in Childhood and Adolescence*, 21(1), 55–77. <https://doi.org/10.1080/09297049.2013.873781>
- Beauchamp, M. H., & Anderson, V. (2010). SOCIAL: An integrative framework for the development of social skills. *Psychological Bulletin*, 136(1), 39–64. <https://doi.org/10.1037/a0017768>
- Bishop, D. V. (1998). Development of the Children's Communication Checklist (CCC): A method for assessing qualitative aspects of communicative impairment in children. *Journal of Child Psychology and Psychiatry*, 39(6), 879–891. <https://doi.org/10.1111/1469-7610.00388>
- Bishop, D. V. M. (2015). *The Children's Communication Checklist-2 (CCC-2), Lasten kommunikointitaitojen kysely, toinen painos* (Yliherva A., Loukusa S., Väisänen R, Trans.). Hogrefe Psykologien Kustannus Oy.

- Blain-Brière, B., Bouchard, C., & Bigras, N. (2014). The role of executive functions in the pragmatic skills of children age 4–5. *Frontiers in Psychology, 5*, 240. <https://doi.org/10.3389/fpsyg.2014.00240>
- Bölte, S., Duketis, E., Poustka, F., & Holtmann, M. (2011). Sex differences in cognitive domains and their clinical correlates in higher-functioning autism spectrum disorders. *Autism: The International Journal of Research and Practice, 15*(4), 497–511. <https://doi.org/10.1177/1362361310391116>
- Bosco, F. M., Tirassa, M., & Gabbatore, I. (2018). Why pragmatics and theory of mind do not (completely) overlap. *Frontiers in Psychology, 9*, 1453. <https://doi.org/10.3389/fpsyg.2018.01453>
- Bowler, D. M., Gaigg, S. B., & Gardiner, J. M. (2008). Effects of related and unrelated context on recall and recognition by adults with high-functioning autism spectrum disorder. *Neuropsychologia, 46*(4), 993–999. <https://doi.org/10.1016/j.neuropsychologia.2007.12.004>
- Buckle, K. L., Leadbitter, K., Poliakoff, E., & Gowen, E. (2021). “No way out except from external intervention”: First-hand accounts of autistic inertia. *Frontiers in Psychology, 12*, 631596. <https://doi.org/10.3389/fpsyg.2021.631596>
- Bury, S. M., Jellet, R., Spoor, J. R., & Hedley, D. (2023). “It defines who I am” or “It’s something I have”: What language do [autistic] Australian adults [on the autism spectrum] prefer? *Journal of Autism and Developmental Disorders, 53*(2), 677–687.
- Cardillo, R., Mammarella, I. C., Demurie, E., Giofrè, D., & Roeyers, H. (2021). Pragmatic language in children and adolescents with autism spectrum disorder: Do theory of mind and executive functions have a mediating role? *Autism Research: Official Journal of the International Society for Autism Research, 14*(5), 932–945. <https://doi.org/10.1002/aur.2423>
- Carrow-Woolfolk, E. (1999). *CASL: Comprehensive assessment of spoken language*. American Guidance Services.
- Christoforou, M., Jones, E. J., White, P., & Charman, T. (2023). Executive function profiles of preschool children with autism spectrum disorder and attention-deficit/hyperactivity disorder: A systematic review. *JCPP Advances, 3*(1), e12123. <https://doi.org/10.1002/jcv.21213>
- Cohen, I. L., & Sudhalter, V. (2005). *The PDD behavior inventory*. Psychological Assessment Resources, Inc.
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum.
- Corbett, B. A., Constantine, L. J., Hendren, R., Rocke, D., & Ozonoff, S. (2009). Examining executive functioning in children with autism spectrum disorder, attention deficit hyperactivity disorder and typical development. *Psychiatry Research, 166*(2–3), 210–222. <https://doi.org/10.1016/j.psychres.2008.02.005>
- Demetriou, E. A., Lampit, A., Quintana, D. S., Naismith, S. L., Song, Y. J. C., Pye, J. E., Hickie, I., & Guastella, A. J. (2018). Autism spectrum disorders: A meta-analysis of executive function. *Molecular Psychiatry, 23*(5), 1198–1204. <https://doi.org/10.1038/mp.2017.75>
- Dennis, M., Lazenby, A. L., & Lockyer, L. (2001). Inferential language in high-function children with autism. *Journal of Autism and Developmental Disorders, 31*(1), 47–54. <https://doi.org/10.1023/a:1005661613288>
- Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64*(1), 135–168. <https://doi.org/10.1146/annurev-psych-113011-143750>
- Ellis Weismer, S., Kaushanskaya, M., Larson, C., Mathée, J., & Bolt, D. (2018). Executive function skills in school-age children with autism spectrum disorder: Association with language abilities. *Journal of Speech, Language, and Hearing Research: JSLHR, 61*(11), 2641–2658. [https://doi.org/10.1044/2018\\_JSLHR-L-RSAUT-18-0026](https://doi.org/10.1044/2018_JSLHR-L-RSAUT-18-0026)
- Faja, S., & Dawson, G. (2014). Performance on the dimensional change card sort and backward digit span by young children with autism without intellectual disability. *Child Neuropsychology: A Journal on Normal and Abnormal Development in Childhood and Adolescence, 20*(6), 692–699. <https://doi.org/10.1080/09297049.2013.856395>
- Filipe, M. G., Veloso, A., Frota, S., & Vicente, S. G. (2020). Executive functions and pragmatics in children with high-functioning autism. *Reading and Writing, 33*(4), 859–875. <https://doi.org/10.1007/s11145-019-09975-2>
- Friedman, L., & Sterling, A. (2019). A review of language, executive function, and intervention in autism spectrum disorder. *Seminars in Speech and Language, 40*(4), 291–304. <https://doi.org/10.1055/s-0039-1692964>

- Gabbatore, I., Bosco, F. M., Mäkinen, L., Leinonen, E., & Loukusa, S. (2021). Social-pragmatic contextual comprehension in Italian preschool and school-aged children: A study using the Pragma test. *Intercultural Pragmatics*, 18(2), 131–162. <https://doi.org/10.1515/ip-2021-2001>
- Gabbatore, I., Dindar, K., Pirinen, V., Vähänikkilä, H., Mämmelä, L., Kotila, A., Bosco, F. M., Leinonen, E., & Loukusa, S. (2023). Silent Finns and Talkative Italians? An investigation of communicative differences and similarities as perceived by parents in typically developing children. *First Language*, 43(3), 313–335. <https://doi.org/10.1177/01427237221149310>
- Gabbatore, I., Longobardi, C., & Bosco, F. M. (2022). Improvement of communicative-pragmatic ability in adolescents with autism spectrum disorder: The adapted version of the cognitive pragmatic treatment. *Language Learning and Development*, 18(1), 62–80. <https://doi.org/10.1080/15475441.2021.1924177>
- Geurts, H. M., & Embrechts, M. (2008). Language profiles in ASD, SLI, and ADHD. *Journal of Autism and Developmental Disorders*, 38(10), 1931–1943. <https://doi.org/10.1007/s10803-008-0587-1>
- Gibbs, R. W., & Colston, H. I. (2012). *Interpreting figurative meaning*. Cambridge University Press.
- Gioia, G. A., Isquith, P. K., Guy, S. C., & Kenworthy, L. (2000). *Behavior rating inventory of executive function (BRIEF): Professional manual*. Psychological Assessment Resources.
- Habib, A., Harris, L., Pollick, F., & Melville, C. (2019). A meta-analysis of working memory in individuals with autism spectrum disorders. *PLoS One*, 14(4), e0216198. <https://doi.org/10.1371/journal.pone.0216198>
- Haesen, B., Boets, B., & Wagemans, J. (2011). A review of behavioural and electrophysiological studies on auditory processing and speech perception in autism spectrum disorders. *Research in Autism Spectrum Disorders*, 5(2), 701–714. <https://doi.org/10.1016/j.rasd.2010.11.006>
- Helland, W. A., Lundervold, A. J., Heimann, M., & Posserud, M. B. (2014). Stable associations between behavioral problems and language impairments across childhood—The importance of pragmatic language problems. *Research in Developmental Disabilities*, 35(5), 943–951. <https://doi.org/10.1016/j.ridd.2014.02.016>
- Hessels, R. S., Hooge, I. T., Snijders, T. M., & Kemner, C. (2014). Is there a limit to the superiority of individuals with ASD in visual search? *Journal of Autism and Developmental Disorders*, 44(2), 443–451. <https://doi.org/10.1007/s10803-013-1886-8>
- Hill, E. L. (2004). Executive dysfunction in autism. *Trends in Cognitive Sciences*, 8(1), 26–32. <https://doi.org/10.1016/j.tics.2003.11.003>
- Hooper, S. R., Poon, K. K., Marcus, L., & Fine, C. (2006). Neuropsychological characteristics of school-age children with high-functioning autism: Performance on the NEPSY. *Child Neuropsychology: A Journal on Normal and Abnormal Development in Childhood and Adolescence*, 12(4–5), 299–305. <https://doi.org/10.1080/09297040600737984>
- Howard, J., Herold, B., Major, S., Leahy, C., Ramseur, K., Franz, L., Deaver, M., Vermeer, S., Carpenter, K. L., Murias, M., Huang, W. A., & Dawson, G. (2023). Associations between executive function and attention abilities and language and social communication skills in young autistic children. *Autism: International Journal of Research and Practice*, 27(7), 2135–2144. <https://doi.org/10.1177/13623613231154310>
- Jarrold, C., Gilchrist, I. D., & Bender, A. (2005). Embedded figures detection in autism and typical development: Preliminary evidence of a double dissociation in relationships with visual search. *Developmental Science*, 8(4), 344–351. <https://doi.org/10.1111/j.1467-7687.2005.00422.x>
- Joseph, R. M., Keehn, B., Connolly, C., Wolfe, J. M., & Horowitz, T. S. (2009). Why is visual search superior in autism spectrum disorder? *Developmental Science*, 12(6), 1083–1096. <https://doi.org/10.1111/j.1467-7687.2009.00855.x>
- Joseph, R. M., McGrath, L. M., & Tager-Flusberg, H. (2005). Executive dysfunction and its relation to language ability in verbal school-age children with autism. *Developmental Neuropsychology*, 27(3), 361–378. [https://doi.org/10.1207/s15326942dn2703\\_4](https://doi.org/10.1207/s15326942dn2703_4)
- Kercood, S., Grskovic, J. A., Banda, D., & Begeske, J. (2014). Working memory and autism: A review of literature. *Research in Autism Spectrum Disorders*, 8(10), 1316–1332. <https://doi.org/10.1016/j.rasd.2014.06.011>
- Korkman, M., Kirk, U., & Kemp, S. L. (2008). *Nepsy II – Lasten neuropsykologinen tutkimus*. Psykologien Kustannus Oy.
- Levinson, S. C. (1983). *Pragmatics (Cambridge textbooks in linguistics)*. Cambridge University Press.

- Lord, C., Rutter, M., & Le Couteur, A. (1995). *Autism diagnostic interview – Revised (ADI-R)* (3rd ed.). Western Psychological Services.
- Lord, C., Rutter, M., DiLavore, P. C., & Risi, S. (2000). *Autism diagnostic observation schedule (ADOS)*. Western Psychological Services.
- Loukusa, S. (2019). Pragma-testi. In *Sosiaalisen ja pragmaattisen kielen ymmärtämisen testi*. Niilo Mäki Instituutti.
- Loukusa, S. (2021). Autism spectrum disorder. In Cummings L. (Ed.), *Pragmatic language disorders: Complex and underserved populations* (pp. 45–78). Springer.
- Loukusa, S., Leinonen, E., Kuusikko, S., Jussila, K., Mattila, M.-L., Ryder, N., Ebeling, H., & Moilanen, I. (2007). Use of context in pragmatic language comprehension by children with Asperger syndrome or high-functioning autism. *Journal of Autism and Developmental Disorders*, 37(6), 1049–1059. <https://doi.org/10.1007/s10803-006-0247-2>
- Loukusa, S., Mäkinen, L., Kuusikko-Gauffin, S., Ebeling, H., & Leinonen, E. (2018). Assessing social-pragmatic inferencing skills in children with autism spectrum disorder. *Journal of Communication Disorders*, 73, 91–105. <https://doi.org/10.1016/j.jcomdis.2018.01.006>
- Loukusa, S., Mäkinen, L., Kuusikko-Gauffin, S., Ebeling, H., & Moilanen, I. (2014). Theory of mind and emotion recognition skills in children with specific language impairment, autism spectrum disorder and typical development: group differences and connection to knowledge of grammatical morphology, word-finding abilities and verbal working memory. *International Journal of Language & Communication Disorders*, 49(4), 498–507. <https://doi.org/10.1111/1460-6984.12091>
- Mäkinen, L., Loukusa, S., Leinonen, E., Moilanen, I., Ebeling, H., & Kunnari, S. (2014). Characteristics of narrative language in autism spectrum disorder: Evidence from the Finnish. *Research in Autism Spectrum Disorders*, 8(8), 987–996. <https://doi.org/10.1016/j.rasd.2014.05.001>
- Marcovitch, S., & Zelazo, P. D. (2009). A hierarchical competing systems model of the emergence and early development of executive function. *Developmental Science*, 12(1), 1–18. <https://doi.org/10.1111/j.1467-7687.2008.00754.x>
- Matthews, D., Biney, H., & Abbot-Smith, K. (2018). Individual differences in children's pragmatic ability: A review of associations with formal language, social cognition, and executive functions. *Language Learning and Development*, 14(3), 186–223. <https://doi.org/10.1080/15475441.2018.1455584>
- McGhee, R. L., Ehrlert, D. J., & DiSimoni, F. (2007). *Token test for children (TTCF-2)*. Pro-Ed.
- Minschew, N. J., & Goldstein, G. (2001). The pattern of intact and impaired memory functions in autism. *Journal of Child Psychology and Psychiatry*, 42(8), 1095–1101. <https://doi.org/10.1111/1469-7610.00808>
- Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: A latent variable analysis. *Cognitive Psychology*, 41(1), 49–100. <https://doi.org/10.1006/cogp.1999.0734>
- Murray, D., Lesser, M., & Lawson, W. (2005). Attention, monotropism and the diagnostic criteria for autism. *Autism: The International Journal of Research and Practice*, 9(2), 139–156. <https://doi.org/10.1177/1362361305051398>
- Narzisi, A., Muratori, F., Calderoni, S., Fabbro, F., & Urgesi, C. (2013). Neuropsychological profile in high functioning autism spectrum disorders. *Journal of Autism and Developmental Disorders*, 43(8), 1895–1909. <https://doi.org/10.1007/s10803-012-1736-0>
- Norbury, C. F., & Bishop, D. V. (2002). Inferential processing and story recall in children with communication problems: A comparison of specific language impairment, pragmatic language impairment and high-functioning autism. *International Journal of Language & Communication Disorders*, 37(3), 227–251. <https://doi.org/10.1080/13682820210136269>
- O’Hearn, K., Asato, M., Ordaz, S., & Luna, B. (2008). Neurodevelopment and executive function in autism. *Development and Psychopathology*, 20(4), 1103–1132. <https://doi.org/10.1017/S0954579408000527>
- Ozonoff, S., & Strayer, D. L. (2001). Further evidence of intact working memory in autism. *Journal of Autism and Developmental Disorders*, 31(3), 257–263. <https://doi.org/10.1023/a:1010794902139>
- Parola, A., Salvini, R., Gabbatore, I., Colle, L., Berardinelli, L., & Bosco, F. M. (2020). Pragmatics, theory of mind and executive functions in schizophrenia: Disentangling the puzzle using machine learning. *PLoS One*, 15(3), e0229603. <https://doi.org/10.1371/journal.pone.0229603>
- Phung, J., Penner, M., Pirlot, C., & Welch, C. (2021). What I wish you knew: Insights on burnout, inertia, meltdown, and shutdown from autistic youth. *Frontiers in Psychology*, 12, 741421. <https://doi.org/10.3389/fpsyg.2021.741421>

- Prutting, C. A., & Kittchner, D. M. (1987). A clinical appraisal of the pragmatic aspects of language. *Journal of Speech and Hearing Disorders*, 52(2), 105–119. <https://doi.org/10.1044/jshd.5202.105>
- Razavi, F., Pourmohamadreza-Tajrishi, M., Haghgoo, H., Bakhshi, E., Tavakoli, S., & Miri, S. M. A. (2019). Relationship between executive functions and pragmatic language in children with autism spectrum disorders. *Iranian Rehabilitation Journal*, 17(3), 225–234.
- Remington, A., & Fairnie, J. (2017). A sound advantage: Increased auditory capacity in autism. *Cognition*, 166, 459–465. <https://doi.org/10.1016/j.cognition.2017.04.002>
- Remington, A., Swettenham, J., Campbell, R., & Coleman, M. (2009). Selective attention and perceptual load in autism spectrum disorder. *Psychological Science*, 20(11), 1388–1393. <https://doi.org/10.1111/j.1467-9280.2009.02454.x>
- Russo, N., Flanagan, T., Iarocci, G., Berringer, D., Zelazo, P. D., & Burack, J. A. (2007). Deconstructing executive deficits among persons with autism: Implications for cognitive neuroscience. *Brain and Cognition*, 65(1), 77–86. <https://doi.org/10.1016/j.bandc.2006.04.007>
- Schmitz, N., Rubia, K., Daly, E., Smith, A., Williams, S., & Murphy, D. G. (2006). Neural correlates of executive function in autistic spectrum disorders. *Biological Psychiatry*, 59(1), 7–16. <https://doi.org/10.1016/j.biopsych.2005.06.007>
- Toplak, M. E., West, R. F., & Stanovich, K. E. (2013). Practitioner review: Do performance-based measures and ratings of executive function assess the same construct? *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, 54(2), 131–143. <https://doi.org/10.1111/jcpp.12001>
- Wang, Y., Zhang, Y-b., Liu, L-l., Cui, J-f., Wang, J., Shum, D. H. K., van Amelsvoort, T., & Chan, R. C. K. (2017). A meta-analysis of working memory impairments in autism spectrum disorders. *Neuropsychology Review*, 27(1), 46–61. <https://doi.org/10.1007/s11065-016-9336-y>
- Wechsler, D. (2010). *WISC-IV – Wechsler Intelligence Scale For Children – IV*. Psykologien Kustannus Oy.
- White, E. I., Wallace, G. L., Bascom, J., Armour, A. C., Register-Brown, K., Popal, H. S., Ratto, A. B., Martin, A., & Kenworthy, L. (2017). Sex differences in parent-reported executive functioning and adaptive behavior in children and young adults with autism spectrum disorder. *Autism Research*, 10(10), 1653–1662. <https://doi.org/10.1002/aur.1811>
- World Health Organization. (1993). *International classification of mental and behavioural disorders (ICD-10)*. Diagnostic criteria for research.
- Yang, J., Zhou, S., Yao, S., Su, L., & McWhinnie, C. (2009). The relationship between theory of mind and executive function in a sample of children from mainland China. *Child Psychiatry and Human Development*, 40(2), 169–182. <https://doi.org/10.1007/s10578-008-0119-4>