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ARTICLE

Co-speech gesture comprehension in autistic children

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Abstract
Co-speech gestures accompany or replace speech in communication. Studies investigating how autistic children understand them are scarce and inconsistent and often focus on decontextualized, iconic gestures. This study compared 73 three- to twelve-year-old autistic children with 73 neurotypical peers matched on age, non-verbal IQ, and morphosyntax. Specifically, we examined (1) their ability to understand deictic (i.e., *pointing*), iconic (e.g., *gesturing ball*), and conventional (e.g., *gesturing hello*) speechless video-taped gestures following verbal information in a narrative and (2) the impact of linguistic (e.g., vocabulary, morphosyntax) and cognitive factors (i.e., working memory) on their performance, to infer on the underlying mechanisms involved. Autistic children displayed overall good performance in gesture comprehension, although a small but significant difference advantage was observed in neurotypical children. Findings suggest that combining speech and gesture sequentially may be relatively spared in autism and might represent a way to alleviate the demand for simultaneous cross-modal processing.

Keywords: autism spectrum disorder; co-speech gestures; gesture comprehension; gesture recognition; non-verbal communication

Résumé
Les gestes co-verbaux accompagnent ou remplacent la parole dans la communication. Les études évaluant la compréhension de ces gestes par les enfants autistes sont rares, présentent des résultats inconsistants et se concentrent généralement sur des gestes iconiques proposés sans contexte linguistique. Cette étude a comparé 73 enfants autistes âgés de trois à douze ans à 73 enfants neurotypiques appariés en âge, en QI non verbal et en compétences morphosyntaxiques. Nous avons examiné (1) leur capacité à comprendre des gestes

déictiques (e.g., pointage), iconiques (e.g., geste représentant un ballon) et conventionnels (e.g., saluer de la main) complétant une phrase dans un récit, ainsi que (2) l'impact des facteurs linguistiques (e.g., vocabulaire, morphosyntaxe) et cognitifs (e.g., mémoire de travail) sur leur performance, afin de mieux comprendre les mécanismes sous-jacents impliqués. Globalement, les enfants autistes ont bien compris les gestes, bien qu'une différence faible mais significative ait été observée en faveur des enfants neurotypiques. Ces résultats suggèrent que la combinaison séquentielle de la parole et du geste pourrait être relativement préservée dans l'autisme. Cette présentation séquentielle pourrait ainsi constituer une stratégie permettant d'alléger la difficulté du traitement simultané de ces modalités.

1. Introduction

Communicative gestures (i.e., "co-speech gestures" or "gestures") are spontaneous body movements such as hand movements, which naturally accompany both the spoken and signed discourse (Kita et al., 1998; Kita & Emmorey, 2023; McNeill, 1992). Gestures constitute crucial non-verbal elements with linguistic meaning, enabling successful communication. Efforts have been recently made to better describe the gestural profiles of children with Autism Spectrum Disorder (ASD),[1] notably for their potential to constitute early markers for ASD diagnosis (Stewart et al., 2022; Zwaigenbaum et al., 2015) and language impairment (Choi & Rowe, 2024; Goldin-Meadow, 2015). While most work has focused on production, studies investigating their gestural comprehension abilities remain scarce. This study proposes to address this gap by investigating the gestural comprehension abilities of autistic children aged 3–12 embedded in a narrative, in comparison to neurotypical peers of comparable age, non-verbal reasoning, and morphosyntactic skills.

Gestures are essential for effective and efficient communication, benefitting both the speaker and the listener. On the one hand, they support message conceptualization and linguistic planning, enabling the transformation of abstract thoughts into structured information that can be verbalized (e.g., Kita, 2000; Kita & Özyürek, 2003). On the other hand, they promote understanding and disambiguating speech (Dargue et al., 2019) while facilitating information retention in short- and long-term memory (Cook et al., 2008). At times, gestures reinforce the spoken message, providing emphasis and enhancing comprehension; in other instances, gestures convey meaning that is absent from speech, providing additional information that enriches the communication by visually reflecting the speaker's underlying thoughts (Goldin-Meadow, 1999, 2003). These visual cues arguably also have a positive impact on thinking, learning, and problem solving (Goldin-Meadow & Alibali, 2013), by reducing the cognitive load in speakers and listeners (Goldin-Meadow, 2004, 2011, 2014; Goldin-Meadow & Alibali, 2013). While gestures often occur with concomitant speech, situations where they replace verbal information are also frequent, for instance in noisy settings (Meissner & Philpott, 1975), in case of word retrieval difficulties (Krauss et al., 2001), or taboos (Brookes, 2014; Kendon, 1988).

Not only are gestures pivotal in language production and conceptualization, but their role in spoken language acquisition is also well established: Gesture production and comprehension noticeably *precede* and *predict* speech outcomes in vocabulary and syntax, both in the neurotypical population and in children with ASD (see Choi & Rowe, 2024;

[1]Both person-first and identity-first language will be used when referring to individuals diagnosed with autism, aiming to acknowledge the diverse preferences within the autistic community (Kenny et al., 2016).

Kilili-Lesta et al., 2022 for reviews). Indeed, the frequency and diversity of gestures used by infants reliably predict their subsequent vocabulary size, with early gestures corresponding to words that will subsequently appear in speech (Colonnesi et al., 2010; Rowe et al., 2008; Rowe & Goldin-Meadow, 2009). Gesture–speech combinations also precede and predict the onset of two-word phrases, underscoring their foundational role in the development of syntax (Goldin-Meadow & Butcher, 2003; Iverson & Goldin-Meadow, 2005; Özçalışkan & Goldin-Meadow, 2005). As such, gestures constitute not only an indicator of overall communicative ability, but also a "harbinger" of subsequent linguistic milestones (Goldin-Meadow, 2015, p. 3).

Importantly, not all gestures are the same, and different gesture *types* convey different meanings. A pioneer classification is McNeill's taxonomy of gestures (McNeill, 1992), distinguishing different gesture types based on their semantic function. In this study, we will focus on: (1) *deictic* gestures, pointing or referring to specific objects or locations in space, (2) *iconic* gestures, directly representing an object or action, by depicting a characteristic of the referent (e.g., mimicking DRIVING[2]), and (3) emblems or *conventional* gestures, which are culturally shared gestures with arbitrary meaning (e.g., THUMBS UP to convey "good"; Ekman & Friesen, 1969).

Co-speech gesture production is delayed, atypical, and/or impaired in children with ASD (see Ramos-Cabo et al., 2019 for an overview). Its pervasive impairment even represents a core characteristic of the non-verbal communicative behaviours identified to establish the autism diagnosis (American Psychiatric Association, 2013). Autistic children indeed have been described to produce fewer gestures in comparison to their typically developing (TD) peers (Mishra et al., 2021; Perrault et al., 2019). This difference is notably observable in toddlers, who produce fewer deictic gestures such as pointing (Manwaring et al., 2018; Mastrogiuseppe et al., 2015). However, differences in gesture use and comprehension between autistic and neurotypical children are not merely quantitative, but also qualitative. Precisely, pointing gestures can be distinguished based on their pragmatic function, aim, and social load (Baron-Cohen, 1989; E. Bates, 1976): *protoimperative* pointing, on the one hand, is used to request or obtain objects. On the other hand, *protodeclarative* pointing serves to share attention and interest by directing addressees to objects or events. Research shows that while children with ASD may demonstrate relatively intact *protoimperative* pointing, they exhibit marked deficits in the comprehension and production of *protodeclarative* pointing (Baron-Cohen, 1989; E. Bates, 1976; Wetherby & Prutting, 1984). This lack of protodeclarative pointing has been associated with reduced interest in social interactions, as well as broader challenges in joint attention, Theory of Mind (i.e., ToM; the ability to attribute mental states to others and predict their behaviours accordingly; Premack & Woodruff, 1978), and social communication (Baron-Cohen, 1989; Brinck, 2004; Camaioni et al., 2004). They are considered hallmark characteristics of ASD. Lower rates of conventional gesture use have also been reported in four- to-twelve-year-old autistic children, in comparison to age-matched TD peers of comparable general language skills (Huang et al., 2020) and full-scale IQ (So et al., 2015).

Many efforts have been engaged to characterize the productive gestural profiles of children with ASD to better inform our understanding of their (non-verbal) communicative behaviours. However, studies exploring the extent to which autistic children *understand* gestures remain limited to date (see Choi & Rowe, 2024 calling for more studies on this

[2]Words in capital letters refer to gestures.

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topic). Yet, a better understanding of the gestural profiles of autistic children is highly valuable, for both diagnostic and intervention purposes. A recent review noticeably emphasized that gestures constitute an early diagnostic marker for ASD (Stewart et al., 2022), helping to detect and identify children at higher risk of autism at earlier stages. Early detection consequently promotes chances to receive early tailored interventions (Zwaigenbaum et al., 2015), which further lead to better social and communicative outcomes (Dawson, 2008; Estes et al., 2015). In addition, better descriptions of gestural profiles in autism may also support the development and implementation of gesture-based therapies, which benefit autistic children across the spectrum (So et al., 2018). Finally, in the light of the well-established relationship between gesture and language development, gestures can also serve as a screening tool for children at higher risk of language delays and impairments (Choi & Rowe, 2024; Goldin-Meadow, 2015; Kilili-Lesta et al., 2022), a common feature in autistic children (Rapin & Dunn, 2003; Schaeffer et al., 2023; Silleresi, 2023).

Moreover, work on the comprehension of gestures has so far yielded inconsistent findings, which may be explained by the variety of tasks and methodology used. In a study investigating the recognition of video-taped decontextualized speechless gestures, Perrault et al. (2019) showed that four- to-eight-year-old children with ASD recognized fewer gestures of iconic and conventional types, in comparison to both TD children and children with language impairment of the same age, suggesting difficulties in this realm beyond language impairment (Perrault et al., 2019). Yet, no mention of the non-verbal reasoning abilities of the sample was provided, nor of their linguistic abilities. Similarly, Stieglitz Ham et al. (2011) showed that 19 autistic children aged 7 to 15 recognized fewer video-taped pantomimes and actions depicting object use compared with their neurotypical peers matched on chronological age, gender, and full-scale IQ (Stieglitz Ham et al., 2011). Evidence of impaired understanding of iconic gestures in combination with speech has also been previously reported in autistic adolescents (Silverman et al., 2010; Hubbard et al., 2012), supporting the possibility of a cross-modal, audiovisual integration deficit.

These findings, however, do not align with previous work conducted by Dimitrova et al. (2017), exploring the gesture comprehension abilities of autistic children aged 2–12 in comparison to vocabulary-matched TD peers. They found no difference in the recognition performance of deictic, iconic, and conventional gestures when participants had to select the picture, out of two choices, corresponding to the gesture performed by the experimenter, either proposed alone or in combination with single words (Dimitrova et al., 2017). Furthermore, in a pantomime comprehension task in which participants were required to select the picture corresponding to a video-taped actor performing a pantomimic action (e.g., *a girl kissing a boy*), 7- to-11-year-old autistic children also performed on par with their TD peers of comparable age and IQ level (Adornetti et al., 2019). Even better recognition performance was exhibited by children with autism compared with neurotypical peers matched on vocabulary (Hamilton et al., 2007), though in a task that did not involve live or video-taped gesturing. Precisely, participants were required to select the correct hand position, among three black-and-white pictures of a hand, that matched a drawing representing a protagonist performing a gesture with a missing hand (e.g., when shown a drawing of a soldier with a missing hand, participants had to choose the corresponding hand from three available options). The group of autistic children provided more correct responses than their neurotypical peers who were younger in chronological age but had comparable vocabulary knowledge (autistic children: 8;1 ± 1; neurotypical children: 4;1 ± 0). The offline nature of the task, which did not involve processing the motion of the gesture, may have favoured the autistic participants' strength in analytic processing and attention to the details (Brosnan et al., 2016; U. Frith, 2003).

Different explanations as to why autistic individuals may experience challenges in co-speech gestures comprehension can be put forth. First, under the integrated-system hypothesis where gestures and speech constitute a unified communicative and cognitive system (e.g., Goldin-Meadow, 2003; Kendon, 2000; McNeill, 1992), difficulties in gesture comprehension may be linked to challenges with language processing (e.g., Goldin-Meadow & Alibali, 2013; Kelly et al., 2010). Second, difficulties with co-speech gestures might stem from reduced attention and appetence towards socio-communicative cues, widely documented in autism (e.g., Chevallier et al., 2012; Klin et al., 2009). Third, challenges may relate to a deficit in multimodal integration of speech and gesture, as suggested by neuroimaging studies (e.g., Hubbard et al., 2012), as well as by the observation that challenges in understanding gesture emerge when these are presented simultaneously with speech in autistic adolescents (Silverman et al., 2010). Noticeably, this difficulty was not attributable to lower comprehension of either speech or gesture alone. As the authors point out, however, it remains to be determined whether the difficulty in integrating speech and gesture stems from the "cross-sensory nature of the task itself" (Silverman et al., 2010, p. 389) or rather from the higher-order process of combining the verbal and gestural information together.

Previous studies on gesture comprehension have helped us to better describe the gestural profiles of autistic individuals. They nevertheless present an incomplete picture of the gestural communicative processes at play in comprehension: Indeed, co-speech gestures, either replacing, interacting, or co-occurring with speech, serve a cognitive or communicative purpose during communicative acts (Clough & Duff, 2020). Such gestures are thus to be understood in their linguistic context, an approach rarely adopted in previous research (e.g., Adornetti et al., 2019; Perrault et al., 2019; Silverman et al., 2010; Stieglitz Ham et al., 2011). Instead, decontextualized stimuli were often used, in the sense that the gestures to be recognized were not integrated into a discourse, contrary to naturalistic situations in which they most likely appear, such as conversations and narrations. Moreover, despite a few exceptions (Dimitrova et al., 2017; Perrault et al., 2019), previous studies have generally investigated a specific gesture type at a time (often iconic gestures), although autistic children tend to primarily face challenges with deictic and conventional gestures (Ramos-Cabo et al., 2019).

To address these gaps, the present study explored the gestural comprehension abilities of children with autism aged 3–12, in comparison to their neurotypical peers carefully matched on age, non-verbal IQ, and receptive morphosyntactic skills. This age range was selected because gesture comprehension is an evolving process developing throughout childhood (Kelly & Church, 1998). During this period, several cognitive skills that may be linked to gesture comprehension in narratives co-develop and undergo significant maturation: attention and executive functions (Anderson, 2002), social cognition such as ToM (Hughes & Devine, 2015), perspective-taking (Beatini et al., 2024), as well as narrative comprehension (Stein & Glenn, 1979). In the present study, we assessed the recognition of three types of gestures (i.e., deictic, iconic, and conventional) that replaced verbal information embedded in an overall story.

Specifically, this study aimed to answer two research questions: (1) Do autistic and neurotypical participants differ in their ability to understand *deictic*, *iconic*, and *conventional* gestures when they are integrated into a narrative and replace verbal information? (2) What is the impact of linguistic (i.e., receptive morphosyntactic and vocabulary skills) and cognitive (i.e., working memory, WM) variables on the performance, so as to shed light on the underlying mechanisms at play in gesture comprehension?

We predicted that children with ASD would show one of two types of performance: On the one hand, they could display lower performance than their TD peers, even after

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controlling for their non-verbal reasoning and linguistic abilities, as difficulties with both speechless iconic and conventional gesture recognition have been reported in autistic children (Perrault et al., 2019). Investigating the respective impact of the linguistic and cognitive variables on the performance will help to elucidate why autistic children might display lower gesture comprehension performance: Indeed, autistic children may experience challenges (a) in parsing the verbal part of the stimulus (namely the spoken sentence preceding the gesture) or (b) in processing the subsequent gestural part of the stimulus; alternatively, challenges may stem from difficulties (c) in integrating these two sources of information (i.e., language and gesture). In the latter case, examining the impact of WM will indicate whether the difficulties in multimodal integration stem from challenges in sequentially maintaining and manipulating these sources of information or whether difficulties lie rather in a higher-order combination of these sources to correctly interpret the message. On the other hand, children with ASD could show similar performance to their TD peers, since our task differed from those of previous studies by only requiring a non-verbal response. This design may have facilitated task performance in children with ASD, by steering clear of their more pronounced challenges in the realm of language production (Rapin & Dunn, 2003).

2. Method

2.1. Participants

2.1.1. Groups

A total of $N = 146$ children, predominantly White, participated in the study. The group of autistic children was composed of $N = 73$ participants aged 3;10 to 11;7 years ($M_{age} = 101 \pm 25.6$ months), to which corresponded $N = 73$ neurotypical children aged between 3;11 and 11;10 years ($M_{age} = 100 \pm 27.4$), carefully matched on age, non-verbal IQ, and receptive morphosyntactic skills with a propensity score (see Supplementary Material, Appendix 1 for further information on the matching procedure). There were more female participants in the neurotypical group than in the autistic group (χ^2 (1) = 38.50, $p < .001$). TD children had no suspicion or diagnosis of ASD, nor of any other developmental disorder or known linguistic or cognitive impairment. Children had no reported visual or auditory impairment. All participants in the autistic group had an official diagnosis of ASD following the criteria of the DSM-5 (American Psychiatric Association, 2013), established by a certified clinician prior to the study with gold-standard tools (e.g., *Autism Diagnostic Observation Schedule*: ADOS-2; Lord et al., 2012, *Autism Diagnostic Interview Revised*: ADI-R; Lord et al., 1994).

2.1.2. Sample recruitment and characteristics

Participants were recruited via flyers, contact with clinicians and hospitals, and websites of associations relevant to the autistic community. Interested families contacted the team via the project's website, emails, or phone calls. As part of an international project, 30.1% of the participants were tested in Switzerland, 32.9% in Germany, 26.7% in France, 3.4% in the UK, 5.5% in the USA, and 1.4% in Canada. Because multilingualism is a widespread phenomenon (Grosjean, 2010), we did not restrict inclusion in the study to monolingual participants, but instead carefully monitored the participants' language backgrounds with the caregiver questionnaire *Quantifying Bilingual EXperience* (Q-BEx; De Cat et al., 2022). The groups of children with ASD and TD children were balanced in their proportion of monolinguals and multilinguals (see Table 1, 47.9% of multilinguals in the group of children with ASD and 45.2% in the group of TD children; χ^2 (1) = 1.40, $p > .05$), with participants considered multilinguals if they had been exposed to two (or more) languages more than 20% of their lifetime, following previous studies (Hantman et al., 2023).

Parental educational level indexed socioeconomic status, given its important correlation with family income (Hauser & Warren, 1997), association with children's academic performance and cognitive development (Rindermann & Ceci, 2018). The highest level of education achieved between the two caregivers was selected and converted into a five-point Likert scale, from (1) elementary school to (5) university. The two groups had relatively high scores of socioeconomic statuses (Table 1). Yet, it was not possible to match participants on this criterion in addition to age, non-verbal IQ, and morphosyntactic skills, and the group of TD children had higher socioeconomic status scores on average (W = 2179.5, $p = .04$). Socioeconomic status was added as a covariate in the statistical analyses to control for its impact.

2.2. Measures

Each participant was individually tested in a quiet room, always accompanied by an experimenter. The *Gesture Comprehension Task* required participants to (1) sequentially process both the verbal and gestural part of the stimulus and (2) to successfully integrate them together to select the correct answer. To account for the cognitive and linguistic resources involved in the task, we monitored and controlled for the resources mobilized

Table 1. Sample description

	Children with ASD (N = 73)	TD children (N = 73)
Age (months)		
Mean ± SD	101 (25.6)	100 (27.4)
Median [min, max]	103 [46, 139]	102 [47, 142]
Sex assigned at birth		
F	18 (24.7%)	35 (47.9%)
M	55 (75.3%)	38 (52.1%)
Parental educational level (min 1, max 5)		
Mean ± SD	3.90 (1.28)	4.37 (0.89)
Median [min, max]	4 [1, 5]	5 [2, 5]
Language of testing		
English	7 (9.6%)	7 (9.6%)
French	41 (56.2%)	14 (19.2%)
German	23 (31.5%)	37 (50.7%)
Italian	2 (2.7%)	15 (20.5%)
Linguistic background		
Monolinguals	38 (52.1%)	40 (54.8%)
Multilinguals	35 (47.9%)	33 (45.2%)

during the task, namely linguistic skills, visual perception of communicative cues, and WM. As such, the assessment started with first a *pre-assessment task* ensuring that the participant had sufficient attentional resources towards gestural cues. This was followed by the *Gesture Comprehension Task*. Then, the *Peabody Picture Vocabulary Test* (Dunn & Dunn, 2007) and the *Test for Receptive Grammar* (Bishop, 2003) monitored the participants' linguistic abilities. *Raven's Progressive Matrices* (Raven et al., 2018) were used to assess non-verbal IQ, and the *Frog Matrices Task* (Morales et al., 2013) measured WM.

2.2.1. Gesture Comprehension Task

To test the participants' gestural comprehension abilities in a narrative context, a new gamified task inspired by Botting et al. (2010) and Wermelinger et al. (2020) was developed. The task was digitalized and included 12 items preceded by two warm-up trials with explanatory feedback. All items formed a coherent story. The task was introduced by Gabi, a 3D character with a natural human-like voice, who was asking for help to understand the story played on TV. All instructions were given orally by this character, ensuring similar quantity and quality of instructions across participants. Participants were asked to watch and listen carefully to a short video and to select, by touching the screen, the corresponding picture out of four response choices.

Language versions. The task was made equivalent in four languages: English, French, German, and Italian. All items and instructions were translated from French to the other languages and were recorded by native speakers of the respective languages. The complete list of items in all languages is available in Supplementary Material, Appendix 2.

Stimuli description. Each stimulus consisted of a video of an actor enunciating a sentence and replacing the last part with a speechless gesture, either of deictic (i.e., pointing gesture, four items), iconic (four items), or conventional (four items) type (see Figure 1 for an example of each gesture type). Natural congruent facial emotions were kept ensuring a naturalistic context. The stimuli always appeared in the same order for all participants (i.e., stimulus with a deictic gesture, followed by an iconic, and a conventional gesture). The videos were recorded by a professional cameraman, which was subsequently post-edited for sound normalization and noise reduction. The stimuli's narrations were short sentences of maximum 12 words, with reduced morphosyntactic and vocabulary difficulties, to avoid penalizing participants with lower language skills (i.e., simple clause syntactic structures, verbs in present tense, words emerging in the first years of life present in the *Mac-Arthur Bates Checklist Inventory* in English (Fenson et al., 2007), German (Szagun et al., 2009), French (Kern et al., 2010), and Italian (Rinaldi et al., 2019)). Gestures were selected to minimize cultural variations in the Western countries the study took place in.

Response choices. Four response options (Figure 2) that did not require verbal naming were presented. This number was chosen following the original task (Botting et al., 2010) and enabled lowering the likelihood of hitting a correct response by chance to 25%. The verbal and non-verbal components of each item were intentionally designed to be ambiguous when processed separately. Accordingly, participants had to integrate both verbal and gestural parts to accurately select the correct item from the four presented options, except for the stimuli of deictic types where paying attention to the pointing gesture was sufficient to succeed. The response options were: (a) the *correct answer*, depicting the correct object or the protagonist performing the correct action, (b) a *gestural* distractor, referring to a gesture close to the target gesture that could be selected if the

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	Language	Sentence produced by the actor...	...speechless gesture ending the sentence	
DEICTIC	ENGLISH	"Lewis goes into the forest to collect..."		...POINTING towards flowers
	FRENCH	"Louis va dans la forêt pour ramasser..."		
	GERMAN	"Luis geht in den Wald und sammelt..."		
	ITALIAN	"Luigi va nella foresta a raccogliere..."		
ICONIC	ENGLISH	"In a tree, there is an animal. It is a..."		...MONKEY gesture
	FRENCH	"Dans un arbre, il y a un animal. C'est un..."		
	GERMAN	"In einem Baum sitz ein Tier. Es ist ein..."		
	ITALIAN	"In un albero c'è un animale. È un..."		
CONVENTIONAL	ENGLISH	"Lewis stops. In front of him, there are two roads. Lewis..."		...DON'T KNOW gesture
	FRENCH	"Louis s'arrête. Devant lui, il y a deux routes. Louis..."		
	GERMAN	"Luis hält an. Vor ihm sind zwei Wege. Luis..."		
	ITALIAN	"Luigi si ferma. Davanti a lui ci sono due strade. Luigi..."		

Figure 1. Example of stimuli of *deictic*, *iconic*, and *conventional* gesture types in the four languages.

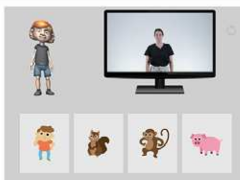
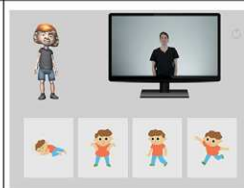
	Deictic gesture	Iconic gesture	Conventional gesture
Screen			
Response options	*From left to right...* (1) Correct response (2) Oddball (3) Visual distractor (4) Semantic distractor	*From left to right...* (1) Gestural distractor (2) Semantic distractor (3) Correct responses (4) Oddball	*From left to right...* (1) Oddball (2) Correct response (3) Semantic distractor (4) Gestural distractor

Figure 2. Example of response choices for stimuli of *deictic*, *iconic*, and *conventional* type.

participant paid only attention to the gesture, but not to the verbal part of the stimulus, (c) a *semantic* distractor, that matched the verbal content of the stimulus but not the gesture seen, and (d) an *oddball*, matching neither the stimulus' verbal information nor the gesture. The oddball pictures were of the same attractiveness and nature as the other response choices to ensure consistency (e.g., animate/inanimate object). For deictic gestures, the gestural distractor (c) was replaced by a *visual* distractor, namely a picture visually close to the target item in terms of colour and/or shape, as it was not possible to conceive a gestural distractor for this type of gesture. The response choices appeared simultaneously at the end of the stimulus in a random order.

Performance calculation. For each item, 1 point was awarded for a correct picture selection, while 0 point was given for an incorrect response, irrespective of the distractor

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selected. The total Gesture Comprehension Task score varied between a minimum of 0 and a maximum of 12 points.

2.2.2. Pre-assessment task

A short six-item pre-assessment task ensured that the participant had sufficient attention towards video-taped gestures. Each item consisted of a video-taped speechless gesture performed by an actor. Participants had to select the video of the same gesture performed by another actor amongst three choices. Participants performing below chance level (i.e., 33%) were excluded. All participants (N = 146) included in this study performed above chance level at this task.

2.2.3. Morphosyntactic assessment

As the Gesture Comprehension Task involved the comprehension of gestures embedded in a sentence, receptive morphosyntactic skills were assessed using the *Test For Receptive Grammar 2* (Bishop, 2003) and its respective adaptations in the different languages of testing, namely French (Lecocq 1996), German (Fox-Boyer et al., 2006) and Italian (Suraniti et al., 2009). This standardized task assesses the comprehension of different grammatical structures with increasing complexity (e.g., passive sentences, “neither nor” constructions, etc.), by requiring participants to select, among four choices, the image corresponding to the sentence heard. Z-scores were used in the analyses.

2.2.4. Receptive vocabulary assessment

Given the predictive role of vocabulary knowledge on the gestural development in both autistic and neurotypical children (Choi & Rowe, 2024; Kilili-Lesta et al., 2022), the PPVT was administered to assess the breadth of receptive vocabulary (i.e., English: Dunn & Dunn, 2007, French: Dunn et al., 1993, German: Lenhard et al., 2015, Italian: Stella et al., 2000). Participants selected, among four options, the picture corresponding to a word heard. Raw scores were converted into z-scores to allow comparison across languages.

2.2.5. Working memory (WM) assessment

As the Gesture Comprehension Task involved WM, the Frog Matrices Tasks (FMT) following Morales et al. (2013) was administered. In this variant of the *Corsi Blocks Task* (Berch et al., 1998), children had to recall the backward location of two to six frogs appearing sequentially. The memory span was determined as the longest sequence of frogs that the participant could recall accurately in at least one of the two trials proposed. Groups did not differ in their WM spans (W = 1884.5, p = .08).

2.2.6 Non-verbal reasoning assessment

The short version of the digitalized *Raven’s Progressive Matrices (Raven’s 2;* Raven et al., 2018) was used to assess and control for non-verbal reasoning. The participant selected the option, among five choices, that best fitted the visual geometric design displayed on the screen. The resulting standardized non-verbal IQ score was used in subsequent analyses.

Descriptive statistics of the linguistic and non-verbal measures are presented in Table 2.

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Table 2. Descriptive statistics of the linguistic and non-verbal measures

	Children with ASD (N = 73)	TD children (N = 73)
Receptive morphosyntax (TROG–2, z-score)		
Mean ± SD	−0.65 ± 1.32	−0.49 ± 1.19
Median [min, max]	−0.45 [−3.23, 1.42]	−0.40 [−3.00, 1.90]
Non-verbal IQ (Raven's 2 IQ score)		
Mean ± SD	95.50 ± 13.60	96.80 ± 13.20
Median [min, max]	93.00 [70.00, 128.00]	97.00 [71.00, 133.00]
Receptive vocabulary (PPVT, z-score)		
Mean ± SD	−0.47 ± 1.78	0.34 ± 1.17
Median [min, max]	−0.29 [−4.00, 3.00]	0.20 [−2.33, 2.30]
Missing values	5 (6.8%)	13 (17.8%)
Working Memory (WM span)		
Mean ± SD	3.49 (2.15)	4.15 (1.77)
Median [min, max]	4.00 [0.00, 6.00]	5.00 [0.00, 6.00]
Missing values	10 (13.7%)	1 (1.4%)

3. Data analyses

A binomial generalized mixed-effects model with a logit function on accuracy was constructed to investigate whether the two groups (children with ASD and TD children) had different gesture comprehension performances, and whether their scores were differently influenced by the type of gesture. Analyses were run in R using R Studio (Version 2023.12.0 + 369) with the *lme4* package (D. Bates et al., 2015).

The fixed effects of the model included group (autistic children, neurotypical children), gesture type (deictic, iconic, conventional), and their interaction. In addition, the following covariates were added to investigate their impact on performance: Receptive morphosyntax, vocabulary knowledge, and WM. Age, the interaction between age and group, socioeconomic status, sex assigned at birth, non-verbal reasoning, and language of testing were also entered as fixed effects to account for their effect and potential differences between groups. Participants and items were entered as random effects. We began by including a maximal random effects structure and only simplified the complexity of random effects in case of convergence issues (Barr et al., 2013). Information on contrast coding and model specifications is available in Supplementary Material, Appendix 3 and under: https://osf.io/vp764/

4. Results

Descriptively, both groups performed well on the task, above chance level with scores approaching ceiling performance for all gesture types (Figure 3). Overall, children with ASD produced an average of 12.10% incorrect responses, whereas TD children made only 3.54% errors, indicating a higher accuracy rate in the neurotypical group.

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The model showed a significant effect of group (β = − 1.64, SE = 0.68, $p = .02$) with autistic participants recognizing significantly fewer gestures than their TD peers (Supplementary Material, Appendix 4). However, the size of the difference was small, estimated at about 2.0% when accounting for all other variables. There was no significant effect of gesture types (all *ps* > *.05*), and the non-significant interaction between groups and gesture types (all *ps* > *.05*) suggests that both groups were not differentially impacted by the different types of gestures (deictic, iconic, and conventional).

Age was a significant positive predictor of the performance (β = 1.23, SE = 0.26, $p < .001$), suggesting better gesture comprehension in older children. However, the non-significant interaction between age and group ($p > .05$) suggests that age did not impact the group's performance differently. Illustrations of the predicted performance as a function of age are presented in Supplementary Material, Appendix 6. They suggest that participants reach a performance plateau around age 8. More advanced analyses, such as generalized additive models (GAMs) would be required to confirm these observations.

A significant effect of vocabulary knowledge was found (β = 0.39, SE = 0.16, $p = .02$), showing that participants with higher vocabulary skills also exhibited better gesture recognition performance. However, there were no significant effects of either receptive morphosyntactic skills or WM on accuracy. Additionally, sex assigned at birth, socio-economic status, non-verbal reasoning, and language of testing did not predict the performance either (all *ps* > .05).

To further examine the role of receptive vocabulary on the performance difference between autistic and neurotypical children, causal mediation analyses were conducted (see Supplementary Material, Appendix 5). Results showed that vocabulary knowledge significantly mediated the group difference in performance: On average, about 18.39% of the total effect of the difference between the two groups was explained by PPVT scores (proportion mediated estimate = 0.18, CI = [0.19, 0.35], $p < .001$; 25.96% in TD children, and 10.81% in children with ASD).

Explanatory post-hoc analyses were further conducted to investigate whether the *monolingual* versus *multilingual* status of the participants differently impacted the performance. *Multilingual status* (monolingual, multilingual) was sum-coded and included in the final model either as a fixed effect (model A) or in interaction with the

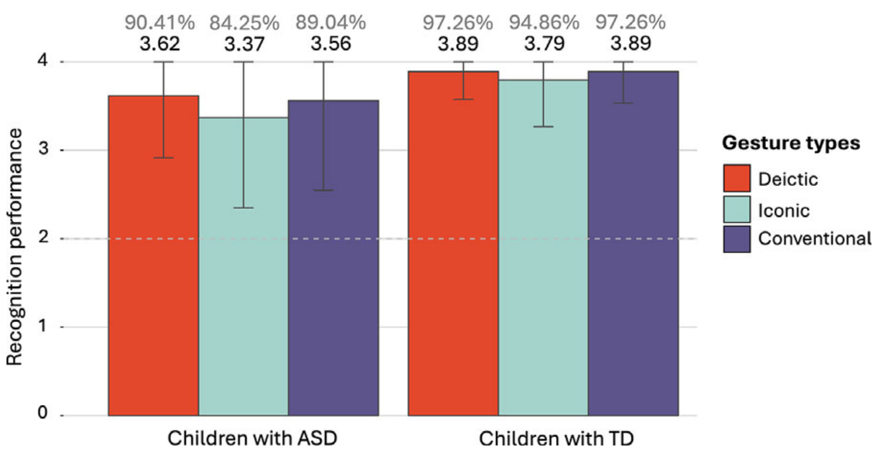

Figure 3. Mean recognition performance per group and gesture types.

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group variable (model B). Results revealed no significant effect of multilingual status in either model (see Supplementary Material, Appendix 7).

To further investigate whether autistic and neurotypical children differed in their error patterns (e.g., selecting the semantic distractor, visual distractor, or oddball), a series of chi-square tests of independence were conducted. These tests allowed us to evaluate whether the observed error frequencies differed significantly between the two groups for each combination of *gesture type* and *error type*, compared with the expected frequencies under the null hypothesis of no association. Given that multiple chi-square tests were conducted, a Bonferroni correction was applied to control for the increased risk of type I error (risk of false positives). Results indicated that when they did not select the correct answer, autistic children were significantly more likely to select the *semantic distractor* than neurotypical children (χ^2 (1) = 11.78, $p < .001$), but only in items with iconic gestures. No significant difference in the proportion of errors was evidenced for other *gesture* types, nor other *error* types. Moreover, both groups produced all three types of errors, without salient preference for a specific type over another. Supplementary Material, Appendix 8 shows a visualization of the distribution of errors for each group and gesture type.

5. Discussion

The first goal of this study was to examine whether and how autistic children understand three types of communicative gesture (i.e., *deictic*, *iconic*, and *conventional*) when these gestures replaced verbal information in a narrative. Their performance was compared to TD peers who were carefully matched on age, non-verbal IQ, and receptive morphosyntactic abilities. After accounting for their age, sex assigned at birth, non-verbal IQ, receptive morphosyntactic abilities, vocabulary knowledge, socioeconomic status, WM, and testing language, children with ASD recognized significantly fewer gestures than their TD peers, irrespective of the gesture type. Despite the small difference between groups, these findings suggest that autistic individuals may not fully grasp all the information conveyed by hand movements that naturally accompany speech in conversation and narration. Consequently, they may miss crucial elements of the intended message, potentially leading to challenges in understanding communicative partners who use gestures alongside speech. The findings go beyond previous work reporting challenges in gesture comprehension of *iconic* and *conventional* gestures in autistic children (Perrault et al., 2019; Stieglitz Ham et al., 2011): In the present study, we observed subtle challenges that seem to arise with gestures being embedded in a richer linguistic context. The (relatively) greater difficulty in integrating multiple sources of information (i.e., here speech and gesture) relative to neurotypical peers aligns with previous research using multimodal audiovisual tasks (Mongillo et al., 2008; Silverman et al., 2010). It is important to acknowledge, however, that all participants, including those with ASD, demonstrated good performance, performing above chance levels already at a younger age. While the group difference was statistically significant, it remained relatively small and may only indicate subtle repercussions in daily living. Moving beyond a deficit-based view of autism (Mottron, 2017), these results can be interpreted as evidence that autistic and neurotypical children, when carefully matched on key variables, perform similarly well in integrating gesture following speech.

As expected, age was identified as a positive predictor of performance in both groups, with older participants recognizing more gestures than younger ones and performing at ceiling. This pattern suggests a gradual maturation of the ability to process gestures over

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time (Capone & McGregor, 2004; Perrault et al., 2019). The size of the age-related improvement in gesture recognition appeared similar between autistic and neurotypical children, although a higher variability in the autistic group was visible. Future studies may examine in more depth developmental aspects in the comprehension of different gesture types in both children with ASD and TD children, for instance with the help of GAMs.

The second goal of this study was to identify the factors that may explain the difference between the groups in the current task. Interestingly, better performance could not solely be attributed to a better comprehension of the verbal story in which gestures were embedded. Indeed, the sole reliance on the verbal information (i.e., the sentential part of the stimulus) was insufficient to select the correct picture, as parsing the visual gestural information was necessary to disambiguate between the correct response and the so-called semantic distractor. Similarly, parsing only the gestural part of the stimulus would have led to confusion between the correct answer and the gestural distractor, potentially leading to a greater proportion of gestural distractors. Further examination of the error patterns revealed no striking differences between autistic and neurotypical children, except for items with *iconic gestures*: When they produced an error in iconic items, children with ASD selected the *semantic* distractor significantly more often than TD children. This behaviour suggests that autistic children accurately parsed the verbal information provided in the stimulus and likely relied on this information more heavily (than on the gesture) when confronted with these items. In other terms, these findings could also suggest a lower reliance on the *gestural* part of the stimulus: This would align with previous work examining the *production* of gesture–speech combinations in school-aged children, which reported lower reliance on gestures by autistic children than their neurotypical peers to add information to their speech (Baumann et al., 2019). Instead, the children with autism in that study relied more strongly on speech than on gestures. More effortful processing of gestures with high communicative load such as pointing, as compared to cues with lower communicative value (like grasping), has also been reported (Aldaqre et al., 2016). In addition, previous research also suggests impaired perception of biological motion in autistic children (Blake et al., 2003), with a preference towards non-social cues over social stimuli (Chevallier et al., 2012). According to the *social motivation theory*, the challenges autistic individuals experience in social cognition, including the detection, interpretation, and use of non-verbal cues such as gestures in the social context (C. D. Frith, 2008), may stem from reduced social motivation (Chevallier et al., 2012; Parish-Morris et al., 2021). This reduced social motivation reflects a diminished tendency to orient towards social cues, seek social interactions, and experience reward from social engagement and bonding maintenance. This possibility was ruled out in our task, as we ensured sufficient attention towards gestural stimuli by proposing a pre-assessment task: Only the participants who performed above chance level to this task were included in the study. Therefore, it is unlikely that group differences were driven by salient reduced attention to the gestures.

Pertaining to potential linguistic factors, morphosyntactic skills did not significantly impact the performance. This is arguably due to the intentionally limited morphosyntactic difficulty of the stimuli's verbal component, restricted to simple clauses with verbs in the present tense only. This reduced linguistic complexity was proposed to avoid penalizing children with language impairment, often represented in ASD (Rapin & Dunn, 2003).

Vocabulary knowledge, in contrast, significantly predicted gesture comprehension, in both children with ASD and TD children. This finding emphasizes the close link between speech and gesture, an intertwinement that has intrigued researchers for decades (e.g., Goldin-Meadow & Alibali, 2013; Kita, 2000; Kita & Emmorey, 2023). It furthermore supports the claim of a probable bidirectional, mutual influence of gesture and language developments: Not only gesture (use) predicts later vocabulary size (e.g., Rowe & Goldin-Meadow, 2009), but vocabulary may in turn predict gesture production, as evidenced notably for word comprehension and gestures in children with high and low risk of ASD (Roemer et al., 2019). The present study aligns with this view and provides, for the first time, empirical evidence of a predictive role of vocabulary on gesture comprehension.

Mediation analysis enabled us to decipher the extent to which vocabulary knowledge mediated the group difference in performance and determine whether the effect of the group difference on gesture comprehension was a direct effect. Analyses showed that vocabulary knowledge significantly mediated the performance difference between autistic and neurotypical children, with about 18% of the total effect being mediated by vocabulary. While this contribution was pivotal, most of the effect (approximately 82% on average across groups) was therefore not explained by vocabulary alone. This indicates that other factors, or their combination, may have contributed to the difference in gesture comprehension between autistic and neurotypical children in this task.

Finally, the (small) gap in performance between groups might not stem from difficulties in recalling and holding both types of input (i.e., language and gesture) to further combine them to answer correctly. Indeed, neither group differed on average in their WM span, nor did this factor have a predictive impact on performance. Yet, challenges in integrating information from multiple sensory modalities, such as verbal descriptions and gestures, have been reported in autistic children and adolescents (Hubbard et al., 2012; Silverman et al., 2010). These studies presented speech and gestures simultaneously, which may have contributed to the difficulties observed. In our task, while the combination of both modalities was necessary to succeed, speech and gestures were processed sequentially. This sequential presentation may have alleviated the challenges associated with simultaneous multisensory integration: Such difficulties are frequently reported in autistic individuals and have been shown to contribute to sensory overload and processing challenges (Iarocci & McDonald, 2006). Thus, the difference in the mode of presentation may explain the relatively spared performance of the autistic participants in our task. While further research should allow confirmation of this possibility, this finding highlights the potential of sequentially presenting information, such as verbal input followed by gestures, as a means to reduce sensory overload. This approach aligns with outcomes from *sensory integration* therapy (Ayres, 2005), where structured and gradual exposure to sensory stimuli has been recognized as enhancing sensory processing and adaptive responses in autistic children (Camino-Alarcón et al., 2024; Schoen et al., 2019). Such interventions in occupational therapy are effective in improving sensory integration, communication, and functional outcomes in autistic children (see Camino-Alarcón et al., 2024 for a review).

These results may also inform augmentative and alternative communication interventions, such as *key-word signing* (KWS), which combines speech with simultaneous manual signs to emphasize key elements of the discourse. KWS has been shown to improve both language comprehension and production in autistic individuals (Tan et al., 2014). However, as underscored by Tan et al. (2014), KWS relies on sustained visual attention to the interlocutor's signs, and reduced attentional focus may impact its effectiveness. Individuals also show variability in their preferences for the modalities in which information is conveyed, depending on a range of factors such as the communicative situation and partners (Iacono et al., 2013; Wendt, 2009). Therefore, some

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flexibility in the presentation of speech with gestures is required to tailor interventions to each child's needs, thereby improving functional outcomes.

Two limitations pertaining to the representativeness of the sample might hinder the generalizability of the findings: First, our sample constitutes a WEIRD sample (i.e., Western, Educated, Industrialized, Rich, and Democratic; Henrich et al., 2010), with the majority of the participants stemming from higher socioeconomic backgrounds. Second, only participants who completed the whole battery of tests were included in the study, potentially excluding children with greater attentional or behavioural difficulties or with higher severity of autism symptoms, a variable that was not monitored in this study. Still, as previous work has reported a negative correlation between autism severity and gesture production (Mastrogiuseppe et al., 2015), a greater difference in gesture comprehension between our groups could be hypothesized if children with high severity scores were included.

Future work might investigate whether the understanding of co-speech gestures is differently impacted by the linguistic environment of autistic children. Indeed, existing work has shown that multilingual neurotypical children present an *increased sensitivity* to communication situations and can better interpret non-verbal elements such as pointing gestures (Yow & Markman, 2011) in comparison to monolingual peers. In the present work, a post-hoc examination revealed no significant impact of multilingual status (i.e., being monolingual or multilingual) on performance. However, multilingualism is a complex and multifactorial phenomenon which groups comparisons based on arbitrary criteria are unlikely to fully capture (de Bruin, 2019; De Houwer, 2023). Therefore, additional investigations are warranted to examine which aspect of the multilingual experience may impact gesture comprehension. Determining whether the multilingual effects observed in neurotypical children hold in the autistic population would help to inform cognitive and communicative processes and, crucially, help to build evidence-based recommendations that are currently lacking (Beauchamp & MacLeod, 2017).

6. Conclusion

The present study provides novel insights into the comprehension abilities of autistic and neurotypical children, particularly in their capacity to understand communicative gestures embedded in a narrative. Precisely, it revealed subtle group differences favouring neurotypical children in their ability to combine speech and gesture into a unified representation which was necessary for task success. Interestingly, this difference could not be attributable to lower linguistic or WM skills. While statistically significant, the difference between groups was small, and children with ASD displayed overall good performance. This relatively spared performance in gesture comprehension may be attributed to the sequential presentation of speech followed by gestures, which likely alleviated sensory processing demands compared with simultaneous multimodal input. These findings have valuable implications for therapeutic and intervention programmes, highlighting the potential of structured, sequential presentation of multimodal cues to enhance comprehension and reduce sensory challenges in autistic children, thereby supporting effective communication strategies.

Supplementary material. The supplementary material for this article can be found at http://doi.org/10.1017/S0305000925000157.

Data availability statement. Data, code to reproduce the analyses, and stimuli video examples are available under: https://osf.io/vp764/

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Authors contribution. PW: conceptualization, methodology, formal analysis, investigation, resources, data curation, supervision, visualization, and writing of the original draft. FB: methodology, investigation, resources, supervision, writing, review, and editing. DC: supervision, writing, review, and editing. ND: conceptualization, writing, review, and editing. ES: formal analysis, writing, review, and editing. SD: conceptualization, methodology, resources, supervision, writing, review, editing, project administration, and funding acquisition. All authors reviewed and approved the manuscript for publication.

References

Adornetti, I., **Ferretti, F.**, **Chiera, A.**, **Wacewicz, S.**, **Żywiczyński, P.**, **Deriu, V.**, **Marini, A.**, **Magni, R.**, **Casula, L.**, **Vicari, S.**, & **Valeri, G**. (2019). Do children with autism spectrum disorders understand pantomimic events? *Frontiers in Psychology*, **10**, 1382. https://doi.org/10.3389/fpsyg.2019.01382

Aldaqre, I., **Schuwerk, T.**, **Daum, M. M.**, **Sodian, B.**, & **Paulus, M**. (2016). Sensitivity to communicative and non-communicative gestures in adolescents and adults with autism spectrum disorder: Saccadic and pupillary responses. *Experimental Brain Research*, **234**(9), 2515–2527. https://doi.org/10.1007/s00221-016-4656-y

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). American Psychiatric Association. https://doi.org/10.1176/appi.books.9780890425596

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child Neuropsychology: A Journal on Normal and Abnormal Development in Childhood and Adolescence*, **8**(2), 71–82. https://doi.org/10.1076/chin.8.2.71.8724

Ayres, A. J. (2005). *Sensory integration and the child: Understanding hidden sensory challenges*. Western Psychological Services.

Baron-Cohen, S. (1989). The autistic child's theory of mind: A case of specific developmental delay. *Journal of Child Psychology and Psychiatry*, **30**(2), 285–297. https://doi.org/10.1111/j.1469-7610.1989.tb00241.x

Barr, D. J., **Levy, R.**, **Scheepers, C.**, & **Tily, H. J**. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, **68**(3), 255–278. https://doi.org/10.1016/j.jml.2012.11.001

Bates, D., **Mächler, M.**, **Bolker, B.**, & **Walker, S**. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, **67**(1). 1–48. https://doi.org/10.18637/jss.v067.i01

Bates, E. (1976). *Language and context: The acquisition of pragmatics*. Academic Press.

Baumann, S. D., **Özçalışkan, Ş.**, & **Adamson, L. B**. (2019). Does autism affect gesturing during parent-child interactions in the early school years? *Research in Autism Spectrum Disorders*, **67**, 101440. https://doi.org/10.1016/j.rasd.2019.101440

Beatini, V., **Cohen, D.**, **Di Tore, S.**, **Pellerin, H.**, **Aiello, P.**, **Sibilio, M.**, & **Berthoz, A**. (2024). Measuring perspective taking with the "Virtual Class" videogame: A child development study. *Computers in Human Behavior*, **151**, 108012. https://doi.org/10.1016/j.chb.2023.108012

Beauchamp, M. L. H., & **MacLeod, A. A. N**. (2017). Bilingualism in children with Autism Spectrum Disorder: Making evidence based recommendations. *Canadian Psychology*, **58**(3), 250–262. https://doi.org/10.1037/cap0000122

Berch, D. B., **Krikorian, R.**, & **Huha, E. M.** (1998). The Corsi Block-Tapping Task: Methodological and theoretical considerations. *Brain and Cognition*, **38**(3), 317–338. https://doi.org/10.1006/brcg.1998.1039

Bishop, D. V. (2003). *Test for reception of grammar, Version 2*. London: Pearson Assessment. Addison-Wesley Professional.

Blake, R., **Turner, L. M.**, **Smoski, M. J.**, **Pozdol, S. L.**, & **Stone, W. L.** (2003). Visual recognition of biological motion is impaired in children with autism. *Psychological Science*, **14**(2), 151–157. https://doi.org/10.1111/1467-9280.01434

Botting, N., **Riches, N.**, **Gaynor, M.**, & **Morgan, G.** (2010). Gesture production and comprehension in children with specific language impairment. *British Journal of Developmental Psychology*, **28**(1), 51–69. https://doi.org/10.1348/026151009X482642

Brinck, I. (2004). The pragmatics of imperative and declarative pointing. *Cognitive Science Quarterly*, **3**(4), 429–446.

Brookes, H. (2014). 115. Gesture and taboo: A cross-cultural perspective. In C. Müller, A. Cienki, E. Fricke, S. Ladewig, D. McNeill, & J. Bressem (Eds.), *Body – language – communication* (Vol. **2**, pp. 1523–1530). De Gruyter Mouton. https://doi.org/10.1515/9783110302028.1523

Brosnan, M., **Lewton, M.**, & **Ashwin, C.** (2016). Reasoning on the autism spectrum: A dual process theory account. *Journal of Autism and Developmental Disorders*, **46**(6), 2115–2125. https://doi.org/10.1007/s10803-016-2742-4

Camaioni, L., **Perucchini, P.**, **Bellagamba, F.**, & **Colonnesi, C.** (2004). The role of declarative pointing in developing a theory of mind. *Infancy*, **5**(3), 291–308. https://doi.org/10.1207/s15327078in0503_3

Camino-Alarcón, J., **Robles-Bello, M. A.**, **Valencia-Naranjo, N.**, & **Sarhani-Robles, A.** (2024). A systematic review of treatment for children with autism spectrum disorder: The sensory processing and sensory integration approach. *Children*, **11**(10), 10. https://doi.org/10.3390/children11101222

Capone, N. C., & **McGregor, K. K.** (2004). Gesture development: A review for clinical and research practices. *Journal of Speech, Language, and Hearing Research*, **47**(1), 173–186. https://doi.org/10.1044/1092-4388(2004/015)

Chevallier, C., **Kohls, G.**, **Troiani, V.**, **Brodkin, E. S.**, & **Schultz, R. T.** (2012). The social motivation theory of autism. *Trends in Cognitive Sciences*, **16**(4), 231–239. https://doi.org/10.1016/j.tics.2012.02.007

Choi, B., & **Rowe, M. L.** (2024). The role of gesture in language development for neurotypical children and children with or at increased likelihood of autism. *Topics in Cognitive Science*, **16**(1), 1–18 https://doi.org/10.1111/tops.12723

Clough, S., & **Duff, M. C.** (2020). The role of gesture in communication and cognition: Implications for understanding and treating neurogenic communication disorders. *Frontiers in Human Neuroscience*, **14**, 323. https://doi.org/10.3389/fnhum.2020.00323

Colonnesi, C., **Stams, G. J. J. M.**, **Koster, I.**, & **Noom, M. J.** (2010). The relation between pointing and language development: A meta-analysis. *Developmental Review*, **30**(4), 352–366. https://doi.org/10.1016/j.dr.2010.10.001

Cook, S. W., **Mitchell, Z.**, & **Goldin-Meadow, S.** (2008). Gesturing makes learning last. *Cognition*, **106**(2), 1047–1058. https://doi.org/10.1016/j.cognition.2007.04.010

Dargue, N., **Sweller, N.**, & **Jones, M. P.** (2019). When our hands help us understand: A meta-analysis into the effects of gesture on comprehension. *Psychological Bulletin*, **145**(8), 765–784. https://doi.org/10.1037/bul0000202

Dawson, G. (2008). Early behavioral intervention, brain plasticity, and the prevention of autism spectrum disorder. *Development and Psychopathology*, **20**(3), 775–803. https://doi.org/10.1017/S0954579408000370

de Bruin, A. (2019). Not all bilinguals are the same: A call for more detailed assessments and descriptions of bilingual experiences. *Behavioral Sciences*, **9**(3), 33. https://doi.org/10.3390/bs9030033

De Cat, C., **Kašćelan, D.**, **Prevost, P.**, **Serratrice, L.**, **Tuller, L.**, & **Unsworth, S.** (2022). *Quantifying bilingual experience (Q-BEx): Questionnaire manual and documentation*. https://doi.org/10.17605/OSF.IO/V7EC8

De Houwer, A. (2023). The danger of bilingual–monolingual comparisons in applied psycholinguistic research. *Applied Psycholinguistics*, **44**(3), 343–357. https://doi.org/10.1017/S014271642200042X

Dimitrova, N., **Özçalışkan, Ş.**, & **Adamson, L. B.** (2017). Do verbal children with autism comprehend gesture as readily as typically developing children? *Journal of Autism and Developmental Disorders*, **47**(10), 3267–3280. https://doi.org/10.1007/s10803-017-3243-9

Dunn, L. M., & **Dunn, D. M.** (2007). *PPVT-4: Peabody picture vocabulary test*. Pearson Assessments.

Dunn, L. M., **Dunn, L. M.**, & **Dunn, L. M.Thériault-Whalen, C. M**. (1993). *Echelle de vocabulaire en images* Peabody: EVIP. PSYCAN.

Ekman, P., & **Friesen, W. V**. (1969). The repertoire of nonverbal behavior: Categories, origins, usage, and coding. *Semiotica*, **1**(1), 49–98. https://doi.org/10.1515/semi.1969.1.1.49

Estes, A., **Munson, J.**, **Rogers, S. J.**, **Greenson, J.**, **Winter, J.**, & **Dawson, G**. (2015). Long-term outcomes of early intervention in 6-year-old children with Autism Spectrum Disorder. *Journal of the American Academy of Child and Adolescent Psychiatry*, **54**(7), 580–587. https://doi.org/10.1016/j.jaac.2015.04.005

Fenson, L., **Marchman, V. A.**, **Thal, D. J.**, **Dale, P. S.**, **Reznick, J. S.**, & **Bates, E**. (2007). *MacArthur-Bates communicative development inventories* (2nd ed.). Towson, MD: Brookes Publishing Co. https://doi.org/10.1037/t11538-000

Fox-Boyer, A. V. (2006). *TROG-D: Test zur Überprüfung des Grammatikverständnisses*. Schulz-Kirchner Verlag GmbH.

Frith, C. D. (2008). Social cognition. *Philosophical Transactions of the Royal Society B: Biological Sciences*, **363**(1499), 2033–2039. https://doi.org/10.1098/rstb.2008.0005

Frith, U. (2003). *Autism: Explaining the enigma* (2nd ed., pp. ix, 249). Blackwell Publishing.

Goldin-Meadow, S. (1999). The role of gesture in communication and thinking. *Trends in Cognitive Sciences*, **3**(11), 419–429. https://doi.org/10.1016/S1364-6613(99)01397-2

Goldin-Meadow, S. (2003). *Hearing gesture: How our hands help us think*. Harvard University Press. https://doi.org/10.2307/j.ctv1w9m9ds

Goldin-Meadow, S. (2004). Gesture's role in the learning process. *Theory Into Practice*, **43**(4), 314–321.

Goldin-Meadow, S. (2011). Learning through gesture. *WIREs Cognitive Science*, **2**(6), 595–607. https://doi.org/10.1002/wcs.132

Goldin-Meadow, S. (2014). How gesture works to change our minds. *Trends in Neuroscience and Education*, **3**(1), 4–6. https://doi.org/10.1016/j.tine.2014.01.002

Goldin-Meadow, S. (2015). Gesture as a window onto communicative abilities: Implications for diagnosis and intervention. *Perspectives on Language Learning and Education*, **22**(2), 50–60. https://doi.org/10.1044/lle22.2.50

Goldin-Meadow, S., & **Alibali, M. W**. (2013). Gesture's role in speaking, learning, and creating language. *Annual Review of Psychology*, **64**(1), 257–283. https://doi.org/10.1146/annurev-psych-113011-143802

Goldin-Meadow, S., & **Butcher, C.** (2003). Pointing toward two-word speech in young children. In S. Kita (Ed.), *Pointing: Where language, culture, and cognition meet* (pp. 85–107). Lawrence Erlbaum Associates Publishers.

Grosjean, F. (2010). *Bilingual: Life and reality*. Harvard University Press. https://www.jstor.org/stable/j.ctt13x0ft8

Hamilton, A. F. de C., **Brindley, R. M.**, & **Frith, U**. (2007). Imitation and action understanding in autistic spectrum disorders: How valid is the hypothesis of a deficit in the mirror neuron system? *Neuropsychologia*, **45**(8), 1859–1868. https://doi.org/10.1016/j.neuropsychologia.2006.11.022

Hantman, R. M., **Choi, B.**, **Hartwick, K.**, **Nadler, Z.**, & **Luk, G**. (2023). A systematic review of bilingual experiences, labels, and descriptions in autism spectrum disorder research. *Frontiers in Psychology*, **14**, 1095164. https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1095164

Hauser, R. M., & **Warren, J. R**. (1997). Socioeconomic indexes for occupations: A review, update, and critique. *Sociological Methodology*, **27**(1), 177–298. https://doi.org/10.1111/1467-9531.271028

Henrich, J., **Heine, S. J.**, & **Norenzayan, A**. (2010). The weirdest people in the world? *Behavioral and Brain Sciences*, **33**(2–3), 61–83. https://doi.org/10.1017/S0140525X0999152X

Huang, Y., **Wong, M. K.-Y.**, **Lam, W.-Y.**, **Cheng, C.-H.**, & **So, W.-C**. (2020). Gestures in storytelling by preschool chinese-speaking children with and without autism. *Frontiers in Psychology*, **11**, 573212. https://doi.org/10.3389/fpsyg.2020.573212

Hubbard, A. L., **McNealy, K.**, **Scott-Van Zeeland, A. A.**, **Callan, D. E.**, **Bookheimer, S. Y.**, & **Dapretto, M**. (2012). Altered integration of speech and gesture in children with autism spectrum disorders. *Brain and Behavior*, **2**(5), 606–619. https://doi.org/10.1002/brb3.81

Hughes, C., & **Devine, R. T**. (2015). Individual differences in theory of mind from preschool to adolescence: Achievements and directions. *Child Development Perspectives*, **9**(3), 149–153. https://doi.org/10.1111/cdep.12124

Iacono, T., **Lyon, K.**, **Johnson, H.**, & **West, D**. (2013). Experiences of adults with complex communication needs receiving and using low tech AAC: An Australian context. *Disability and Rehabilitation: Assistive Technology*, **8**(5), 392–401. https://doi.org/10.3109/17483107.2013.769122

Iarocci, G., & **McDonald, J**. (2006). Sensory integration and the perceptual experience of persons with autism. *Journal of Autism and Developmental Disorders*, **36**(1), 77–90. https://doi.org/10.1007/s10803-005-0044-3

Iverson, J. M., & **Goldin-Meadow, S**. (2005). Gesture paves the way for language development. *Psychological Science*, **16**(5), 367–371. https://doi.org/10.1111/j.0956-7976.2005.01542.x

Kelly, S. D., & **Church, R. B**. (1998). A comparison between children's and adults' ability to detect conceptual information conveyed through representational gestures. *Child Development*, **69**(1), 85–93. https://doi.org/10.2307/1132072

Kelly, S. D., **Özyürek, A.**, & **Maris, E**. (2010). Two sides of the same coin: Speech and gesture mutually interact to enhance comprehension. *Psychological Science*, **21**(2), 260–267. https://doi.org/10.1177/0956797609357327

Kendon, A. (1988). How gestures can become like words. In *Cross-cultural perspectives in nonverbal communication* (pp. 131–141). Hogrefe & Huber Publishers.

Kendon, A. (2000). Language and gesture: Unity or duality. Language and gesture, 2, 47–63. https://doi.org/10.1017/cbo9780511620850.004

Kenny, L., **Hattersley, C.**, **Molins, B.**, **Buckley, C.**, **Povey, C.**, & **Pellicano, E**. (2016). Which terms should be used to describe autism? Perspectives from the UK autism community. *Autism*, **20**(4), 442–462. https://doi.org/10.1177/1362361315588200

Kern, S., **Langue, J.**, **Zesiger, P.**, & **Bovet, F**. (2010). Adaptations françaises des versions courtes des inventaires du développement communicatif de MacArthur-Bates. *Approche Neuropsychologique des Apprentissages chez l'Enfant*, **107**(108), 217–228.

Kilili-Lesta, M., **Voniati, L.**, & **Giannakou, K**. (2022). Early gesture as a predictor of later language outcome for young children with Autism Spectrum Disorder (ASD): A systematic literature review. *Current Developmental Disorders Reports.*, **9**(4), 110–126. https://doi.org/10.1007/s40474-022-00250-8

Kita, S. (2000). How representational gestures help speaking. *Language and Gesture*, **1**, 162–185.

Kita, S., **Emmorey, K.** (2023). Gesture lin ks language and cognition for spoken and signed languages. *Nat Rev Psychol* **2**, 407–420. https://doi.org/10.1038/s44159-023-00186-9.

Kita, S., & **Özyürek, A**. (2003). What does cross-linguistic variation in semantic coordination of speech and gesture reveal?: Evidence for an interface representation of spatial thinking and speaking. *Journal of Memory and Language*, **48**(1), 16–32. https://doi.org/10.1016/S0749-596X(02)00505-3

Kita, S., **Van Gijn, I.**, & **Van Der Hulst, H**. (1998). Movement phases in signs and co-speech gestures, and their transcription by human coders. In I. Wachsmuth & M. Fröhlich (Eds.), *Gesture and sign language in human-computer interaction* (Vol. **1371**, pp. 23–35). Berlin Heidelberg: Springer. https://doi.org/10.1007/BFb0052986

Klin, A., **Lin, D. J.**, **Gorrindo, P.**, **Ramsay, G.**, & **Jones, W**. (2009). Two-year-olds with autism orient to nonsocial contingencies rather than biological motion. *Nature*, **459**(7244), 257–261. https://doi.org/10.1038/nature07868

Krauss, R. M., **Chen, Y.**, & **Gottesman, R. F**. (2001). Lexical gestures and lexical access: A process model. In D. McNeill (Ed.), *Language and gesture* (1st ed., pp. 261–283). Cambridge University Press. https://doi.org/10.1017/CBO9780511620850.017

Lecocq, P. (1996). *L'É.CO.S.SE: Une épreuve de compréhension syntaxico-sémantique*. Presses universitaires du Septentrion.

Lenhard, A., **Lenhard, W.**, **Segerer, R.**, & **Suggate, S**. (2015). *Peabody picture vocabulary test-4. Deutsche Fassung*. Pearson Assessment.

Lord, C., **Rutter, M.**, **DiLavore, P. C.**, **Risi, S.**, **Gotham, K.**, & **Bishop, S**. (2012). *Autism diagnostic observation schedule* (2nd ed.). Western Psychological Services.

Lord, C., **Rutter, M.**, & **Le Couteur, A**. (1994). Autism diagnostic interview-revised: A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *Journal of Autism and Developmental Disorders*, **24**(5), 659–685. https://doi.org/10.1007/BF02172145

Manwaring, S. S., **Stevens, A. L.**, **Mowdood, A.**, & **Lackey, M**. (2018). A scoping review of deictic gesture use in toddlers with or at-risk for autism spectrum disorder. *Autism & Developmental Language Impairments*, **3**, 2396941517751891. https://doi.org/10.1177/2396941517751891

Mastrogiuseppe, M., **Capirci, O.**, **Cuva, S.**, & **Venuti, P**. (2015). Gestural communication in children with autism spectrum disorders during mother–child interaction. *Autism*, **19**(4), 469–481. https://doi.org/10.1177/1362361314528390

McNeill, D. (1992). *Hand and mind: What gestures reveal about thought*. University of Chicago Press.

Meissner, M., & **Philpott, S. B**. (1975). The sign language of Sawmill workers in British Colombia. *Sign Language Studies*, **9**, 9. https://ida.gallaudet.edu/sls/9

Mishra, A., **Ceballos, V.**, **Himmelwright, K.**, **McCabe, S.**, & **Scott, L**. (2021). Gesture production in toddlers with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, **51**(5), 1658–1667. https://doi.org/10.1007/s10803-020-04647-5

Mongillo, E. A., **Irwin, J. R.**, **Whalen, D. H.**, **Klaiman, C.**, **Carter, A. S.**, & **Schultz, R. T**. (2008). Audiovisual processing in children with and without autism spectrum disorders. *Journal of Autism and Developmental Disorders*, **38**(7), 1349–1358. https://doi.org/10.1007/s10803-007-0521-y

Morales, J., **Calvo, A.**, & **Bialystok, E**. (2013). Working memory development in monolingual and bilingual children. *Journal of Experimental Child Psychology*, **114**(2), 187–202. https://doi.org/10.1016/j.jecp.2012.09.002

Mottron, L. (2017). Should we change targets and methods of early intervention in autism, in favor of a strengths-based education? *European Child & Adolescent Psychiatry*, **26**(7), 815–825. https://doi.org/10.1007/s00787-017-0955-5

Özçalışkan, Ş., & **Goldin-Meadow, S**. (2005). Gesture is at the cutting edge of early language development. *Cognition*, **96**(3), B101–B113. https://doi.org/10.1016/j.cognition.2005.01.001

Parish-Morris, J., **Schultz, R. T.**, & **Herrington, J. D**. (2021). Towards the integration of social cognition and social motivation in autism spectrum disorder. In *The neural basis of mentalizing* (pp. 67–83). Springer Nature Switzerland AG. https://doi.org/10.1007/978-3-030-51890-5_4

Perrault, A., **Chaby, L.**, **Bigouret, F.**, **Oppetit, A.**, **Cohen, D.**, **Plaza, M.**, & **Xavier, J**. (2019). Comprehension of conventional gestures in typical children, children with autism spectrum disorders and children with language disorders. *Neuropsychiatrie de l'Enfance et de l'Adolescence*, **67**(1), 1–9. https://doi.org/10.1016/j.neurenf.2018.03.002

Premack, D., & **Woodruff, G**. (1978). Does the chimpanzee have a theory of mind? *Behavioral and Brain Sciences*, **1**(4), 515–526. https://doi.org/10.1017/S0140525X00076512

Ramos-Cabo, S., **Vulchanov, V.**, & **Vulchanova, M**. (2019). Gesture and language trajectories in early development: An overview from the autism spectrum disorder perspective. *Frontiers in Psychology*, **10**, 1211. https://doi.org/10.3389/fpsyg.2019.01211

Rapin, I., & **Dunn, M**. (2003). Update on the language disorders of individuals on the autistic spectrum. *Brain & Development*, **25**(3), 166–172. https://doi.org/10.1016/s0387-7604(02)00191-2

Raven, J. C., **Rust, J.**, **Chan, F.**, & **Zhou, X**. (2018). *Raven's progressive matrices 2, clinical edition*. Pearson.

Rinaldi, P., **Pasqualetti, P.**, **Stefanini, S.**, **Bello, A.**, & **Caselli, M. C.** (2019). The Italian Words and Sentences MB-CDI: Normative data and concordance between complete and short forms. *Journal of Child Language*, **46**(3), 546–566. https://doi.org/10.1017/S0305000919000011

Rindermann, H., & **Ceci, S. J**. (2018). Parents' education is more important than their wealth in shaping their children's intelligence: Results of 19 samples in seven countries at different developmental levels. *Journal for the Education of the Gifted*, **41**(4), 298–326. https://doi.org/10.1177/0162353218799481

Roemer, E. J., **West, K. L.**, **Northrup, J. B.**, & **Iverson, J. M**. (2019). Word comprehension mediates the link between gesture and word production: Examining language development in infant siblings of children with autism spectrum disorder. *Developmental Science*, **22**(3), e12767. https://doi.org/10.1111/desc.12767

Rowe, M. L., & **Goldin-Meadow, S**. (2009). Early gesture selectively predicts later language learning. *Developmental Science*, **12**(1), 182–187. https://doi.org/10.1111/j.1467-7687.2008.00764.x

Rowe, M. L., **Özçalişkan, Ş.**, & **Goldin-Meadow, S**. (2008). Learning words by hand: Gesture's role in predicting vocabulary development. *First Language*, **28**(2), 182–199. https://doi.org/10.1177/0142723707088310

Schaeffer, J., **Abd El-Raziq, M.**, **Castroviejo, E.**, **Durrleman, S.**, **Ferré, S.**, **Grama, I.**, **Hendriks, P.**, **Kissine, M.**, **Manenti, M.**, **Marinis, T.**, **Meir, N.**, **Novogrodsky, R.**, **Perovic, A.**, **Panzeri, F.**, **Silleresi, S.**, **Sukenik, N.**, **Vicente, A.**, **Zebib, R.**, **Prévost, P.**, & **Tuller, L**. (2023). Language in autism: Domains, profiles and co-occurring conditions. *Journal of Neural Transmission*. https://doi.org/10.1007/s00702-023-02592-y

Schoen, S. A., **Lane, S. J.**, **Mailloux, Z.**, **May-Benson, T.**, **Parham, L. D.**, **Smith Roley, S.**, & **Schaaf, R. C**. (2019). A systematic review of ayres sensory integration intervention for children with autism. *Autism Research*, **12**(1), 6–19. https://doi.org/10.1002/aur.2046

Silleresi, S. (2023). *Developmental profiles in autism spectrum disorder*. John Benjamins Publishing Company. https://doi.org/10.1075/lald.68

Silverman, L. B., **Bennetto, L.**, **Campana, E.**, & **Tanenhaus, M. K**. (2010). Speech-and-gesture integration in high functioning autism. *Cognition*, **115**(3), 380–393. https://doi.org/10.1016/j.cognition.2010.01.002

So, W.-C., **Wong, M. K.-Y.**, **Lam, C. K.-Y.**, **Lam, W.-Y.**, **Chui, A. T.-F.**, **Lee, T.-L.**, **Ng, H.-M.**, **Chan, C.-H.**, & **Fok, D. C.-W**. (2018). Using a social robot to teach gestural recognition and production in children with autism spectrum disorders. *Disability and Rehabilitation: Assistive Technology*, **13**(6), 527–539. https://doi.org/10.1080/17483107.2017.1344886

So, W.-C., **Wong, M. K.-Y.**, **Lui, M.**, & **Yip, V**. (2015). The development of co-speech gesture and its semantic integration with speech in 6- to 12-year-old children with autism spectrum disorders. *Autism*, **19**(8), 956–968. https://doi.org/10.1177/1362361314556783

Stein, N. L., & **Glenn, C. G.** (1979). An analysis of story comprehension in elementary school children: A test of a schema. In R. O. Freedle (Ed.), *New directions in discourse processing* (pp. 53–120). Ablex Publishing Company.

Stella, G., **Pizzoli, C.**, & **Tressoldi, P.** (2000). *Il Peabody Test–Test di vocabolario ricettivo*. Omega Edizione, Torino.

Stewart, J. R., **Vigil, D. C.**, **Olszewski, A.**, & **Thornock, C**. (2022). Gesture use in children with autism spectrum disorder: A scoping review. *Clinical Archives of Communication Disorders*, **7**(3), 94–104. https://doi.org/10.21849/cacd.2022.00675

Stieglitz Ham, H., **Bartolo, A.**, **Corley, M.**, **Rajendran, G.**, **Szabo, A.**, & **Swanson, S**. (2011). Exploring the relationship between gestural recognition and imitation: Avidence of dyspraxia in autism spectrum disorders. *Journal of Autism and Developmental Disorders*, **41**(1), 1–12. https://doi.org/10.1007/s10803-010-1011-1

Suraniti, S., **Neri, V.**, & **Ferri, R**. (2009). *TROG-2: Contributo alla validazione italiana*. Giunti O.S.

Szagun, G., **Schramm, S.**, & **Stumper, B**. (2009). *Fragebogen zur frühkindlichen Sprachentwicklung (FRAKIS) und FRAKIS-K (Kurzform).* Frankfurt: Pears on Assessment.

Tan, X. Y., **Trembath, D.**, **Bloomberg, K.**, **Iacono, T.**, & **Caithness, T**. (2014). Acquisition and generalization of key word signing by three children with autism. *Developmental Neurorehabilitation*, **17**(2), 125–136. https://doi.org/10.3109/17518423.2013.863236

Wendt, O. (2009). Research on the use of manual signs and graphic symbols in autism spectrum disorders: A systematic review. In P. Mirenda & T. Iacono (Eds.), *Autism spectrum disorders and AAC* (pp. 83–140). Baltimore, MD: Paul H. Brookes.

Wermelinger, S., **Gampe, A.**, **Helbling, N.**, & **Daum, M.** (2020). Do you understand what I want to tell you? Early sensitivity in bilinguals' iconic gesture perception and production. *Developmental Science*, **23**(5), e12943. https://doi.org/10.1111/desc.12943

Wetherby, A. M., & **Prutting, C. A**. (1984). Profiles of communicative and cognitive-social abilities in autistic children. *Journal of Speech, Language, and Hearing Research*, **27**(3), 364–377. https://doi.org/10.1044/jshr.2703.364

Yow, W. Q., & **Markman, E. M**. (2011). Young bilingual children's heightened sensitivity to referential cues. *Journal of Cognition and Development*, **12**(1), 12–31. https://doi.org/10.1080/15248372.2011.539524

Zwaigenbaum, L., **Bauman, M. L.**, **Stone, W. L.**, **Yirmiya, N.**, **Estes, A.**, **Hansen, R. L.**, **McPartland, J. C.**, **Natowicz, M. R.**, **Choueiri, R.**, **Fein, D.**, **Kasari, C.**, **Pierce, K.**, **Buie, T.**, **Carter, A.**, **Davis, P. A.**, **Granpeesheh, D.**, **Mailloux, Z.**, **Newschaffer, C.**, **Robins, D.**, … **Wetherby, A**. (2015). Early identification of autism spectrum disorder: Recommendations for practice and research. *Pediatrics*, **136**(Suppl 1), S10–S40. https://doi.org/10.1542/peds.2014-3667C

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