Journal of Experimental Child Psychology 210 (2021) 105205

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

Attention to intentional versus incidental pointing gestures in young autistic children: An eye-tracking study

Pauline Maes *, Fanny Stercq, Mikhail Kissine

ACTE (Autism in Context: Theory and Experiment) at LaDisco (Center for Linguistics Research) and ULB Neuroscience Institute, Université libre de Bruxelles, 1050 Brussels, Belgium

A R T I C L E I N F O

Article history:
Received 22 February 2021
Revised 17 May 2021
Available online 13 June 2021

Keywords:
Autism spectrum disorder
Minimally verbal
Intentional pointing
Incidental pointing
Response to joint attention
Eye tracking

A B S T R A C T

Whereas a reduced tendency to follow pointing gestures is described as an early sign of autism, the literature on response to joint attention indicates that autistic children perform better when a point is added to other social cues such as eye gaze. The purpose of this study was to explore pointing processing in autism when it is the only available cue and to investigate whether autistic children discriminate intentional pointing gestures from incidental pointing gestures. Eye movements of 58 autistic children (48 male) and 61 typically developing children (36 male) aged 3–5 years were recorded as the children were watching videos of a person uttering a pseudoword and pointing intentionally with one hand and incidentally with the other hand. After 3 s, two different potential referents for the pseudoword gradually emerged in both pointed-at corners. In comparison with typically developing children, autistic children's fixations were significantly farther away from both pointed-at zones. Upon hearing a novel word, typically developing children shifted their visual attention toward the zone pointed intentionally. This trend did not emerge in the group of autistic children regardless of their level of vocabulary. Autistic children, independently of their level of language, pay little attention to pointing when no other social cues are available and fail to discriminate intentional pointing gestures from incidental ones. They seem to grasp neither the spatial nor the social value of pointing.

* Corresponding author.
E-mail address: pauline.ad.maes@ulb.be (P. Maes).

https://doi.org/10.1016/j.jecp.2021.105205

Introduction

Autism spectrum disorder (ASD) is an early-onset neurodevelopmental condition that is characterized by impairments in social communication and interaction along with repetitive and restricted patterns of behaviors, activities and interests (American Psychiatric Association [APA], 2013). Early deficits in nonverbal communication, and more specifically in joint attention, constitute a key characteristic of ASD (Clifford & Dissanayake, 2008; Zwaigenbaum, Bryson, & Garon, 2013), which is also frequently linked to delayed and atypical language acquisition trajectories (Bottema-Beutel, 2016; Murray et al., 2008).

Joint attention can be said to take place when it is mutually manifest to two individuals that they focus their attention on the same object or event. Pointing gestures are probably among the most conspicuous social cues that may be used to bring about such a shared attention frame.

A pointing index finger often represents a complete communicative act (at least in Western societies); after being directed toward a nearby object or event and by reading the intentions behind the pointer's gesture, the recipient can infer the communicative value of said gesture (Tomasello, 2008). Difficulties in following someone else's pointing are listed as an early feature of autism in the *Diagnostic and Statistical Manual of Mental Disorders–Fifth Edition* (DSM-5; APA, 2013). A failure to understand that pointing is a bid for establishing joint attention can occur because the recipient fails to grasp the sociocommunicative value of the gesture. It could also be that the pointing finger is not even perceived as spatially salient by the recipient, whose attention will, as a result, not be oriented toward the pointed-at location. Current evidence is rather mixed as to the exact extent to which autistic children can understand pointing, mainly because most studies have used pointing gestures in combination with other social cues (Akechi, Kikuchi, Tojo, Osanai, & Hasegawa, 2013; Parish-Morris, Hennon, Hirsh-Pasek, Golinkoff, & Tager-Flusberg, 2007; Presmanes, Walden, Stone, & Yoder, 2007; Sullivan et al., 2007).

The most straightforward behavioral response to joint attention (RJA)—largely attested in typically developing (TD) toddlers (Carpenter, Nagell, Tomasello, Butterworth, & Moore, 1998)—consists in directing one's gaze toward the object or event that is being pointed at by the interactional partner; reaching for this object can also be counted as RJA. A variety of (combined) social cues has been used to elicit RJA from autistic children: eye gaze (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Presmanes et al., 2007; Sullivan et al., 2007; Yoder, Stone, Walden, & Malesa, 2009), vocal prompts (Presmanes et al., 2007; Yoder et al., 2009), head tilts (Yoder et al., 2009), and pointing gestures (Dawson et al., 1998; Presmanes et al., 2007; Sullivan et al., 2007; Yoder et al., 2009). Independent of the cues used, all these studies reported lower rates of RJA in autism. Interestingly, however, two studies found that RJA increased in toddlers with high likelihood of ASD when a pointing gesture was added as a social cue (Presmanes et al., 2007; Sullivan et al., 2007).

In toddlers with high likelihood of ASD, RJA scores are correlated with expressive and receptive vocabulary (Presmanes et al., 2007; Sullivan et al., 2007; Yoder, Watson, & Lambert, 2015). Joint attentional events bring about shared referential contexts, which are claimed by many to be determining for early lexical acquisition (Tomasello, 2008; Tomasello & Farrar, 1986). In this relation, it has been argued that the use and understanding of pointing gestures represent a precursor for language acquisition—or at least facilitate the acquisition of new words (Colonnesi, Stams, Koster, & Noom, 2010). A well-established result is that young TD children use social cues coming from their interlocutor to determine the reference of new words (Akhtar & Tomasello, 2000; Baldwin, 1993; Moore, Angelopoulos, & Bennett, 1999). Several studies reported that autistic children experience difficulties in using the speaker's gaze to select the correct object between two possible referents for a new word (Baron-Cohen, Baldwin, & Crowson, 1997; Preissler & Carey, 2005). However, autistic children's performance improves when gaze direction is used in combination with pointing gestures (Akechi et al., 2013) or when other perceptual cues (e.g., moving, light-up, or colorful object) also highlight the target object (Parish-Morris et al., 2007).

In sum, whereas a reduced tendency to respond to joint attention is a core characteristic of ASD, the presence of a pointing gesture seems to increase autistic children's performance. What remains unclear, however, is the extent to which autistic children genuinely process pointing. The pointing effects reported in the studies discussed above could be explained by the mere accumulation of several salient cues. Only one study has observed how autistic children perform when the only available cue is a pointing finger (Field, Lewis, & Allen, 2019), showing that these children were able to acquire new words after following a pointing finger without congruent gaze. Studies focusing on the processing of a pointing finger as the sole cue for RJA are needed to better delineate social gesture processing in ASD.

TD children as young as 14 months understand the communicative intentions of a pointing adult (Behne, Carpenter, & Tomasello, 2005). It could be that in autism pointing, like eye gaze (Ristic et al., 2005), is processed independently of its social and communicative value, that is, as a salient and abrupt change in space that can lead to a shift in attention. An interesting finding, in that respect, is that autistic children map novel words to objects after following an intentional pointing finger but also after following an incidental pointing gesture (Field et al., 2019). Incidental pointing in this study happened when the speaker pointed at the target with his protruding index finger while looking off into the distance in the opposite direction of the point. Eye gaze and pointing gesture thus provided contradictory cues, directing the children's attention toward opposite locations. Even though the eye gaze did not direct the children toward the competing referent, it still misled them and directed them away from the correct location, hence potentially competing with the pointing finger if the children privileged eye gaze direction. Note that Field and colleagues (2019) reported that 4-year-old TD children also mapped new labels on objects pointed at incidentally by the adult, which further indicates that such pointing gestures carry referential value even if they are incongruent with the gaze direction. Although these results suggest that autistic children may treat an incidental pointing gesture as a cue to respond to joint attention, more studies should implement a stricter definition of incidental pointing to explore autistic children's ability to differentiate intentional pointing gestures from incidental pointing gestures.

Field et al. (2019) study also shares a major limitation with many word-mapping studies in autism: The paradigm is quite sophisticated and requires a verbal response, so that participants are often verbal autistic children with relatively high adaptative functioning and nonverbal IQs. With the exception of two studies (Luyster & Lord, 2009; Parish-Morris et al., 2007), all the major studies on RJA in autism investigated autistic children over 5 and up to 12 years of age (Akechi et al., 2013; Baron-Cohen et al., 1997; Dawson et al., 1998; Field et al., 2019; Preissler & Carey, 2005). Given that joint attention is especially important during the early stages of language acquisition (Carpenter et al., 1998, Tomasello, 1999), more studies integrating younger and minimally verbal autistic children are clearly needed in order to gain better insight into pointing following and its relation to language in autism.

The current study

The current study aimed at investigating whether young verbal and nonverbal autistic children (a) are sensitive to pointing gestures in a word-learning situation when no other cues are available and (b) are able to discriminate intentional pointing from incidental pointing. Participants were presented with videos of actors simultaneously pointing, intentionally and incidentally, toward opposite corners of a table while repeating a pseudoword. Spontaneous visual observation of the scene should help to determine whether participants are more likely to follow an intentional or incidental pointing gesture. Our paradigm offered an ecological context for assessing pointing following as a cue for RJA in a word-mapping context without requiring any explicit verbal response from the participants. It is important to highlight that the focus of our study was to observe spontaneous attention to pointing and not lexical acquisition abilities.

Three predictions may be drawn from the foregoing. First, autistic children should differ from a TD control group in their spontaneous attention toward the zone pointed at intentionally. We hypothesized that the autistic children would allocate less attention at the zone pointed at intentionally than their TD peers. Second, they should also differ from the control group in their ability to discriminate intentional pointing from incidental pointing. Whereas TD children should show a preference for the zone pointed at intentionally, we hypothesized that autistic children would allocate a similar amount of attention to both pointed-at zones but less attention overall than TD children. Finally, autistic children with a lower expressive vocabulary should be less able to discriminate intentional pointing from incidental pointing than autistic children with broader expressive vocabulary. The proportion of attention allocated to the zone pointed at intentionally was expected to be lower in nonverbal or minimally verbal autistic children than in more verbal autistic children.

Method

Participants

A total of 67 autistic children aged 3–5 years were initially recruited for this study. These children were matched on chronological age with a control group of 61 TD children. Because the purpose of our study was to include both verbal and minimally verbal autistic children, we did not try to match autistic and TD children on verbal or nonverbal IQs.

Participants were recruited by using our lab internal database, using flyers and posts on social media, or contacting kindergartens (for the TD group) and special education preschools (for the autistic group) all over the French-speaking region of Belgium. Inclusion criteria for the TD children were being exposed to French at home or school, not having a known neurodevelopmental or psychiatric disorder, and having no intellectual delay. For the autistic children, inclusion criteria were being exposed to French at home or at school and having received an official diagnosis of ASD by a multidisciplinary team. Data from 9 autistic children were excluded either because the family moved to another country before completing the study ($n = 1$), because of data loss due to technical misfunction ($n = 3$), because the child was older than 5 years when entering the study ($n = 2$), or because the child did not display willingness to take part in the experiment ($n = 3$).

Our final sample comprised eye-tracking data for 58 children in the autistic group (48 male and 10 female) and 61 children in the TD group (36 male and 25 female). In the autistic group, verbal IQ scores are missing for 29 children and nonverbal IQ scores are missing for 15 children. All participants in the TD group scored in the typical range on verbal and nonverbal IQs and below cutoffs for autistic spectrum on the Autism Diagnostic Observation Schedule–Second Edition (ADOS-2) (Lord et al., 2000). Of the autistic children, 8 scored below cutoffs for autism on the ADOS-2 and 2 of them scored below cutoffs for autistic spectrum. In addition, ADOS-2 scores are missing for 1 autistic participant because the child failed to cooperate and was experiencing distress during assessment. All the group differences remained statistically significant when we excluded from the ASD group the 8 children who did not reach cutoffs for autism and the child who was not able to complete the ADOS-2. Because all these children received an official diagnosis of ASD, we decided not to exclude them from the study. Finally, two parents of children in the TD group and five parents of autistic children did not complete our ad hoc questionnaire. In total, 14 and 18 MacArthur–Bates Communicative Development Inventories (CDI) reports (Fenson, 1993) are missing in the autistic group at the time of the study (T1) and 1 year later (T2), respectively. Table 1 summarizes the participants in our final sample.

Eye-tracking task

We created 24 3-s stimuli that consisted of a video of 24 different adults (12 men and 12 women) sitting at a table and facing the camera. To increase the generalizability of reported results (see Yarkoni, 2020, for a recent plea) and minimize potential biases inherent to arbitrary video characteristics, we used a different adult for each stimulus rather than have a single one performing the pointing across trials.

Each video included three phases: attention-getter (1 s), pseudoword phase (3 s), and referent phase (3 s). Each stimulus video started with a 1-s fixation star in the middle of the screen accompanied by an attractive jingle to redirect participants' attention to the center of the screen. During the pseudoword phase, a video showed an adult uttering a pseudoword while pointing intentionally with the right or left hand toward the right or left corner of the table, respectively, and incidentally pointing with the other hand toward the other corner of the table. In contrast to traditional fast-mapping paradigms, no pointed referent was displayed on the screen during the utterance of the pseudoword. This

Table 1
Participants' descriptive statistics.

	ASD group		TD group		
	n[a]	Mean (*SD*); range	*n*	Mean (*SD*); range	*p*
Chronological age (months)	58	56.55 (9.95); 39–71	61	54.54 (9.82); 36–71	.269
ADOS-2 total score	57	18.26 (6.13); 4–28	61	1.41 (1.86); 0–7	<.001
ADOS-2 comparison score	57	6.84 (1.93); 2–10	61	1.18 (0.46); 1–3	<.001
Nonverbal IQ[b]	43	86.6 (17.12); 47–115	61	103.93 (9.7); 70–129	<.001
Verbal IQ[c]	29	77 (16.93); 56–130	61	103.3 (19.37); 70–149	<.001
Raw expressive vocabulary, T1[d]	44	165.2 (186.52); 0–577	–	–	–
Raw expressive vocabulary, T2[d]	40	217.37 (211.52); 0–623	–	–	–
Socioeconomic status	53	9.4 (2.55); 5.5–16.5	59	11.59 (3.15); 3.0–18	<.001

Note. ASD, autism spectrum disorder; TD, typically developing; ADOS-2, Autism Diagnostic Observation Schedule–Second Edition; T1, time of the study; T2, 1 year later.
[a] Due to a lack of data for some participants, sample size varied from one measure to another.
[b] Nonverbal IQ was measured by the Leiter International Performance Scale–Third Edition.
[c] Verbal IQ was measured by the Peabody Picture Vocabulary Test–Revised.
[d] Expressive vocabulary was measured by the MacArthur–Bates Communicative Development Inventories.

feature of our videos ensured that children could explore both gestures without their attention being drawn away from the pointed-at zone by arbitrary characteristics of these referents. During the referent phase, a snapshot of the last frame of the corresponding pseudoword utterance video was displayed for an additional 3 s. Two different drawings of imaginary animals (different drawings in each trial) gradually emerged from a cloud of smoke in the two corners of the frame (i.e., in the corners that were intentionally and incidentally pointed at by the adult). Mirroring word-mapping paradigms, these images could be processed as potential referents of the pseudoword without privileging in any way intentional pointing over incidental pointing across trials.

In each trial, intentional and incidental pointing took place at the same time. Intentional pointing was defined as the socioculturally conventional communicative gesture of an extended finger. Incidental pointing was defined as a natural arm gesture comparable in spatial salience to the intentional pointing finger but without a specific conventional communicative value. Incidental pointing was implemented in one of three different ways counterbalanced across trials: chin resting on the fist with the elbow pointing toward the corner of the table, hand palm placed on the table while pointing toward the corner, or hand placed behind the neck with the elbow pointing toward the corner (see Fig. 1). The three full-length videos from which the snapshots used in the illustrations in Fig. 1 were extracted are also available in the online supplementary material.

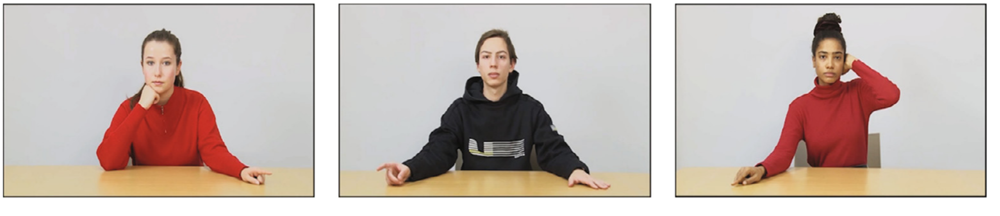

Fig. 1. Types of incidental pointing gestures.

The pseudowords uttered by the actors were created using the Lexique3 database (http://www.lexique.org) (New, Pallier, Ferrand, & Matos, 2001). Then, FrenchPOND (the French version of the CLEARPOND online database) was used to control for phonological neighbors (Marian, Bartolotti, Chabal, & Shook, 2012). All pseudowords that had at least one French word as a phonological neighbor were excluded. All the included pseudowords were disyllabic and composed of five or six phonemes (e.g., fevɛRs).

A total of 24 trials (see Fig. 2) were presented to each participant for a total duration of 3 min. Trials were pseudorandomized across participants in such a way that a maximum of two stimuli of the same incidental pointing type appeared in a row and a maximum of three stimuli where the actors were pointing intentionally with the same arm appeared in a row.

The task was created and displayed on a 1920 × 1080 computer screen using Tobii Studio. Eye movements were recorded at 60 Hz using a Tobii Pro X2-60 remote eye tracker located just below the screen. Participants were seated approximately 60 cm from the screen to ensure optimal measures. Before starting the task, participants completed a standard 5-point calibration procedure. There were no specific instructions for the task. Children were simply encouraged to look at the screen as if they were watching a cartoon. If children lost interest during the task, they were encouraged to actively look at the screen.

Psychometric measures

The French adaptation of the Peabody Picture Vocabulary Test–Revised (PPVT-R) was used to obtain a measurement of receptive vocabulary (Dunn & Dunn, 2007). During the administration of this standardized test, the experimenter presented children with four images and named one image. Children were then asked to point to the corresponding picture with their finger. Some autistic children experienced difficulties in pointing and were given a toy or small object and asked to place it on the corresponding picture. Even then, we were not able to obtain a receptive vocabulary score for all autistic children (see Table 1).

The first four subtests of the Cognitive Battery from the Leiter International Performance Scale–Third Edition (Leiter-3) were administered to measure nonverbal IQ (Roid, Pomplun, & Martin, 2009). IQ is notoriously difficult to assess in minimally verbal autistic children (Tager-Flusberg et al., 2017). However, we choose not to exclude those children who could not complete the Leiter-3 because it would have simply amounted to excluding most minimally verbal autistic children from the analyses.

The ADOS-2 was administered by a neuropsychologist with an official ADOS-2 certification to all children—both TD and autistic—to confirm the absence or presence of autism (Lord et al., 2000). Module 1 was used with children who displayed little or no speech, and Module 2 was used with children who used phrase speech.

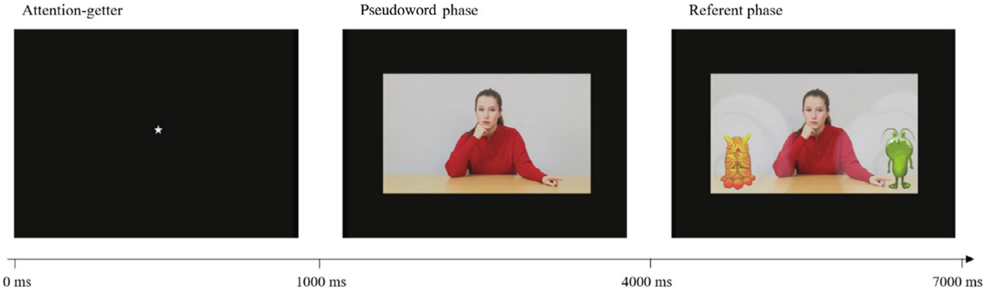

Fig. 2. Time course of one trial.

Questionnaires

Parents were asked to fill out an ad hoc questionnaire reporting general information about their children (e.g., what medication they receive, whether they suffer from any pathology, whether they were raised in a bilingual setting) and their personal and family medical history; a component of this questionnaire is based on the Family Affluence Scale (Torsheim et al., 2016) and assesses the economic and educational levels of parents in order to provide an estimate of children's socioeconomic background.

Because reliable verbal IQ scores often could not be collected from autistic children, parents of autistic children were also asked to fill out the French version of the CDI to obtain a measure of raw expressive vocabulary (Fenson, 1993). Parents were handed over the first version (words and gestures) or second version (words and utterances) of the CDI, depending on the information about their children's verbal level that they or their children's teacher provided us and after the children had been observed during the first experimental session. (Parents of TD children were not asked to fill out the CDI because all these participants were over 30 months of age and would have scored at ceiling.) Parents were contacted again 1 year after their children took part in the study and were asked to fill out the CDI a second time. As a result, for a subset of our sample of autistic children, we were able to collect CDI data at T1 and T2.

Procedure

Ethical approval was received for the study from the Erasme-ULB ethics committee in accordance with the Declaration of Helsinki. Participants' parents signed a written consent for their children to be enrolled in this study after being informed of theirs rights and all aspects of the experimental design. When possible, children were asked for oral assent.

The study reported in this article is part of a four-session project on early linguistic development in ASD. Because the other three sessions targeted developmental skills that are not directly related to the topic of the current article, they are not reported here. All questionnaires were handed over to parents during the first session. The eye-tracking task reported in this article took place during the last session along with administration of the PPVT-R. The ADOS-2 was administered during the second session, and the Leiter-3 was administered during the third session. All sessions included other eye-tracking tasks unrelated to the topic of this article; the first session also included parent–child free play.

Testing of the participants took place in our lab, at the children's homes, or at the children's school. Participants were individually tested by the first author or by the lab neuropsychologist.

Results

Eye-tracking data preparation

Eye-tracking data were exported using the Data Export tool in Tobii Studio. For each participant, horizontal and vertical coordinates (in pixels) of the averaged left and right eye gaze points on the screen were extracted every 16 ms. Two areas of interest (AOIs) were defined and kept constant during the pseudoword phase. The two AOIs were 280 $\times$ 345-pixel squares delimiting the corners of the video pointed at intentionally and incidentally (see Fig. 3). Subsequently, the coordinates of the center of these two AOIs were determined. For each gaze point on the screen of each participant, the Euclidian distances between the gaze point and the center of the AOIs were measured, resulting in a value for the distance to the correct AOI (i.e., to the zone pointed at intentionally) and to the incorrect AOI (i.e., to the zone pointed at incidentally). Using distance rather than proportion metrics has the advantage of avoiding arbitrary cutoffs based on categorical AOI delimitation and yields more robust models based on a higher number of data points (Nixon, van Rij, Mok, Baayen, & Chen, 2016). Prior to conducting the statistical analysis, we applied the offline method used in Clin, Maes, Stercq, and Kissine (2020) to correct for potential calibration errors (see supplementary material). The corrected gaze coordinates were used to measure the distance between a gaze point and the center of the two AOIs.

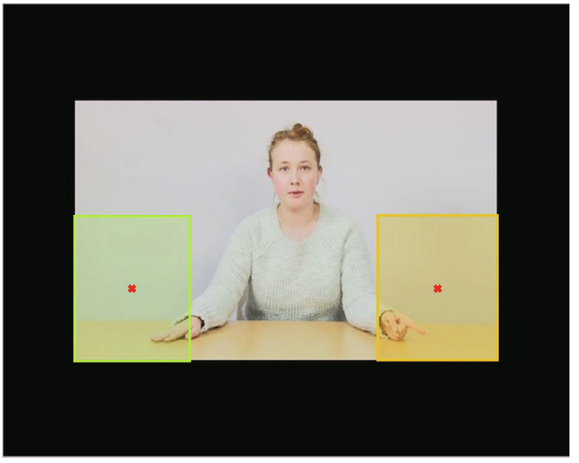

Fig. 3. Areas of interest and their respective centers.

Analytic plan

All statistical analyses were conducted in R (R Core Development Team, 2019). Multilevel linear regressions were implemented in the lme4 package (Bates, Mächler, Bolker, & Walker, 2015) to analyze the Euclidean distance (in pixels and averaged over 100-ms intervals) between the center of the two AOIs and the children's fixations during the pseudoword phase. Group (ASD vs. TD), time (in 100-ms intervals), incidental pointing type (chin on fist vs. hand palm vs. hand behind neck), and raw expressive vocabulary (at T1 vs. T2) were used as independent variables. Tukey post hoc comparisons were implemented using the *emmeans* or *emtrends* function from the emmeans package (Lenth, Singmann, Love, Buerkner, & Herve, 2020).

Tables including stepwise comparisons of multilevel linear regressions of all reported results can be found in the supplementary material.

Do autistic children allocate less attention to pointing gestures than TD children?

Attention to the two pointing gestures (intentional and incidental) was assessed independently by analyzing the distance (averaged over 100-ms intervals) between the children's fixations on the screen and the center of each AOI during the pseudoword phase (see Fig. 4). Stepwise comparisons of multilevel linear regressions with by-participant and by-item random intercepts revealed a group effect for the distance both from the correct (intentionally pointed-at) AOI, $\chi^2(1) = 15.41$, $p < .001$, and from the incorrect (incidentally pointed-at) AOI, $\chi^2(1) = 13.38$, $p < .001$, with the distance being greater in the ASD group (correct: $z = 4.03$; incorrect: $z = 3.73$). In sum, autistic children seemed to pay less attention to pointing gestures, be they incidental or intentional.

Do autistic children and TD children discriminate intentional pointing gestures from incidental pointing gestures?

To determine whether children distinguished intentional pointing gestures from incidental ones, we computed the relative distance between the children's fixations and both AOI centers by subtracting the distance to the incorrect AOI from the distance to the correct AOI (averaged over 100 ms). Thus, values less than 0 indicate that the fixation point is closer to the intentionally pointed-at AOI and values greater than 0 indicate that it is closer to the incidentally pointed-at AOI.

As can be seen in Fig. 5, TD children tended to shift their visual attention closer to the AOI pointed at intentionally upon hearing a novel word, whereas no such trend was visible in the ASD group.

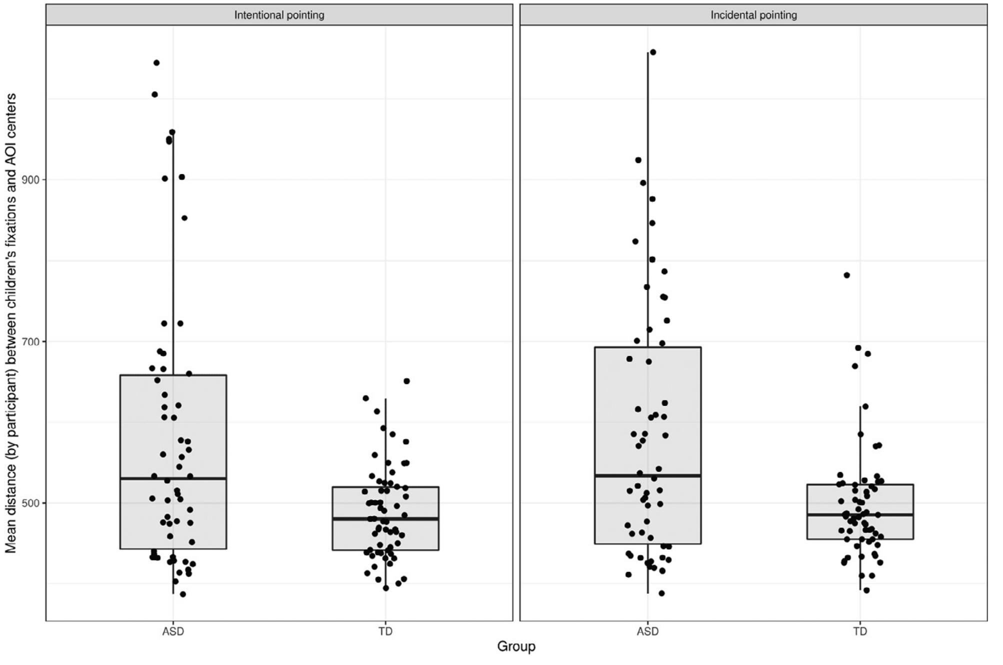

Fig. 4. Mean distance in pixels between children's fixations on the screen and both pointing gestures during the pseudoword phrase. AOI, area of interest; ASD, autism spectrum disorder; TD, typically developing.

Stepwise comparisons of multilevel linear regressions with by-participant and by-item random intercepts indicated that adding group as a fixed effect did not improve the model fit (p = .387). However, the addition of time, $\chi^2(1)$ = 65.01, p < .001, as well as the Group × Time interaction, $\chi^2(1)$ = 24.26, p < .001, significantly improved the model fit. The slope of relative distance was significantly dropping away from 0 for TD children (β = −2.28; 95% confidence interval (CI) [−2.75, −1.80]), but not for ASD children (β = −0.32; 95% CI [−0.93, 0.30]), with this slope difference being significant (z = 4.93, p < .001). That is, TD children, but not autistic children, rapidly shifted their visual attention toward the intentional pointing gesture upon hearing a novel word, suggesting that TD children, but not autistic children, attribute a referential value to the pointing finger.

Finally, we tested whether the type of incidental pointing gesture (see Fig. 1) had an influence on the children's looking preferences using multilevel linear regression models with by-item random intercepts and incidental pointing type by-participant random slopes. Stepwise comparisons revealed no effect of incidental pointing and no Group × Incidental Pointing interaction on relative distance (both ps > .06).

Are language skills linked to attention to pointing gestures in ASD?

These analyses were performed on the subset of our sample of autistic children (n = 44 for T1; n = 40 for T2) for whom a score of raw expressive vocabulary from the CDI was available. To explore whether expressive vocabulary correlated with attention to pointing gestures in ASD, we used models of the relative distance between the children's fixations and the intentional and incidental AOI centers. Stepwise comparisons of multilevel linear regressions with by-participant and by-item random intercepts indicated that adding raw expressive vocabulary as a fixed effect did not improve the model fit at T1 (p = .93) or at T2 (p = .40). These results indicate that autistic children's language level at T1 or T2 was not related to their attention to intentional versus incidental pointing. Autistic children who had

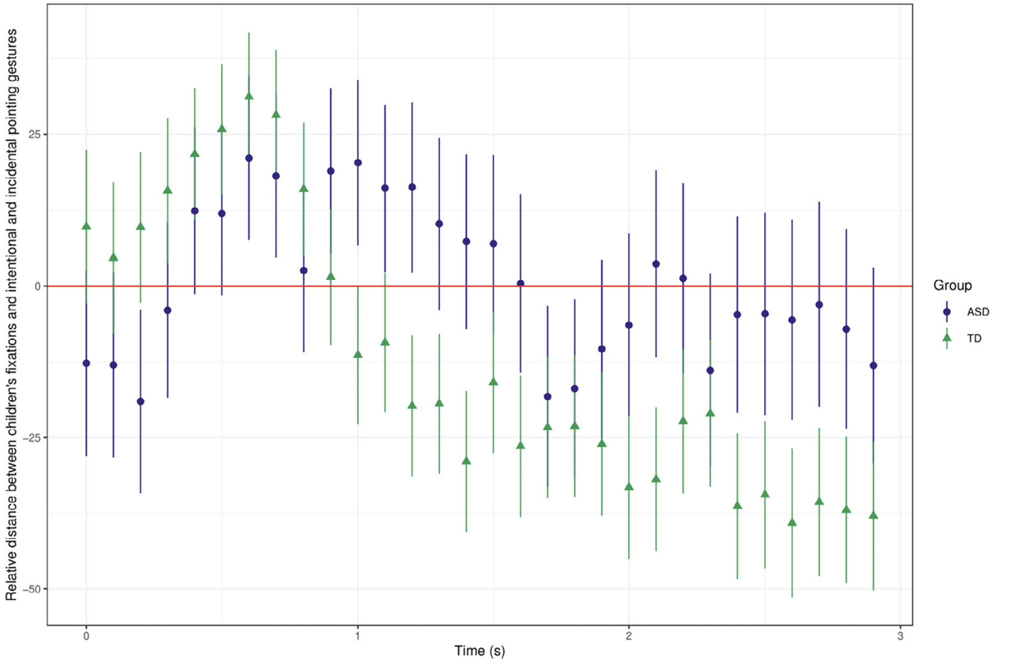

Fig. 5. Mean relative distance between the children's fixations and intentional and incidental pointing gestures by group over time during the pseudoword phase. ASD, autism spectrum disorder; TD, typically developing.

greater expressive vocabulary at the time of taking the task or 1 year later were not more sensitive to pointing gestures than those with lower expressive vocabulary.

Discussion

The current study is the first to precisely target the ability to follow intentional pointing gestures, with no other social cues available, in young (3- to 5-year-old) autistic children. The study also adds to the existing literature by including a large sample of young autistic children, including many with minimal or no verbal skills. Three research questions were addressed in this article. First, we investigated whether autistic children were sensitive to pointing gestures (intentional or incidental) when no other social cues were available. Second, we asked whether autistic children were able to discriminate intentional pointing gestures from incidental pointing gestures. Finally, we examined the relationship between the processing of intentional pointing and language abilities in ASD.

Autistic children's ability to follow pointing gestures

Our results indicate that, unlike TD children, autistic children do not preferentially allocate their visual attention to the zones pointed at in an intentional or incidental fashion. In comparison with TD children, autistic children's fixations were systematically farther away from both zones. These results show that, in general, autistic children do not shift their attention toward the socially relevant information (viz. the pointing gestures) when presented with a novel word.

These observations are in line with studies on autistic children that report difficulties in using social cues to identify referents for new words (Baron-Cohen et al., 1997; Preissler & Carey, 2005) or atypically low response to bids for joint attention (Dawson et al., 1998; Presmanes et al., 2007; Sullivan et al., 2007; Yoder et al., 2009). Our results also indicate that autistic children's increased performance in tasks where a pointing gesture is combined with other social cues (Akechi et al., 2013; Presmanes et al., 2007; Sullivan et al., 2007) cannot be attributed to a better understanding of pointing relative to other social cues. Increased RJA when a pointing gesture is added can probably be best explained by sheer accumulation of several social cues, whatever these may be. In other words, a pointing finger is probably not treated by autistic children as more valuable or relevant than other social cues in a context of joint attention. Rather, the accumulation of several congruent and spatially salient pointers (e.g., eye gaze, head tilts, points) may help to draw autistic children's attention to an object or event. However, as shown in the current study, a pointing gesture (intentional or incidental) alone might not suffice for prompting autistic children to shift their attention toward the pointed-at direction.

Autistic children's ability to discriminate intentional and incidental pointing gestures

Upon hearing a novel word, TD children, but not autistic children, privileged the zone that was pointed at intentionally versus the one that was pointed at in an incidental manner. This group difference further indicates that autistic children have difficulties in discriminating intentional pointing gestures from incidental ones. The fact that TD children preferentially gazed at the pointing finger in the presence of the incidental gesture suggests that a pointing finger (even without a congruent gaze) carries more communicative value than the three types of incidental gestures we used.

The difficulty in discriminating intentional pointing gestures from incidental ones in autistic children could be interpreted in two nonexclusive ways. First, lack of difference in the number of fixations between the two zones in the ASD group could be explained by the fact that autistic children simply do not pay sufficient attention to either of these two zones. Therefore, both arm gestures would be spatially and socially irrelevant for them. Second, it could also be that the children do notice these gestures as spatially relevant but fail to grasp the social and communicative significance of the intentional pointing gestures. As a result, they treat both intentional and incidental pointing gestures as equally salient spatial cues on par, say, with an arrow (Ristic et al., 2005).

Field et al. (2019) is the only other study to date to have investigated autistic children's sensitivity to incidental pointing gestures. These authors reported that 9-year-old autistic children, matched on receptive language age with a group of 4-year-old TD children, mapped a novel word to an object after following both an intentional pointing gesture and an incidental one. These results suggest that older autistic children follow pointing gestures in general but fail to recognize the social value behind the intentional pointing gestures. Note, however, that in Field et al.'s study, the TD control group of children also used incidental pointing gestures as a cue to identify the object being labeled by the experimenter. It is worth stressing, however, that Field et al. operationalized incidental pointing as a condition in which the speaker pointed toward one of the objects with his protruding finger while looking off into the distance in the opposite direction. That is, in Field et al.'s incidental condition, the directions of the point and the gaze competed—resulting in incongruent rather than truly incidental social cues. Moreover, autistic children are known to pay little attention to the eye region (Chawarska & Shic, 2009; Chita-Tegmark, Arunachalam, Nelson, & Tager-Flusberg, 2015), which left, in Field et al. (2019) incidental condition, the pointing finger as the only cue to find the correct object in both the intentional and incidental conditions.

Extending Field et al. (2019) insights to younger autistic children, we investigated whether autistic children can discriminate between intentional and incidental pointing gestures in two precise ways. First, we defined the incidental pointing gestures more rigorously as a spatially salient natural arm gesture with no competing eye gaze cue. Second, we presented the incidental and intentional pointing gestures simultaneously. Because autistic children in our study did not shift their attention toward the intentional pointing gestures upon hearing a novel word, it is likely that they failed to grasp their sociocommunicative value.

Relationship between pointing following and language abilities in ASD

Difficulties in processing pointing, and in discriminating intentional pointing gestures from incidental ones, could have a strong impact on vocabulary acquisition in ASD for two reasons. First, because autistic children fail to follow a pointing finger indicating a new referent, they might miss many of the opportunities from which their TD peers benefit to acquire new words. Second, autistic children might map a novel word onto an incorrect object as they follow an incidental spatially salient cue such as incidental pointing.

Somewhat surprisingly, however, the ability to follow someone's pointing gestures was not linked to language levels in our sample of autistic children. Contrary to our third hypothesis, autistic children with larger expressive vocabulary were not more likely than those with smaller expressive vocabulary to discriminate intentional pointing gestures from incidental ones. Moreover, the level of expressive vocabulary acquired by autistic children 1 year later did not predict their ability to follow pointing gestures. This contrasts with findings that toddlers with high likelihood of ASD with greater language abilities (both expressive and receptive) perform better on RJA tasks (Presmanes et al., 2007; Sullivan et al., 2007; Yoder et al., 2009) and that joint attention in general is a strong predictor of language outcome (Anderson et al., 2007; Ellis Weismer & Kover, 2015). However, it resonates with results by Luyster and Lord (2009), who found no difference in expressive vocabulary between a group of young autistic children who were able to follow social cues to infer the meanings of new words and a group of autistic children who were not able to do so. These results suggest that the ability to acquire words based on social cues such as pointing is not systematically related to levels of expressive vocabulary in autism.

Despite difficulties in following someone's pointing, some autistic children in our sample were able to acquire and develop language. This observation questions models that see joint attention as a prerequisite to language development (Colonnesi et al., 2010; Tomasello, 2008). These results are also consistent with claims that the link between joint attention and language acquisition may be overestimated in autism (Kissine, 2021) and in typical development (Akhtar & Gernsbacher, 2007). In that respect, our results provide indirect support to investigating other predictors of language outcomes in autism such as autism symptom severity (Thurm, Manwaring, Swineford, & Farmer, 2015) and social motivation (Su, Rogers, Estes, & Yoder, 2021).

Limitations and future directions

One of the objectives of our study was to investigate pointing processing in nonverbal or minimally verbal autistic children. In these children, it would have been difficult to assess word recall without introducing biases related to verbal instructions and task length. This, however, is a clear limitation of our study because we do not know whether our participants were able to acquire the novel words that were presented to them and, if they were, how they chose the referents for these words. It remains possible that our autistic participants did acquire some of the novel words they were exposed to even though their fixation patterns suggest that they were not paying attention to the pointing gestures. Assessing fast mapping would probably have been possible in a subset of autistic participants with higher verbal abilities. However, in this study, it would have introduced a lot of heterogeneity from one child to another in an already quite demanding experimental procedure. In addition, this latter question raises important issues about lexical encoding and consolidation in autistic children (Norbury, Griffiths, & Nation, 2010), which is somewhat orthogonal to focusing on attention allocated to pointing gestures, as we did here.

Another limitation is that children in our TD group had overall higher nonverbal and verbal IQs than autistic children and we did not include control (typically or atypically developing) groups matched on these measures with the autistic children. However, this kind of limitation is inherent in researching nonverbal or minimally verbal autistic children due to the difficulty in assessing IQ in this population (Courchesne, Girard, Jacques, & Soulières, 2019; Tager-Flusberg et al., 2017). Nonverbal IQ scores in autism are reliably linked neither with language development (Munson et al., 2008) nor with adaptative function (Alvares et al., 2019). Although we believe that this is a promising venue for future research, the task of finding comparison groups matched in verbal and nonverbal IQs would have been virtually impossible because of the missing scores in our autistic group. However, this limitation should not stop researchers from conducting research on nonverbal or minimally verbal autistic children, who represent a large proportion of the spectrum from 3 to 5 years of age and remain underrepresented in the scientific literature.

It would be interesting in future studies to compare trials with simultaneous incidental and intentional pointing with trials with a single type of pointing (incidental or intentional). Note, however, that a 3-min eye-tracking task is already very demanding for 3- to 5-year-old autistic children, and adding such separate trials would considerably increase the attentional load for these participants.

Future research could replicate this study with other kinds of potential referents (e.g., novel objects) and in more natural settings—with face-to-face interaction with an experimenter or with dynamic pointing gestures—resembling real-life interactions with caregivers. Moreover, our study questions the role of RJA in language acquisition. Future studies should assess the efficiency of intensive intervention targeting joint attention on language development in ASD (Murza, Schwartz, Hahs-Vaughn, & Nye, 2016).

Conclusion

Using an original eye-tracking method, we observed the processing of intentional and ecologically valid incidental pointing gestures in young autistic children, including many nonverbal or minimally verbal children. In comparison with chronological-age-matched TD children, autistic children paid less attention to both intentional and incidental pointing gestures. Furthermore, unlike their TD peers, autistic children did not appear to favor intentional pointing over incidental pointing. Young autistic children, regardless of their level of language, seem to have difficulties in detecting the spatial and social relevance of pointing. This result may have important implications for investigating language acquisition trajectories in young autistic children.

CRediT authorship contribution statement

Pauline Maes: Methodology, Formal analysis, Investigation, Writing - original draft. **Fanny Stercq:** Conceptualization, Methodology, Funding acquisition, Project administration. **Mikhail Kissine:** Conceptualization, Formal analysis, Funding acquisition, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This work was supported by the ROGER DE SPOELBERCH Foundation and the Walloon Region of Belgium. We are grateful to all the participating children, parents, and schools that collaborated with us. We also thank Morgane Colin for help with recruitment and data collection.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jecp.2021.105205.

References

Akechi, H., Kikuchi, Y., Tojo, Y., Osanai, H., & Hasegawa, T. (2013). Brief report: Pointing cues facilitate word learning in children with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 43*, 230–235.

Akhtar, N., & Gernsbacher, M. A. (2007). Joint attention and vocabulary development: A critical look. *Language and Linguistics Compass, 1*, 195–207.

Akhtar, N., & Tomasello, M. (2000). The social nature of words and word learning. In R. M. Golinkoff (Ed.), *Becoming a word learner: A debate on lexical acquisition* (pp. 115–135). Oxford, UK: Oxford University Press.

Alvares, G. A., Bebbington, K., Cleary, D., Evans, K., Glasson, E. J., Maybery, M. T., ... Whitehouse, A. J. O. (2019). The misnomer of "high functioning autism": Intelligence is an imprecise predictor of functional abilities at diagnosis. *Autism, 24*, 221–232.

American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: Author.

Anderson, D. K., Lord, C., Risi, S., DiLavore, P. S., Shulman, C., Thurm, A., ... Pickles, A. (2007). Patterns of growth in verbal abilities among children with autism spectrum disorder. *Journal of Consulting and Clinical Psychology, 75*, 594–604.
Baldwin, D. A. (1993). Infants' ability to consult the speaker for clues to word reference. *Journal of Child Language, 20*, 395–418.
Baron-Cohen, S., Baldwin, D. A., & Crowson, M. (1997). Do children with autism use the speaker's direction of gaze strategy to crack the code of language? *Child Development, 68*, 48–57.
Bates, D., Mächler, M., Bolker, B. M., & Walker, S. C. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*(1). https://doi.org/10.18637/jss.v067.i01.
Behne, T., Carpenter, M., & Tomasello, M. (2005). One-year-olds comprehend the communicative intentions behind gestures in a hiding game. *Developmental Science, 8*, 492–499.
Bottema-Beutel, K. (2016). Associations between joint attention and language in autism spectrum disorder and typical development: A systematic review and meta-regression analysis. *Autism Research, 9*, 1021–1035.
Carpenter, M., Nagell, K., Tomasello, M., Butterworth, G., & Moore, C. (1998). Social cognition, joint attention, and communicative competence from 9 to 15 months of age. *Monographs of the Society for Research in Child Development, 63*(4), 1–174.
Chawarska, K., & Shic, F. (2009). Looking but not seeing: Atypical visual scanning and recognition of faces in 2- and 4-year-old children with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 39*, 1663–1672.
Chita-Tegmark, M., Arunachalam, S., Nelson, C. A., & Tager-Flusberg, H. (2015). Eye-tracking measurements of language processing: Developmental differences in children at high risk for ASD. *Journal of Autism and Developmental Disorders, 45*, 3327–3338.
Clifford, S. M., & Dissanayake, C. (2008). The early development of joint attention in infants with autistic disorder using home video observations and parental interview. *Journal of Autism and Developmental Disorders, 38*, 791–805.
Clin, E., Maes, P., Stercq, F., & Kissine, M. (2020). No preference for direct versus averted gaze in autistic adults: A reinforced preferential looking paradigm. *Molecular Autism, 11*, 91.
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*, 352–366.
Courchesne, V., Girard, D., Jacques, C., & Soulières, I. (2019). Assessing intelligence at autism diagnosis: Mission impossible? Testability and cognitive profile of autistic preschoolers. *Journal of Autism and Developmental Disorders, 49*, 845–856.
Dawson, G., Meltzoff, A. N., Osterling, J., Rinaldi, J., & Brown, E. (1998). Children with autism fail to orient to naturally occurring social stimuli. *Journal of Autism and Developmental Disorders, 28*, 479–485.
Dunn, L. M., & Dunn, D. M. (2007). *Peabody picture vocabulary test-fourth edition*. Bloomington, MN: NCS Pearson.
Ellis Weismer, S., & Kover, S. T. (2015). Preschool language variation, growth, and predictors in children on the autism spectrum. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 56*, 1327–1337.
Fenson, L. (1993). *MacArthur communicative development inventories: User's guide and technical manual*. Boston: Cengage Learning.
Field, C., Lewis, C., & Allen, M. L. (2019). Referent selection in children with autism spectrum condition and intellectual disabilities: Do social cues affect word-to-object or word-to-location mappings? *Research in Developmental Disabilities, 91* 103425.
Kissine, M. (2021). Autism, constructionism and nativism. Language. Retrieved from http://homepages.ulb.ac.be/~mkissine/language_perspectives.pdf
Lenth, R., Singmann, H., Love, J., Buerkner, P., & Herve, M. (2020). Package "emmeans." https://github.com/rvlenth/emmeans
Lord, C., Risi, S., Lambrecht, L., Cook, E. H., Leventhal, B. L., Dilavore, P. C., ... Rutter, M. (2000). The autism diagnostic observation schedule–generic: A standard measure of social and communication deficits associated with the spectrum of autism. *Journal of Autism and Developmental Disorders, 30*, 205–223.
Luyster, R., & Lord, C. (2009). Word learning in children with autism spectrum disorders. *Developmental Psychology, 45*, 1774–1786.
Marian, V., Bartolotti, J., Chabal, S., & Shook, A. (2012). CLEARPOND: Cross-linguistic easy-access resource for phonological and orthographic neighborhood densities. *PLoS ONE, 7*(8), 43230.
Moore, C., Angelopoulos, M., & Bennett, P. (1999). Word learning in the context of referential and salience cues. *Developmental Psychology, 35*, 60–68.
Munson, J., Dawson, G., Sterling, L., Beauchaine, T., Zhou, A., Koehler, E., ... Abbott, R. (2008). Evidence for latent classes of IQ in young children with autism spectrum disorder. *American Journal on Mental Retardation, 113*, 439–452.
Murray, D. S., Creaghead, N. A., Manning-Courtney, P., Shear, P. K., Bean, J., & Prendeville, J.-A. (2008). The relationship between joint attention and language in children with autism spectrum disorders. *Focus on Autism and Other Developmental Disabilities, 23*(1), 5–14.
Murza, K. A., Schwartz, J. B., Hahs-Vaughn, D. L., & Nye, C. (2016). Joint attention interventions for children with autism spectrum disorder: A systematic review and meta-analysis. *International Journal of Language and Communication Disorders, 51*, 236–251.
New, B., Pallier, C., Ferrand, L., & Matos, R. (2001). A lexical database for contemporary French on internet: LEXIQUE. *Annee Psychologique, 101*, 447–462.
Nixon, J. S., van Rij, J., Mok, P., Baayen, R. H., & Chen, Y. (2016). The temporal dynamics of perceptual uncertainty: Eye movement evidence from Cantonese segment and tone perception. *Journal of Memory and Language, 90*, 103–125.
Norbury, C. F., Griffiths, H., & Nation, K. (2010). Sound before meaning: Word learning in autistic disorders. *Neuropsychologia, 48*, 4012–4019.
Parish-Morris, J., Hennon, E. A., Hirsh-Pasek, K., Golinkoff, R. M., & Tager-Flusberg, H. (2007). Children with autism illuminate the role of social intention in word learning. *Child Development, 78*, 1265–1287.
Preissler, M. A., & Carey, S. (2005). The role of inferences about referential intent in word learning: Evidence from autism. *Cognition, 97*, 813–823.
Presmanes, A. G., Walden, T. A., Stone, W. L., & Yoder, P. J. (2007). Effects of different attentional cues on responding to joint attention in younger siblings of children with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 37*, 133–144.

R Core Development Team (2019). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing.
Ristic, J., Mottron, L., Friesen, C. K., Iarocci, G., Burack, J. A., & Kingstone, A. (2005). Eyes are special but not for everyone: The case of autism. *Cognitive Brain Research, 24*, 715–718.
Roid, G. H., Pomplun, M., & Martin, J. J. (2009). Nonverbal intellectual and cognitive assessment with the Leiter International Performance Scale-Revised (Leiter-R). In J. A. Naglieri & S. Goldstein (Eds.), *Practitioner's guide to assessing intelligence and achievement* (pp. 265–290). New York: John Wiley.
Su, P. L., Rogers, S. J., Estes, A., & Yoder, P. (2021). The role of early social motivation in explaining variability in functional language in toddlers with autism spectrum disorder. *Autism, 25*, 244–257.
Sullivan, M., Finelli, J., Marvin, A., Garrett-Mayer, E., Bauman, M., & Landa, R. (2007). Response to joint attention in toddlers at risk for autism spectrum disorder: A prospective study. *Journal of Autism and Developmental Disorders, 37*, 37–48.
Tager-Flusberg, H., Plesa Skwerer, D., Joseph, R. M., Brukilacchio, B., Decker, J., Eggleston, B., ... Yoder, A. (2017). Conducting research with minimally verbal participants with autism spectrum disorder. *Autism, 21*, 852–861.
Thurm, A., Manwaring, S. S., Swineford, L., & Farmer, C. (2015). Longitudinal study of symptom severity and language in minimally verbal children with autism. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 56*, 97–104.
Tomasello, M. (1999). *The cultural origins of human cognition*. Cambridge, MA: Harvard University Press.
Tomasello, M. (2008). *Origins of human communication*. Cambridge, MA: MIT Press.
Tomasello, M., & Farrar, M. J. (1986). Joint attention and early language. *Child Development, 57*, 1454–1463.
Torsheim, T., Cavallo, F., Levin, K. A., Schnohr, C., Mazur, J., Niclasen, B., & Currie, C. (2016). Psychometric validation of the Revised Family Affluence Scale: A latent variable approach. *Child Indicators Research, 9*, 771–784.
Vadillo, M. A., Street, C. N. H., Beesley, T., & Shanks, D. R. (2015). A simple algorithm for the offline recalibration of eye-tracking data through best-fitting linear transformation. *Behavior Research Methods, 47*, 1365–1376.
Yarkoni, T. (2020). The generalizability crisis. Behavioral and Brain Sciences. Advance online publication. doi:10.1017/S0140525X20001685.
Yoder, P., Stone, W. L., Walden, T., & Malesa, E. (2009). Predicting social impairment and ASD diagnosis in younger siblings of children with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 39*, 1381–1391.
Yoder, P., Watson, L. R., & Lambert, W. (2015). Value-added predictors of expressive and receptive language growth in initially nonverbal preschoolers with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 45*, 1254–1270.
Zwaigenbaum, L., Bryson, S., & Garon, N. (2013). Early identification of autism spectrum disorders. *Behavioural Brain Research, 251*, 133–146.