Different Ways of Making a Point: A Study of Gestural Communication in Typical and Atypical Early Development

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Deictic pointing is among the most impaired gestures in children with autism. Research on typical development demonstrates that contact with the referent and handshape when *pointing*, are associated with different communicative intentions and developmental stages. Despite their importance, the morphological features of *pointing* remain largely unexplored in autism. The aim of the present study was to map out *pointing* production in autism with a focus on *handshape* and *contact with the referent*. Participants (age range = 1–6 years old) with ASD (n = 16), at high risk for autism (n = 13) and typically developing children (n = 18) interacted with their caregivers in a gesture elicitation task. Results showed that children with ASD produced fewer *pointing* gestures overall and fewer *index finger pointing without contact with the referent* compared to the typically developing children. ***Autism Res*** *2021, 14: 984–996*. © 2020 The Authors. *Autism Research* published by International Society for Autism Research and Wiley Periodicals LLC.

Lay Summary: Children with autism produce less gestures than typical children, and pointing gestures appear to be more affected than other gesture types. Whether children point using their index finger or the palm, and whether they touch or not the referent is crucial for understanding communicative intentions. This is the first study to document experimentally exactly how pointing gestures differ in autism in comparison to typical development. We found important qualitative differences in the communicative patterns of children with autism and at risk for autism, that may serve to identify potential new markers for early diagnosis.

Keywords: autism; pointing; handshape; proximal gestures; distal gestures; nonverbal communication

Introduction

Pointing gestures play an important role in early development. Deictic pointing is used to direct a colocutor's attention to an object present in the communicative situation, and is, as such, inherently related to joint attention [Baldwin, 1995]. Furthermore, pointing not only serves to single out the object, but is a means of making definite reference that is intimately linked to gesture and speech [Butterworth, 2003]. Notably, according to Werner and Kaplan [1963], infants' communicative pointing denotes an important first step toward true symbolic understanding. Communication skills are one of the most severely affected abilities in individuals with autism spectrum disorder (ASD), and an atypical joint attention profile has been reported for this population [Chawarska, Klin, Paul, & Volkmar, 2007; Mundy, Sigman, & Kasari, 1990]. A distinction is often found between the initiation of joint attention, by producing a pointing gesture, and response to joint attention. It has been documented that it is the former that is more severely affected in autism, while the latter develops on time [Nyström, Thorup, Bölte, & Falck-Ytter, 2019], and functions adequately in childhood, and can support learning [Mundy, Kim, McIntyre, Lerro, & Jarrold, 2016].

From this perspective, joint attention behaviors, such as *declarative*/*imperative* pointing, have often been in the focus of research investigating the specific communication deficit in children with ASD. The *declarative*/*imperative* classification categorizes pointing from the point of view of its communicative function: to share interest/inform about something (i.e., *declarative* pointing) or to obtain a desired object (i.e., *imperative* pointing) [Bates, Camaioni, & Volterra, 1975]. Research in gesture production in children with autism shows that *declarative* pointing is impaired, while *imperative* pointing appears to be largely intact in this population [Baron-Cohen, 1989; Goodhart & Baron-Cohen, 1993; Camaioni, Perucchini, Muratori, Parrini, & Cesari, 2003]. Research has also documented that the respective proportion between

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imperative (requesting) behaviors and referential (deictic) behaviors in children with autism is different from typical children and reflects a prevalence of *imperative* behaviors over referential behaviors [Stone, Ousley, Yoder, Hogan, & Hepburn, 1997].

These findings are a major stepping-stone in the understanding of the early development of children with autism; however, the predictive value of specific gesture types for verbal communication remains open to further investigation. Özçaliskan, Adamson, and Dimitrova [2016] report that deictic gestures predicted the vocabulary of children with TD and ASD, independently of their communicative function (whether *imperative* or *declarative*). In contrast, Ökcün-Akçamuş, Acarlar, Keçeli Kaysili, and Alak [2017] found that within the deictic category, only *declarative* gestures predicted higher lexical diversity (number of different words) in children with autism.

Gesture Taxonomy

Besides the contradictory findings concerning the predictive role of declarative gestures for language skills in children with autism, the approach used to classify gestures according to a dichotomous *imperative/declarative* taxonomy employed in most pointing studies in typical development and ASD, poses some serious methodological limitations. One important limitation is that this taxonomy requires highly structured experiments, where only either *declarative* or *imperative* gestures, one at a time can be studied. This is due to the fact that pointing is classified according to the communicative intention of the child and the contexts that prompt the intention of interacting socially and sharing an experience (*declarative* pointing) are very different from the contexts that prompt the intention of obtaining something from the interlocutor (*imperative* pointing). This brings another limitation, as the design of these highly structured experiments makes the *imperative/declarative* taxonomy ill-suited for studying spontaneous gesture production in infants (see also the comprehensive criticism in Bourjade, Cochet, Molesti, & Guidetti, 2020]. Finally, because child intentions are extremely difficult to operationalize, the classification of pointing gestures into *imperative/declarative* is prone to examiner's subjective interpretations and hinders the objective codification of gestures. Bourjade et al. [2020] duly point out that some situational or motivational factors do not always allow researchers to infer the communicative function of gestures: the eliciting stimuli may not provoke in all children the necessary enthusiasm to respond to the stimulus or provoke the expected reaction.

In addition to the described methodological limitations, an important criterion related to communication form has been overlooked in the study of gestures in ASD, namely handshape. Handshape plays a crucial role in the development of communication skills and allows for an objective classification of gesture production based on communication form and physical features of the hand, rather than communicative function. Liszkowski, Brown, Callaghan, Takada, and de Vos [2012] found that typically developing infants' pointing production begins with *open palm* pointing at around 8 months of age and is followed by *index finger* pointing at 10 months of age. Notably, they found that younger infants rely more on *open palm* pointing, but this pattern starts shifting soon after *index finger* pointing emerges, and by the 12th month of life, *index finger* pointing becomes the most prevalent pointing handshape among infants. Importantly, Liszkowski et al. [2012] found no cross-cultural differences in the emergence, contextual usage and frequency of *index finger* pointing in preverbal infants from locations, as remote and culturally diverse, as Papua New Guinea, Indonesia, Japan, Peru, Mexico and Canada. Even though salient cultural differences have been found in adult reference-making involving different body parts [Wilkins, 2003], index finger handshape appears to be universal in infant pointing.

Gesture Morphology in Development

Research on typical development (TD) has also established a link between communicative intentions and pointing handshape. While infants tend to produce *index finger pointing* to express interest or to inform about something (i.e., *declarative* pointing), *open palm* pointing is typically used to make requests (i.e., *imperative* pointing; Cochet & Vauclair, 2010). Interestingly, *imperative* gestures may transition from *open palm* pointing into *index finger* pointing in noisy contexts (e.g., when the target is surrounded by distractors) [Cochet, Jover, Oger, & Vauclair, 2014]. This finding may indicate a shared ground between *open palm* gestures and *index finger* pointing, replicating the developmental evidence of gesture refinement from *open palm* to *index finger* between 8 and 10 months [Liszkowski et al., 2012]. However, unlike *open palm* pointing, pointing with the index finger is more frequently paired with vocalizations in TD infants [Liszkowski & Tomasello, 2011]. This suggests that, compared to *open palm* pointing, *index finger* pointing is ontogenetically more complex and has a tighter connection to verbal and nonverbal communication skills development.

Notably, the association between *index finger* pointing and declarative intention, on the one hand, and between *open palm* pointing and imperative intention, on the other, is also found in caregivers, and appears to be stereotyped. Thus, different handshapes can function as effective cues for TD infants to infer the social intentions behind different gestures. As early as 12 months of age, infants can accurately discriminate between the intentions conveyed by *index finger* and *open palm* pointing [Esteve-Gibert, Prieto, & Liszkowski, 2016], which parallels their own gesture production.

Despite the evidence that handshape can serve as a proxy for communication skills in TD, no study has specifically addressed the role of pointing hand configurations in ASD. The only study that involves an attempt to recognize this factor, albeit in a heterogeneous way, is the longitudinal study of toddlers at high risk for autism (HR) from 2 to 3 years of age by LeBarton and Iverson [2016]. They analyzed the production of *pointing*, *showing*, *conventional*, *iconic* and *functional acts* in an at-home semistructured protocol with the aim of detecting differences in the gesture types used by different groups of HR children: those who went on to receive an autism diagnosis, those who presented with language delay (LD) and children who followed typical development. Pointing gestures were categorized into *index*, *palm*, *touch* and *object*. This study found that the children later diagnosed with autism produced fewer *palm* pointing gestures, as well as fewer *touch* pointing gestures compared to the TD children at age three. Although the task employed is ecological and effective for the purpose of this study (i.e., to distinguish differences in gesture types between ASD, LD and TD children), it was not tailored to elicit pointing gestures specifically, which limits the reliability of the results concerning the pointing gesture categories. This became apparent in the low pointing production of all children in the sample: "several POINT forms were produced by too few children and too infrequently in each group" [LeBarton & Iverson, 2016, p. 10].

Regardless of its limitations on pointing gesture description, LeBarton and Iverson [2016] also analyzed a very important morphological aspect of pointing that has not received enough attention, namely contact with the referent. Bates, Benigni, Bretherton, Camaioni, and Volterra [1979] found that the extension of the index finger originally emerges as a form of object manipulation between 9 and 13 months of age and is followed by the acquisition of *index finger* pointing for communicative purposes. In addition, Drew, Baird, Taylor, Milne, and Charman [2007] argued that "[…] touching an object with an index finger point might be an earlier form of *distal index finger pointing*" (p. 650). Contact with the referent could, therefore, be a residual feature in the process of pointing development that might distinguish between early gestures and more refined *deictic declarative pointing* acquired later. Furthermore, pointing to distal objects appears later in development (around the 13th month) compared to *proximal pointing* which may involve touching the referent (e.g., pointing to a picture in a book) emerging around 10 months of age [Butterworth, 2003]. This in turn, may suggest that *pointing* with no contact with the referent is based on more cognitively advanced mechanisms than *pointing with contact*. Toth, Dawson, Meltzoff, Greenson, and Fein [2007] explored the cognitive, social, and communication abilities of nonautistic HR children and showed that HR toddlers produced fewer *distal (no contact) gestures* compared to typically developing children. This finding of impaired *distal gestures* in children at high risk for autism would entail that children with an established ASD diagnosis would present with an even more pronounced impairment in *distal (no contact) pointing*. A recent scoping review of deictic gesture use in toddlers with or at-risk for autism documents great variability in how deictic gestures were categorized, defined and measured across the 19 studies included in the review, leading to inconclusive findings concerning exactly what aspects of gesture production characterize the specific profile of children with autism [Manwaring, Stevens, Mowdood, & Lackey, 2018].

The Current Study

The main aim of the current study was to operationalize gesture production by identifying characteristic manual features of the pointing gesture independently of communicative function. As such, it is a theoretical and methodological advancement in the study of pointing gestures in ASD, HR and TD children based on pointing morphology. We addressed the following research questions: (1) Are there group differences in the overall production of *pointing gestures*? (2) Are there morphological differences in pointing across groups? If so, (2.1) are those differences based on *handshape*? And/or (2.2.) are the differences based on *contact with the referent*? (3) Are there group differences in *instrumental gesture* production? (4) Are there differences in object manipulation across groups? In order to explore parental input and its possible effect on infant gesture production, we also analyzed caregivers' gesture production and asked the same set of questions described above. An additional analysis on caregiver to child gesture production ratio was conducted to compare caregivers gesture production in proportion to child gesture production per group.

Consistent with assumptions in extant research, we were specifically interested in two features which characterize the presence of more advanced and sophisticated gesture communication, *index finger pointing* and *pointing without contact with the referent*. We predicted that children in the ASD group would: (1) produce overall fewer gestures compared to HR and especially to TD children, (2) present with differences in both *handshape* and *contact with the referent* by displaying lower *index finger pointing* and *pointing without contact with the referent* gesture production compared to HR and TD children, (3) produce more *instrumental gestures* than HR and TD children, and (4) manipulate objects more than HR and TD children. Based on earlier findings of the developmental trajectories of HR children, we expected that their gesture production would reflect certain similarities with the group with autism diagnosis, while still largely falling within the normal range. We specifically predicted an intermediate pattern between the ASD and the TD, involving similarities with the ASD group in more object manipulation instances, reduced *index finger*, and reduced *pointing without contact with referent* production, but with a lower *instrumental gesture* production, similar to the TD pattern. As for the TD group, we expected to find the most sophisticated morphological pattern, with more instances and prevalence of *index finger* and *pointing without contact*, as well as a sophisticated communicative pattern, with exclusively pointing gesture production and minimal *object manipulation* instances.

Methods

The present study aimed at an exhaustive analysis of the morphology of *pointing gestures* in children with autism based on features of hand morphology and contact with the referent. Unlike previous studies where measures reflecting the form of pointing were analyzed together with various communication, social, cognitive and other measures [LeBarton & Iverson, 2016; Toth et al., 2007], we focused exclusively on the description of pointing gestures in ASD attending to the physical features of the manual pattern. To do this, we included measures of *handshape* and *contact with the referent* with two mutually exclusive levels each; *index finger pointing/open palm pointing* and *contact pointing/no contact pointing*, respectively. An additional methodological improvement is the inclusion of three groups of participants for a complete comparison of the selected features of gesture morphology: an ASD group, a High-Risk (HR) and a Typically developing (TD) group. The ASD group comprised participants with an established diagnosis, thus contributing to the reliability of observed specific pointing production patterns. The HR group contributed to further describe traits of the broader autism phenotype [Pisula & Ziegart-Sadowska, 2015], and to characterize early ASD features present in children that are not yet diagnosed with ASD. Findings from this group could serve to identify behavioral red flags from early on. The TD group consisted of children at no familial risk for ASD and thus served as a reliable control group. Finally, and given that a pointing-specific task is needed in order to elicit and conduct a fine-grained morphological analysis of this specific type of gestures, a seminaturalistic paradigm with proven efficacy in the elicitation of *pointing gestures* was employed. Importantly, the task allows, in addition, for the description of spontaneous gesture production.

Two additional measures were included in the analyses: *instrumental gestures* and *object manipulation*. *Instrumental* gestures were included, as they have been identified as ASD-specific gestures [Mastrogiuseppe, Capirci, Cuva, & Venuti, 2015] that involve an unusual hand configuration, featuring taking the arm or the hand of the communicative partner and directing it to an object or a place to indicate the need/willingness of some action to be carried out (e.g., the child with ASD takes the hand of the mother and places it on a jar to request her to open it). Object manipulations, for their part, were included to control for noncommunicative manual actions and to investigate for possible alternative ways of interaction across groups. This was driven mainly by consideration for the ASD group and commonly observed lack of social interest in that population [Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2012; Grelotti, Gauthier, & Schultz, 2002], and their difficulty to establish joint attention (see Mundy, 2018; for a review).

Participants

Three groups of Spanish monolingual children between 15 and 72 months of age (n = 47; 16 female) were recruited for the present study as part of a longitudinal research project monitoring the development of communication skills in ASD, HR and a control group of TD children over one year. 10 participants with medical conditions (acute traumatic brain injury), preterm birth, speech impairment and/or not enough video footage were excluded from the analysis (initially n = 57). Parents of the three target groups were provided with information about the study and those interested in participating received an information sheet and signed a consent form. ASD and HR children were recruited from three Autism associations and TD children from nursery and play schools. All participating families came from monolingual, northern regions of Spain and were native speakers of Spanish.

The ASD group consisted of 16 children with an ASD diagnosis (2 female; mean age = 51.81 months; age range = 35-72 months; SD = 10.45). Parents provided diagnostic reports by licensed psychologist, psychiatric and/or neuropediatric medical doctors from the Spanish Public Health System. The HR group consisted of 13 children (7 female; mean age = 36 months; age range = 15-64 months; SD = 16.23) with an older sibling with an ASD diagnosis. The control group consisted of 18 typically developing children (7 female; mean age = 37.72; age range = 17-68 months; SD = 16). The HR and the TD children were matched on chronological age, while the children with autism were older than both TD and HR groups (Fig. 1). An ANOVA revealed an effect of age between groups $F(2,46) = 5.61$, $P = 0.007$, MSE = 9158.04. There was a significant difference between the children with ASD and the TD children, $F(1,33) = 8.97$, $P = 0.005$, MSE = 5994.03; and between the children with ASD and the HR children, $F(1,28) = 177.86$,

Figure 1. Participant groups' age in months.

$P = 0.004$, MSE = 1793.35. No significant difference was found between the TD and the HR children, $F(1,30) = 259.29$, $P = 0.771$, MSE = 7519.61.

The current study was reviewed by and received the approval of The Ethics Committee for the Research on Human Participants of the University of the Basque Country to conduct the data collection in Spain and received the approval of The Regional Committee for Medical Research Ethics (REC Central Norway) to conduct the data analyses in Norway.

Study Paradigm

We employed the paradigm designed by Liszkowski et al. [2012] which has proven highly effective in eliciting pointing gestures in TD children across cultures and languages (i.e., Papua New Guinea, Indonesia, Japan, Peru, Mexico, Canada). It allows for spontaneous caregiver-child interactions, while controlling for confounding variables by employing the same set-up across participants. To our knowledge, this is the first time this paradigm has been applied in atypical populations. We used the linguistic annotator ELAN to identify the occurrence of the behaviors of interest (i.e., segmentation) and tag each of them (*index finger pointing*, *open palm pointing*, *no contact pointing*, *contact pointing*, *instrumental gestures* and *object manipulations*) during the caregiver–toddler interactions [ELAN, 2018].

Materials and Procedure

Individual testing sessions with each family included the administration of several experimental and standardized tests as part of a larger longitudinal study within the Horizon2020 ITN *DCOMM*. The current study only reports data from the gesture elicitation task adapted from Liszkowski et al. [2012]. The task consisted of 5-min caregiver-child free interactions in front of a wall with a set of stimuli comprised of laminated images of a house, a car, a boat, different plants and animals, as well as various real objects (see Fig. 2). This set-up was used in each of the testing locations together with two HD cameras placed opposite one another. This ensured a careful recording of the gesture production data, which was coded offline. Caregivers were asked to "look and comment together on the objects and images on the wall," while carrying the child or standing side by side in front of the stimulus set, in the case of older children (see Fig. 3). These instructions differ slightly from the original experiment in Liszkowski et al. [2012], which explicitly stated not to touch or manipulate the stimuli in the set-up. Given that we tested the differences in the production of *pointing* with and without contact with the referent, as well as *object manipulations*, instead of asking not to touch the stimuli, we asked participants not to remove the objects/images from the wall.

Figure 2. Stimulus set-up.

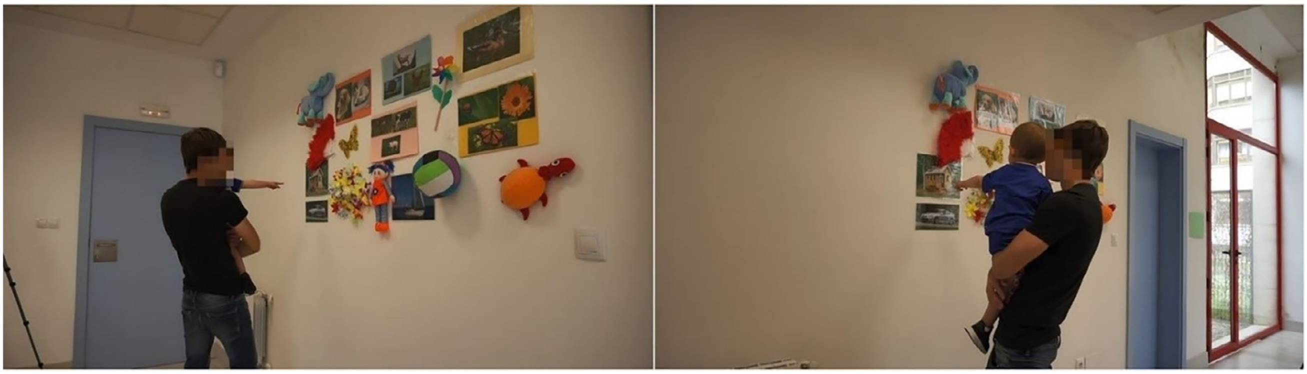

Figure 3. View from the two opposing cameras of a caregiver and a child participating in the task.

Gesture Coding

Video-recordings were synchronized and coded offline using ELAN. Each gesture was segmented (i.e., selection of the time interval where a gesture takes place including the three gesture phases: preparation, stroke and retraction) and then annotated (i.e., categorization of each gesture) following the coding scheme specified below:

- Pointing gestures (as defined by *handshape* and *contact with the referent*).
  - *Contact index finger pointing*: pointing with the index finger extended while touching the referent at least for two seconds.
  - *No contact index finger pointing*: pointing with the index finger extended without touching the referent.
  - *Contact open palm pointing*: proximal pointing with the whole hand (facing either upwards or downwards) touching the referent at least for two seconds.
  - *No contact open palm pointing*: pointing with the whole hand (facing either upwards or downwards) without touching the referent.
- Instrumental gestures: as reported by Mastrogiuseppe et al. [2015]. The infant takes the hand/arm of the parent and guides it to an object/image in the set-up.
- Object manipulation: noncommunicative manual acts that involve touching, tapping, caressing, squeezing, etc. the objects in the set-up.

This coding system was applied to both, infants' and caregivers' gesture production.

Coding Reliability

Two coders coded the parent–child interaction recordings. The first author of the present study coded 100% of the videos and a second coder, a trained psychologist blind to participant group assignment, coded 36% of the videos. These were 37.5% of the data of the ASD group, 46.15% HR and 33.33% of the TD group and were randomly selected for quality assurance. Inter-rater reliability was calculated on gesture annotations. The percentage of agreement for a total of 425 observations (i.e., gestures) was 88.9% (Cohen's Kappa; $\kappa = 0.867$).

Data Analyses

In order to answer the first research question on group differences in overall *pointing* production, we counted all the pointing subtypes (*no contact index finger pointing*, *contact index finger pointing*, *no contact open palm pointing* and *contact open palm pointing)* in a global category of *total pointing*. For the second research question that involved the group comparisons in *pointing* based on the parameters of *handshape* and *contact with the referent*, the subcategories *no contact index finger pointing*, *contact index finger pointing*, *no contact open palm pointing* and *contact open palm pointing* were collapsed attending to the two morphological features. Thus, the final measures consisted of two categories with two mutually exclusive levels: A category of *handshape*, with the levels *index finger pointing* and *open palm pointing*, and a category of *contact with the referent*, with the levels *no contact pointing* and *contact pointing*. Finally, the category *instrumental gestures* was excluded from the analysis due to the very low number of children producing them (two children in the ASD group).

Due to the nonnormal distribution of various measures, group differences in *handshape*, *contact with the referent* and object manipulation were analyzed with nonparametric tests (Kruskal–Wallis H test). Wilcoxon rank sum test (also known as Mann–Whitney U test) was employed as post hoc pairwise comparison test, and a correction for False Discovery Rate was carried out for the *pointing gestures* measures (*handshape* and *contact with the referent*) with the Benjamini Hochberg method. *Handshape*, *contact with the referent* and *object manipulation* were included, separately, as within-subjects factors, and group (ASD, HR and TD) as between-subjects factor when testing for group differences with the Kruskal–Wallis H test.

The analyses on caregiver gesture production followed the same steps described for infant gesture production.

The caregiver-to-child pointing production ratio was calculated by dividing the caregivers' pointing counts according to *handshape* and *contact with the referent*, by infants' pointing counts attending to the same features. For instance, in order to obtain the caregiver-to-child pointing production ratio based on *handshape*, and on *index finger* more specifically, the counts of caregivers' *index finger pointing* were divided by the counts of infants' *index finger pointing*. Following the previous example, a number larger than 1 in the ASD caregiver-to-child ratio would indicate a larger proportion of *index finger pointing* for the caregivers group than the children group with ASD. The resulting numbers were used in the same procedure described above to analyze group differences in toddlers' pointing production (i.e., Kruskal–Wallis *H* test and Mann–Whitney *U* test as post hoc pairwise comparison test).

Results

Descriptive statistics of all the coded behaviors in the three groups of children are provided in Table 1.

Total Production of Pointing Gestures

Consistent with previous studies, Kruskal–Wallis *H* test revealed that there were group differences in the total production of *pointing gestures*, χ^2 = 6.75, df = 2, P = 0.034 (P-value after FDR correction with the BH method). Post hoc pairwise comparisons with the Wilcoxon rank sum test revealed that the ASD group produced significantly fewer total *pointing gestures* than the TD group (W = 68.5, P = 0.009, d = −1.02) (Fig. 4). The production of the HR group was not found to be significantly different from the ASD and TD group (ASD × HR: W = 80.5, P = 0.312, d = −0.480; HR × TD: W = 84.5, P = 0.199, d = −0.600).

Morphological Features of Pointing

Handshape. Statistically significant differences were found in *index finger pointing* (χ^2 = 7.69, df = 2, P = 0.021). Post hoc pairwise comparisons showed that the ASD group produced significantly fewer *index finger pointing gestures* than the TD group (W = 65.5, P = 0.006, d = −1.08) (Fig. 5). The HR group was not found to be significantly different from the ASD and TD groups (ASD × HR: W = 76, P = 0.226, d = −0.567; HR × TD: W = 81, P = 0.154, d = −0.613).

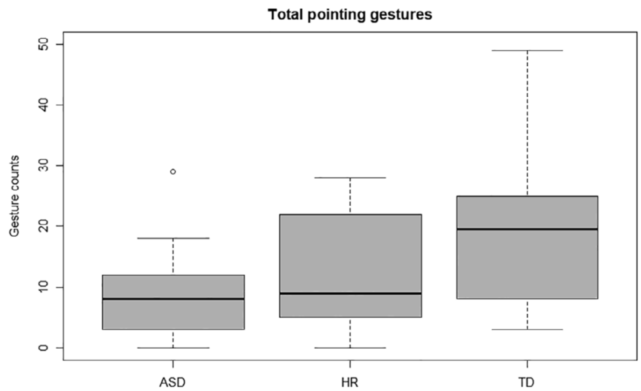

Figure 4. Total pointing gesture.

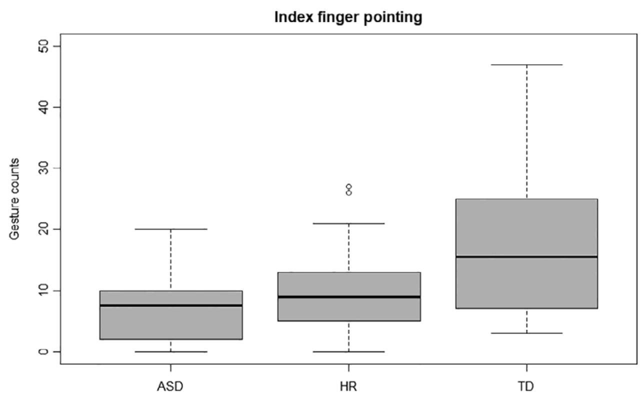

Figure 5. Index finger pointing production.

Table 1. Descriptive Statistics of Child Pointing Gesture and Object Manipulation Counts by Group

	ASD (n = 16; F = 2)			HR (n = 13; F = 7)			TD (n = 18; F = 7)		
	M (SD)	Min	Max	*M* (SD)	Min	Max	*M* (SD)	Min	Max
Total pointing	8.75 (7.27)	0	29	12.8 (9.56)	0	28	20.0 (13.5)	3	49
Index pointing	6.75 (5.56)	0	20	10.8 (8.87)	0	27	18.1 (13.4)	13.4	47
Open palm pointing	2.00 (2.73)	0	9	1.92 (3.17)	0	12	1.94 (2.04)	0	6
No contact pointing	5.19 (4.69)	0	17	6.15 (3.74)	0	12	12.1 (10.1)	2	41
Contact pointing	3.56 (3.48)	0	12	6.62 (8.12)	0	23	7.89 (8.63)	0	36
Object manipulation	7.31 (6.69)	0	19	8.46 (7.13)	0	21	5.56 (3.03)	0	10

M: mean; SD: standard deviation.

Contact with the referent. Kruskal–Wallis *H* test revealed significant group differences in the production of *no contact pointing* (χ^2 = 6.88, df = 2, *P* = 0.032). As predicted, the ASD group displayed a significantly fewer number of *no contact pointing gestures* than the TD group (ASD × TD: *W* = 73, *P* = 0.014, *d* = −0.861) (Fig. 6). The HR group was not found to be significantly different from the ASD group (*W* = 83.5, *P* = 0.377, *d* = −0.480), but a trend to significance was found in the comparison of the HR and the TD group (*W* = 74, *P* = 0.087, *d* = −0.735).

Object Manipulation

Contrary to our predictions, no statistically significant group differences were found in object manipulation (χ^2 = 0.557, df = 2, *P* = 0.756).

Caregiver Gesture Production

Descriptive statistics of all the coded behaviors in the three groups of caregivers are provided in Table 2.

No statistically significant result was found in caregivers' gesture production measures except for *instrumental gestures* (χ^2 = 7.47, df = 2, *P* = 0.023). Post hoc pairwise comparisons revealed that caregivers with ASD children produced a greater number of *instrumental gestures* compared to the caregivers of TD children (*W* = 216, *P* = 0.007, *d* = 1.02) (Fig. 7).

Caregiver object manipulation. No statistically significant differences were found in *object manipulation* across the caregivers of ASD, HR and TD children.

Caregiver-to-Child Gesture Production Ratios

Caregiver-to-child gesture ratios were obtained by dividing the counts of caregivers' pointing gestures (*index finger*, *open palm*, *contact* and *no contact pointing*, separately) by the counts of children's pointing gestures (same categories listed for caregivers' pointing). Kruskal–Wallis *H* test was used to test group differences (caregivers of ASD children, caregivers of HR children and caregivers of TD children) and Wilcoxon rank sum test as post hoc pairwise comparison test for each of the ratio category.

Caregiver-to-child index finger pointing production ratio. This ratio was obtained by dividing the counts of caregivers' *index finger pointing* by the counts of children *index finger pointing*. Kruskal–Wallis *H* test showed a statistically significant group difference (χ^2 = 9.35, df = 2, *P* = 0.009). Post hoc pairwise comparisons revealed differences between the ratios of the caregivers with ASD children and the caregivers of TD children (*W* = 184,

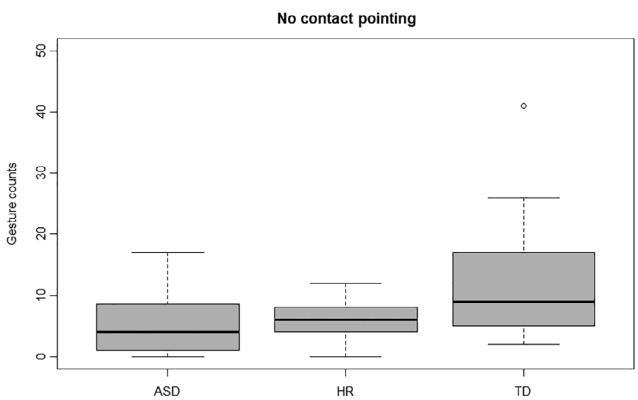

Figure 6. No contact pointing production.

Figure 7. Caregivers' instrumental gestures.

Table 2. Descriptive Statistics of the Coded Caregiver Behaviors by Group

	ASD caregivers (*n* = 16)			HR caregivers (*n* = 13)			TD caregivers (*n* = 18)		
	M (SD)	Min	Max	*M* (SD)	Min	Max	*M* (SD)	Min	Max
Total pointing	17.8 (12.3)	0	50	15.8 (9.27)	6	37	14.1 (8.91)	1	41
Index pointing	17.5 (12.2)	0	50	15.0 (8.31)	6	32	13.7 (8.86)	1	41
Open palm pointing	0.31 (0.60)	0	2	0.84 (1.46)	0	5	0.33 (0.76)	0	3
No contact pointing	8.31 (8.55)	0	35	5.92 (3.75)	1	12	7.00 (5.25)	0	18
Contact pointing	9.50 (6.04)	0	20	9.92 (8.10)	0	25	7.06 (7.61)	0	29
Object manipulation	4.81 (4.29)	0	14	4.92 (4.73)	0	15	2.56 (2.55)	0	9
Instrumental gestures	3.31 (3.75)	0	10	3.08 (6.51)	0	24	0.55 (1.15)	0	4

M: mean; SD: standard deviation.

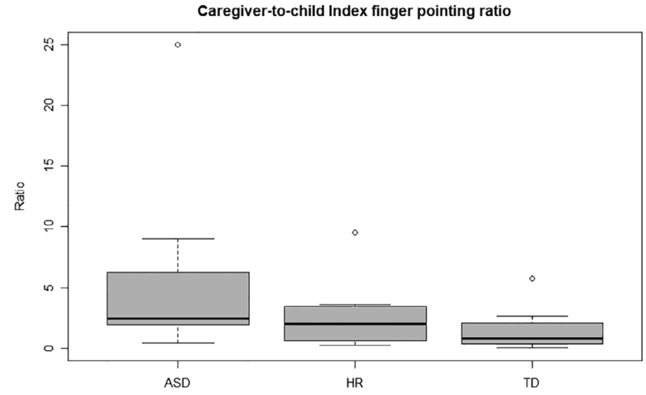

Figure 8. Caregiver-to-child index finger pointing ratio.

$P = 0.007$, $d = 0.511$). No differences were found in the group of caregivers with HR children (ASD × HR: $W = 97.5$, $P = 0.301$, $d = 0.332$; HR × TD: $W = 138.5$, $P = 0.204$, $d = -0.420$) (Fig. 8).

Caregiver-to-child no contact pointing production ratio. This ratio was obtained by dividing the counts of caregivers' *no contact pointing* by children's *no contact pointing* counts. No statistically significant group differences were found among the three groups of caregivers ($\chi^2 = 2.91$, df = 2, $P = 0.232$).

Caregiver-to-child object manipulation ratio. The caregiver-to-child object manipulation ratio was obtained by dividing the counts of caregivers' *object manipulation* by children's *object manipulation* counts. No statistically significant difference was found across caregivers ($\chi^2 = 2.38$, df = 2, $P = 0.304$).

Discussion

The present study aimed at providing a comparative analysis of the morphology of pointing gesture production in ASD, children at high risk for autism (HR) and TD children, within a taxonomy of manual features, attending to *handshape* and *contact with the referent*. The goal was to fill a gap in extant research identified in the scoping review by Manwaring et al. [2018] and to provide a more objective assessment in the study of gesture production with a focus on *deictic pointing gestures* in ASD. The current taxonomy is novel in that it dissects the gesture movement into two crucial features, the presence of an extended index finger and (absence of) contact with the referent, both of which characterize mature and sophisticated declarative pointing. Two additional behavioral measures were included, *instrumental gestures* and *object manipulations*. *Instrumental gestures* have been identified as specific to individuals with autism [Mastrogiuseppe et al., 2015] and involve a peculiar hand configuration (i.e., grasping the hand/arm of the communicative partner). The number of instrumental gestures was very low with only two children with autism producing them, and were excluded from further analysis. *Object manipulations*, for their part, were measured, as they involve manual acts which, unlike gestures, do not perform a communicative purpose. These same measures were collected also for parents and analyzed for possible differences that could influence toddlers' performance, thus providing a reliable measure of child-to-caregiver alignment. Furthermore, a robust *pointing* elicitation paradigm, used for the first time in atypical populations, was employed for the assessment of spontaneous *pointing gesture* production.

The results from the analyses of the data confirmed our original expectations. Thus, the children from the ASD group produced fewer *pointing gestures* than the typically developing children (TD) based on a composite measure of *total pointing gestures*. The analysis of *pointing gesture* by type revealed a significant difference between the children with autism and the typically developing children, both in handshape and contact with the referent. Thus, the children with autism produced fewer *index finger pointing gestures* and fewer *no contact pointing gestures* than typical controls. This difference in the nature of the gestures produced by the children with autism is thus indicative of a qualitative difference in gesture production. This finding is consistent with previous studies documenting a prevalence of specific behavior types, such as requesting or behavior regulation behaviors over others [Maljaars, Noens, Jansen, Scholte, & van Berckelaer-Onnes, 2011; Paparella, Stickles Goods, Freeman, & Kasari, 2011]. However, these earlier studies are based on behavior function rather than a characterization of gesture morphology offered in the present study. The current results reveal an important developmental difference in gesture production between children on the autism spectrum and typically developing children concerning the fine motor characteristics of *pointing gestures*. In the present study, the typically developing children were younger than the participants with autism (Fig. 1). We demonstrate that *index-finger pointing* was less evident in the group with autism, in addition to *pointing without contact with the referent*. It has been suggested that *deictic pointing gesture* is referential in nature and is used, on a par with language, to direct the interlocutor's attention to a referent, and is as such inherently related to speech [Butterworth, 2003], as well as providing a first important step toward true symbolic use [Werner & Kaplan, 1963]. Just like language, *distal (no contact) pointing* is useful in referring to entities regardless of their proximity (spatial or temporal) to the speaker, and, as such, approximates deictic words in its potential to refer to a variety of objects, situations or people. Recent work in language typology argues that demonstratives constitute a universal class of spatial terms that invoke an egocentric, bodyanchored frame of reference grounded in basic principles of spatial and social cognition [Diessel, 2014], thus establishing a link between the physical manual action world and symbolic systems. *Distal (no contact) pointing* is characterized by two features, the presence of an extended index finger and the absence of contact with the referent, both of which were included in the current analyses. These features can thus be used independently and/or jointly for the identification of more sophisticated and mature forms of pointing across development.

While we had hypothesized that children on the autism spectrum would manipulate objects more than their TD peers, we found no statistically significant group differences in that respect. Interestingly, a recent study [West, Roemer, Northrup, & Iverson, 2020] found impaired object manipulation in HR infants who subsequently received an ASD diagnosis. There is an important methodological difference, however, between the current study and West et al. [2020] which lies in the definition of "object manipulation." While our category follows a traditional understanding of object manipulation (i.e., touching, tapping, caressing, squeezing, etc.), the actions described as "object manipulation" by West et al. [2020] involved those that traditionally fall under functional acts, which exploit the object's affordances, such as making a toy plane fly, brushing your teeth, etc. Such actions have been argued to lead to more advanced symbolic actions of the type evident in pretend play [Bretherton et al., 1981]. Thus, the results in West et al. [2020] of delayed production of this gesture category in children at risk for autism are consistent with the idea that symbol formation might be impaired on the autism spectrum [Vulchanova & Vulchanov, in press]. In addition, and in line with the interpretation in West et al. [2020], it is plausible, that these results are due to motor difficulties in the broader spectrum. Thus, motor impairments could also explain the difficulties in *index finger pointing* in the ASD group observed in the current study, on an assumption that pointing with an extended index finger is motorically more complex than open palm pointing [Butterworth, 2003].

Our findings are consistent with the notion that *index finger pointing* without contact with the referent is the most complex form of nonverbal communication. The deficits observed in the autism group suggest a developmental delay and evidence an earlier, less sophisticated, stage in the production of communicative gestures in children on the spectrum. To the best of our knowledge, our results provide the first objectively measured evidence of a deficit in *distal (no contact) pointing* on the autism spectrum.

The current results suggest that children at high risk for autism are an intermediate group, given the absence of statistically significant differences between them and the two other participant groups. It is important to stress that a trend to significance was found in *distal (no contact) pointing* between the HR and the TD children. This comes to suggest that children at high risk display gesture behavior similar to both children with autism and to children with typical development. This is consistent with the idea of a broad autism phenotype (BAP), whereby siblings and family members of individuals with autism present with similar cognitive and behavioral traits [Rubenstein & Chawla, 2018]. It is also consistent with the evidence that the autism traits in the BAP/HR population are subdiagnostic and many children in that group will not go on to receive a diagnosis.

Importantly, the parallel parent–child analyses of gesture production provide evidence that the infant and toddler gesture production in the study cannot have been influenced by parental gesture behavior, given the absence of statistically significant differences between the caregivers' groups. The only statistically significant difference in caregivers' gesture production was found in *instrumental gestures*, whereby the parents of children with autism produced significantly more *instrumental gestures* than the other two groups. This is an interesting result, as we had rather expected to find this behavior in the child ASD group. We interpret this finding as indicative of parental eagerness to perhaps compensate for the absence of child gesture behavior.

Finally, the caregiver-to-child pointing production ratio showed significant differences in the ratios of *index finger pointing* between the ASD and the control groups, with the parents of children with autism producing overwhelmingly more *deictic pointing* gestures than their children in comparison to the parents and children in the control group. Using the same experimental paradigm, Kishimoto [2017] demonstrated that caregivers produced more index-finger points than younger children, while the production ratio becomes more balanced, as the children grow older and mature. Taken together, these results and the *instrumental gesture* results above, indicate that the participating children with autism do not easily pattern their behavior after the parents, neither by producing more *instrumental gestures*, nor by copying the frequent *index finger pointing* of the parents. This is consistent with the evidence of lack of flexibility and adjustment to circumstances in response to social context (*Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* (5th ed.; DSM V; American Psychiatric Association [APA], 2013). In addition, the lack of balance in deictic gesture production between the caregivers and the children with autism suggests that these children are at an earlier stage in development in comparison to their typical peers.

The lack of group differences in pointing production between the parents of children with ASD, parents of children at high risk for ASD and parents of typically developing children shows that children with ASD are also exposed to rich communicative environments, thus, having the same opportunities to learn how to use gestures in a communicative way. However, the group differences in caregiver-to-child gestural ratio reveal that ASD children fail to reciprocate parents' communicative behavior, most probably as a result of the social and communication deficit in that population. Indeed, Curcio [1978] found impaired gestural imitation in nonverbal ASD children between 4 and 12 years of age, which is close to our sample age-wise.

The current study is among the very few to study a mixed group of children with autism reflecting the variation observed on the spectrum (see also Maljaars et al., 2011). The ASD group in the study was characterized by the high variability in the severity level of the participants in this group, which was also reflected in the lack of normal distribution. Often, research in autism has been criticized for low validity by providing evidence of a subsection of the spectrum only, specifically, of the higher end of it. Chakrabarti [2017; p. 436] noted that "Research on the autistic phenotype has focused mostly on higher functioning individuals on the spectrum, neglecting those on the lower end." Taking into consideration that the ASD is an umbrella term that covers a wide range of severity levels [APA, 2013], it is important to describe the behavioral patterns of individuals across the spectrum. Our results thus provide a more reliable picture of the condition as a whole.

The precise characterization of the morphology of gesture based on handshape and presence/absence of contact with the referent provides a system for identification of early gesture production in typical children and children with autism of value for both caregivers and professionals. The features on which the system is based are directly observable and easily recognized and can thus be directly implemented in early detection and intervention.

The current study is not without its limitations. Like many studies of young participants with autism, and aiming at longitudinal data collection, the current one is based on a relatively small sample size. In addition, originally recruited participants had to be dropped from further study due to comorbid conditions or preterm birth. The data which were collected feature primarily pointing gestures, given the controlled design. Finally, the production of *instrumental gestures* was restricted to two participants with autism, and thus, were not analyzed and reported presently, due to their extremely low prevalence in the data.

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Ethical Considerations

The study conforms to the standards of the Declaration of Helsinki and was reviewed and received the approval of The Ethics Committee for the Research on Human Participants of the University of the Basque Country to conduct the data collection in Spain and received the approval of The Regional Committee for Medical Research Ethics (REC Central Norway) to conduct the data analyses in Norway. Written consent was obtained from all the caregivers/legal tutors of the children that participated in the study.

Authorship

SR-C collected the data, conducted the data analyses and wrote the manuscript. VV and MV wrote the Discussion section and revised the manuscript for submission.

Conflict of Interest Statement

The authors have no conflict of interest to declare.

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