Social interactions between 24-month-old children and their older sibling with autism spectrum disorder: Characteristics and association with social-communicative development

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Abstract

This study compared sibling interactions between 24-month-old children and their older sibling with ASD (high-risk; *n*=24) with 24-month-old children and their typically developing older sibling (low-risk; *n*=32). First, high-risk sibling pairs showed lower levels of positive behaviour and younger siblings of children with ASD imitated their older sibling less. Second, in the high-risk group positive interactions were positively associated with the youngest child's language abilities. However, this association was no longer significant after controlling for language abilities at 14 months. Third, more total interactions in the high-risk group, both negative and positive, were associated with more ASD characteristics. Thus, early sibling interactions might reveal interesting information in light of the (atypical) developmental trajectories of younger siblings of children with ASD.

Autism spectrum disorder (ASD) is characterized by persistent deficits in social communication and social interaction (American Psychiatric Association 2013). These deficits, including atypicalities in eye contact, joint attention, responsiveness (to social cues), imitation, and social orienting or interest, are often evident in the first two years of life (Bryson et al. 2007; Osterling, Dawson, & Munson 2002; Wetherby, Watt, Morgan, & Shumway 2007; Zwaigenbaum et al. 2005). In addition, receptive as well as expressive language development is frequently delayed and/or deviant in children with ASD (Barbaro & Dissanayake 2012) and clinically significant structural language impairments are common (Boucher 2012).

The risk of recurrence of ASD in siblings of children with ASD (hereafter, *high-risk siblings*; HR-sibs) is estimated around 18.7% (Ozonoff et al. 2011). In addition, HR-sibs more frequently show subclinical features of ASD, also referred to as the Broader Autism Phenotype (BAP) (Ozonoff et al. 2014; Sucksmith, Roth, & Hoekstra 2011). This includes delays in social communication such as the use of eye contact, gestures, and orientation to name (Gamliel, Yirmiya, & Sigman 2007; Gammer et al. 2015; Mitchell et al. 2006; Toth, Dawson, Meltzoff, Greenson, & Fein 2007). Aside from BAP, HR-sibs without ASD also show more language difficulties, such as delays in receptive language (Hudry et al. 2014; Toth et al. 2007) or are delayed in their cognitive development during the first three years of life (Brian et al. 2014). Thus, the developmental trajectories of HR-sibs are often characterized by early deficits, irrespective of a later ASD diagnosis. Consequently, studies evaluating possible risk or protective factors for HR-sibs with atypical developmental trajectories would be valuable.

The heritability of the susceptibility to ASD is estimated between 64 and 91%, dependent on the prevalence rate used (from 1% up to 5% for BAP) (Tick, Bolton, Happé, Rutter, & Rijsdijk

2016). In addition, when studying ASD, environmental factors and the gene-environment interaction need to be considered as well (Mandy & Lai 2016), particularly at a young age when brain plasticity is high and social communication and language develop rapidly (Barbaro & Dissanayake 2012; Elsabbagh & Johnson 2010). Although it is clear that the social environment does not *cause* ASD, it can influence the manifestation of the ASD phenotype and its functional impact (Mandy & Lai 2016). Early child characteristics such as social-communicative and language impairments can have an impact on the social interactions with family members. This can for example result in a diminished active engagement in social interaction, which may lead to a limited exposure to adequate social input. Since social input is needed to promote the development of social communication and language during early sensitive periods, altered social interactions can mediate the link between early susceptibilities and later outcome (Boucher 2012; Dawson 2008; Mandy & Lai 2016). Moreover, Bijou and Ghezzi's (1999) behaviour interference theory poses that children with ASD are less inclined to orient towards social stimuli, inhibiting the development of reinforcing social stimuli needed to promote later social and verbal behaviour (Bijou & Ghezzi 1999). Nevertheless, in comparison to genetic and neurobiological research, research on the social environment in ASD is limited.

In typical development, caregivers and siblings are the most important social interaction partners during infancy and early childhood (Lamb 1978). Sibling interactions have an impact on the social-communicative, emotional, cognitive and behavioural development of young children (Buist & Vermande 2014; Harrist et al. 2014). During these interactions there is a bidirectional influence of the characteristics and behaviours of both interaction partners (Gottlieb 2007; Pettit & Arsiwalla 2008), changing the nature of the interaction over time.

Warm sibling interactions characterized by natural teaching and caregiving experiences benefit the development of both siblings (Brody 2004; Buist & Vermande 2014; Feinberg, Solmeyer, & McHale 2012). In addition, more positivity in the sibling relationship and more positive behaviours of the older sibling are linked to better empathy development of the younger sibling (Tucker, Updegraff, McHale, & Crouter 1999). Conversely, negative sibling interactions can lead to poorer developmental outcomes (Bank, Patterson, & Reid 1996). Sibling interactions that mainly consist of conflict lead to higher levels of anxiety and depression, and lower levels of academic or social competence and global self-worth (Buist & Vermande 2014). However, some level of conflict, in balance with warmth, can promote the development of anger management and conflict resolution skills (Brody, Stoneman, & Mackinnon 1982).

Siblings influence each other through *social learning*, including observing each other, immediate or deferred imitation and modelling (Bandura 1977; Feinberg et al. 2012; Whiteman, McHale, & Soli 2011). In typically developing sibling dyads, younger siblings are more likely to imitate their older brother or sister than vice versa (Whiteman, Bernard, & McHale 2010). Through observing, remembering and imitating actions from their older sibling, HR-sibs might learn ASD-specific behaviours contributing to a behavioural phenotype that resembles the BAP or the early ASD phenotype. In addition, due to the presence of social-communicative and language impairments in children with ASD and possibly in HR-sibs as well, their sibling interactions may differ in social quality or occur less frequently (resulting in less social input). Together with other contributing factors (e.g., family stressors), this may affect the HR-sibs’ development. There is some evidence suggesting that lower levels of social input or less positivity during sibling interactions are associated with deficits in the development of language and empathy (Kuhl 2004; Tucker et al. 1999).

It is important to emphasize that sibling interactions are embedded within a broader social environment. Different interactional systems (e.g., siblings, parents, peers) are likely to influence and interact with each other, influencing child development. In addition, characteristics of the child and social environment influence each other in a bidirectional way (Dawson 2008; Gottlieb 2007). Thus, the association between the sibling interaction and the development of HR-sibs depends on characteristics of the other interaction partner (e.g., ASD severity and behavioural difficulties of the child with ASD) as well as other social contexts (e.g., maternal depression, family stressors; Walton & Ingersoll 2015). Support has been found for a diathesis-stress model, suggesting an interaction between early susceptibilities of the HR-sib (e.g., BAP characteristics) and aspects of the social environment (Walton & Ingersoll 2015).

Although research on characteristics of sibling interactions including a child with ASD is scarce, it provides some support for the reduced social interactions within HR sibling pairs. The studies of Knott, Lewis, and Williams (1995, 2007) found that, in comparison to children with Down syndrome, children with ASD (age range: 3;10-9;0 years) initiated fewer interactions, were less responsive and spent less time with their younger/older sibling (age range: 1;11-12;5 years). Walton and Ingersoll (2015) reported that HR-sibs (mean age: 10;43 years) were less involved and more avoidant during interactions with their brother/sister with ASD (mean age: 9;35 years), compared to typically developing sibling pairs. In the study of Kaminsky and Dewey (2001), based on self-report, HR-sibs (mean age: 11;67 years) reported less conflict than siblings of typically developing children. However, since early signs of ASD are already visible in the first two years of life (e.g., Barbaro & Dissanayake 2012; Zwaigenbaum et al. 2005), and given that the transactional processes between infants and the social environment start from birth onwards, studying sibling interactions in a younger age group is necessary to increase our understanding of the characteristics of sibling interactions including a child with ASD. In addition, since sibling interactions are associated with children's social-communicative functioning in typical development, these associations should also be evaluated in sibling pairs including a child with ASD.

The present study aimed to characterize the social interactions between 24-month-old HR-sibs and their older siblings with ASD. These HR sibling pairs were compared with low-risk (LR) sibling pairs of 24-month-old LR-sibs and a typically developing older sibling to evaluate whether sibling interactions differed between both groups. In line with the studies of Knott et al. (1995, 2007) and Walton and Ingersoll (2015), suggesting fewer interactions and less involvement in HR sibling pairs, and considering the social-communicative and language impairments in children with ASD as well as a considerable proportion of HR-sibs, we expected lower levels of social interaction in HR sibling pairs compared to LR sibling pairs.

Second, we evaluated the rate at which HR-sibs imitated their older sibling with ASD in comparison with low-risk controls, which is an important aspect of social learning. In line with research reporting impaired immediate imitation in HR-sibs (Stone, McMahon, Yoder, & Walden 2007; Zwaigenbaum et al. 2005), we expected that HR-sibs would imitate their sibling less than LR-sibs.

Finally, the association between the frequency of sibling interactions and the youngest siblings' social-communicative (including ASD-characteristics) and language abilities at 24 months was evaluated. If early sibling interactions have an impact on child development, as previously suggested based on the social learning theory and research in typically developing populations (e.g., Brody 2004), we would expect an association between the overall sibling interactions and the HR-sib's current development. In addition, these associations could differ depending on the valence of these sibling interactions. Based on research in typically developing sibling pairs, we expected positive associations between warm/positive sibling interactions and social-communicative and language skills. Regarding negative sibling interactions, existing literature is inconsistent reporting both positive and negative associations with child development (Bedford, Volling, & Avioli 2000; Buist & Vermande 2014). Hence, we were not able to formulate specific hypotheses or expectations with regard to negative sibling interactions. When considering the increased level of ASD-characteristics in HR-sibs and the social learning processes that occur during early sibling interactions, we also aimed to assess whether an association exists between the HR-sibs' ASD characteristics and the interaction with their sibling with ASD.

Methods

Participants

Participants were 24-month-old children and their older sibling, who were drawn from an ongoing prospective follow-up study of both younger siblings of children with ASD (high-risk siblings; HR-sibs) and a control group of younger sibling of typically developing children (low-risk siblings; LR-sibs). The sample comprised 56 sibling pairs, including 24 high-risk sibling pairs (9 male-male, 8 female-male, 2 male-female and 5 female-female; younger-older) and 32 low-risk sibling pairs (9 male-male, 9 female-male, 10 male-female and 4 female-female). LR sibling pairs consisted of LR-sibs and their older typically developing sibling (TD-sibs) without first- or second-degree relatives with ASD. HR sibling pairs included HR-sibs and their older sibling with a formal ASD diagnosis (ASD-sibs). ASD diagnosis was made by a multidisciplinary team and confirmed with the Social Responsiveness Scale, Second Edition (SRS-2; Constantino & Gruber 2012), and the Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord 2003). SCQ and SRS were available for all 24 children with ASD. Fifteen children scored above the threshold for ASD on both the SCQ and the SRS, the other nine scored above the threshold on the SRS. As part of the multidisciplinary assessment, cognitive functioning of children with ASD was evaluated using either the Wechsler Intelligence Scale for Children (WISC-III-NL; Kort et al. 2005), the Wechsler Preschool and Primary Scale of Intelligence (WPPSI-III-NL; Hendriksen and Hurks 2009), the Snijders-Oomen Non-Verbal Intelligence Test (SON-R; Tellegen et al. 1998), or the Bayley Scales of Infant Development (BSID-II-NL: Meulen et al. 2004; Bayley-III-NL: Baar et al. 2014). Eleven of the children with ASD scored within the normal range (IQ between 85-115). Of the other 13 children, 3 scored very low (IQ<55), 9 children scored below average (IQ between 55-85), and 1 child scored above average (IQ>115).

Sample characteristics are presented in Table 1. To calculate the family's socioeconomic status (SES), Hollingshead's four factor index was used based on both parents' education level and occupation (Hollingshead 1975). In both groups, the family SES score corresponded with the fourth social stratum as defined by Hollingshead (medium business, minor professional, technical). There were no significant group differences in the sex ratio of both younger and older siblings or in the chronological age of the youngest sibling or family SES. ASD-sibs were on average older than TD-sibs ($F(1,54)=23.498$, $p<.001$).

Table 1. *Sample characteristics and general description play observation*

	Low-risk (*n*=32)	High-risk (*n*=24)	
	Sibling pair		
Family SES (*M*(*sd*))	51.81 (7.00)	45.67 (11.39)	*U* = 269.50
Education mother	*6.38(0.79)*	*5.42(1.14)*	
Occupation mother	*6.47(2.17)*	*5.71(2.77)*	
Education father	*5.97(1.09)*	*4.67(1.40)*	
Occupation father	*6.59(1.81)*	*5.33(2.71)*	
Time spent together (%)			$\chi^2(1) = 8.65$*
Never/seldom	7%	35%	
Sometimes	23%	30%	
Often/always	70%	35%	
Day-care attendance (%)	93%	70%	$\chi^2(1) = 5.22$*
Representative? (% yes)	**83.3%**	**78.3%**	$\chi^2(1) = .219$
	Youngest sibling		
Chronological age			
M(*sd*)	24.75 (.77)	24.69 (.77)	*F*(1,54) = .072
Range	23.23-27.03	23.23-26.40	
Sex ratio (M:F)	19:13	11:13	$\chi^2(1) =1.01$
Interaction (%)	**19.4%**	**19.6%**	*U* = 383.00
Mutuality	4.2%	4.6%	*U* = 332.00
Interaction with parent	6.6%	7.8%	*U* = 382.00
Interaction with experimenter	8.6%	7.2%	*U* = 342.00
Non-interaction (%)	**80.6%**	**80.4%**	*U* = 383.00
Orientation to sibling	7.1%	9.3%	*U* = 316.00
Solitary play	73.5%	71.1%	*U* = 330.00
	Oldest sibling		
Chronological age			
M(*sd*)	55.69 (13.91)	87.85 (34.00)	*F*(1,54) = 23.498 ***
Range	36.50-97.03	47.43-154.37	
Sex ratio (M:F)	18:14	17:07	$\chi^2(1) = 1.24$
Interaction (%)	**16.5%**	**18.4%**	*U* = 339.00
Mutuality	4.1%	4.7%	*U* = 333.00
Interaction with parent	4.1%	7.1%	*U* = 372.00
Interaction with experimenter	8.3%	6.6%	*U* = 318.50
Non-interaction (%)	**83.5%**	**81.6%**	*U* = 339.00
Orientation to sibling	4.2%	6.5%	*U* = 309.50
Solitary play	79.3%	75.1%	*U* = 324.50

Note. Chronological age is reported in months; *p<.05,***p<.001; *M*=mean, *sd*=standard deviation

To assess the social experiences of the younger siblings, parents were asked whether or not their youngest child attended day-care and how often both siblings were together at home (seldom/sometimes/often). As shown in Table 1, LR-sibs more frequently attended day-care than HR-sibs (93% vs. 70%; $\chi^2(1)=5.22$, $p=.031$). In addition, siblings in the LR group spent more time together than siblings in the HR group ($\chi^2(1)=8.65$, $p=.013$).

Procedure

As part of the prospective follow-up study, both HR- and LR-sibs were assessed at 24 months. This included the Mullen Scales of Early Learning (MSEL; Mullen 1995), the Autism Diagnostic Observation Schedule-Second Edition (ADOS-2; Lord et al. 2012), the Dutch version of the MacArthur-Bates Communicative Development Inventory (N-CDI; Fenson et al. 1993; Zink & Lejaegere 2002), and the Quantitative Checklist for Autism in Toddlers (Q-CHAT; Allison et al. 2008). Descriptive characteristics as well as group differences are presented in Table 2. Compared to LR-sibs, HR-sibs showed lower scores in terms of language development (MSEL receptive language) and cognitive functioning (MSEL Early Learning Composite) as well as a higher level of ASD characteristics (ADOS social affect and total score).

An additional appointment was scheduled at the participants' home to observe sibling interactions. Children were encouraged to play together at the beginning of each session. They were given zoo-themed building blocks, a marble run and an animal sound keyboard, with which they could play consecutively for 10, 10 and 5 minutes. Different sets of toys were chosen to elicit different kinds of play (parallel, associative and cooperative play). Since there were no clear systematic differences in sibling interaction characteristics between the three play contexts, the scores were summed and considered as one play interaction. During the observation, one parent was always present in the room, continuing normal routines (e.g., household tasks or work). Parents were asked not to interfere during the play observation. If children initiated social interaction with the parent, they could respond briefly as they normally would. At the beginning of each appointment, parents received general information about the study and were asked to sign an informed consent.

Table 2. *Language level, cognitive functioning and ASD characteristics of HR and LR siblings (mean(standard deviation))*

	Low-risk (*n*=32)	High-risk (*n*=24)	
MSEL			
Receptive language	26.31(2.43)	23.88(5.08)	*F*(1,54)=5.659*
Expressive language	22.78(2.09)	21.25(4.31)	*F*(1,54)=3.090
Early Learning Composite	105.44(10.16)	96.29(21.51)	*F*(1,54)=4.475*
N-CDI			
Word comprehension	94.62(18.98)	82.38(26.38)	*F*(1,40)=3.052
Word production	66.23(23.50)	50.50(29.95)	*F*(1,40)=3.596
ADOS-2			
Social affect	1.78(1.07)	3.08(1.95)	*U*=218.50**
Repetitive and stereotyped behaviours	3.63(2.42)	4.08(2.87)	*U*=350.50
Total	1.56(1.11)	2.92(2.15)	*U*=247.50*
Q-Chat	24.81(6.53)	22.15(7.09)	*F*(1,38)=1.379

Note. MSEL=Mullen Scales of Early Learning; N-CDI=the Dutch version of the MacArthur-Bates Communicative Development Inventory; ADOS-2=Autism Diagnostic Observation Schedule-2nd edition (Calibrated Severity Score); Q-Chat=Quantitative Checklist for Autism in Toddlers

Measures

The *MSEL* (Mullen 1995) is a comprehensive measure of five developmental domains for infants and preschool children (0-68 months): Gross Motor, Fine Motor, Visual Reception, Receptive Language, and Expressive Language. Overall cognitive ability is represented by the Early Learning Composite (ELC). The MSEL has demonstrated good internal consistency and test-retest stability (Mullen 1995).

The *N-CDI* (Fenson et al. 1993; Zink & Lejaegere 2002), is a parent-report measure of receptive and expressive vocabulary. It yields meaningful raw counts of word comprehension as well as word production. When compared with a language measure that uses professional observation, the Dutch Non-Speech Test (NNST; Zink & Lembrechts 2000), the N-CDI has adequate reliability or internal consistency and good criterion validity. The (N-)CDI has previously been used in populations with or at risk for ASD (e.g., Adamson, McArthur, Markov, Dunbar, & Bakeman 2001; Luyster, Lopez, & Lord 2007; Samango-Sprouse et al. 2015; Zwaigenbaum et al. 2005).

The *ADOS-2* (Lord et al. 2012) is a semi-structured, standardized assessment of communication, social interaction, play/imaginative use of materials, and restricted and repetitive behaviours. Based on the child's language level, either the toddler module (82%) or module 2 (18%) was administered. In line with Shephard et al. (2016) Calibrated Severity Scores were used for Social Affect, Repetitive and Restricted Behaviours, and Total Score (Gotham, Pickles, & Lord 2009; Hus, Gotham, & Lord 2014) to account for differences in module administration and language level.

The *Q-CHAT* (Allison et al. 2008) contains 25 items, scored on a 5-point scale, and is a screening tool to identify ASD-symptoms in toddlers. It is especially useful in the identification of threshold and sub-threshold autistic features and has potential as a quantitative phenotypic measure (Allison et al. 2008).

The combination of the ADOS-2 and Q-CHAT provides us with both an observational measure as well as a parent-report measure of ASD characteristics in high-risk siblings. In the high-risk group, the correlation between both measures was moderate (ADOS Social Affect: r=.440; ADOS Restricted and Repetitive Behaviours: r=.450; ADOS Total score: r=.411). In the low-risk group, the correlation was low (ADOS Social Affect: r=.197; ADOS Restricted and Repetitive Behaviours: r=-.006; ADOS Total score: r=.169).

Sibling interaction

All play sessions were videotaped and the behaviours of both siblings were coded. For play with marble run and blocks, both lasting 10 minutes, the middle 8 minutes were selected and coded using The Observer XT, version 11.5 (Noldus 2013). For play with keyboard, lasting 5 minutes, the middle 4 minutes were selected for coding. The middle of each session was coded because we expected the middle part to be the most representative for the entire play session and to allow for a short familiarisation phase in the beginning of each session. First, a frequency coding scheme was used. Frequencies of social initiations and responses, both negative and positive, were coded. *Social initiations* are communicative attempts to initiate a new interaction, directed towards another individual. *Responses* are related to and follow a previous initiation within five seconds. Initiations and responses can be either positive/prosocial (e.g., sharing a toy, allowing the other sibling to do something) or negative (e.g., refusing a request). Next, the time children spent in interaction with each other (mutuality), with the parent and with the experimenter was also coded. To account for the time not spent in interaction with another person, the following non-interactive behaviours were coded: distress, doing nothing or looking at a random object, orientation towards the sibling or sibling's activity, repetitive/stereotyped behaviour, and time spent in a purposeful activity (e.g., play).

Second, to obtain a broader evaluation of the course of the play observation, five global rating scales were included. Each scale ranged from 1 (low frequency/quality) to 5 (high frequency/quality). *Interference of the parent* refers to the extent to which the parent interfered or interrupted during the play observation. *Proximity* indicates the distance between both children during play. In this scale, interpersonal distance is taken into account as well. Two children who are further away in distance but are in close interaction (e.g., dancing together from a distance), are considered to be in close proximity. *Imitation* of the younger as well as the older sibling was coded when the child shows behaviour that is a direct and exact repetition of the other child. Finally, *togetherness* reflects the degree to which both children are enjoying the interaction *together*. Examples of togetherness are: warmth, positive affect, joint pleasure, engagement in a joint activity, mutuality, sharing, etc.

Clips were independently rated by trained master students blind to the participants' diagnostic status. Prior to coding the clips included in this study, coders were intensively trained using practice tapes until interrater reliability was at a minimum of 90% (i.e., agreement with the criterion set by the first author). The training continued until each of the coders was reliable. If not reliable, training continued using new practice tapes. Approximately 15% of the clips (39 clips in total) included in the study were then randomly selected to determine interrater agreement and were coded by all coders. Next, single measures intraclass correlation coefficients (ICC) were calculated. ICC's between .60-.74 reflect good interrater agreement and ICC's between .75-1.00 reflect excellent interrater agreement (Cicchetti 1994). Due to their low frequency, the following behaviours could not be coded reliably (ICC<.60) and are therefore excluded from further analyses: distress, doing nothing or looking at a random object, repetitive/stereotyped behaviour, and imitation by the oldest sibling. For the frequency coding scheme, ICC's of the included behaviours ranged between .74 and .95 for the youngest child and between .76 and .96 for the oldest child. For the global rating scales, ICC's ranged between .76 and .84.

Data analysis

Preliminary analyses revealed several outliers in the data (i.e., values higher/lower than the mean +/- 3 times the standard deviation (sd)). Since outliers were not considered to be random but characteristic of our sample, outliers were replaced by the highest/lowest value allowed (mean +/- 3sd) rather than deleted.

Concerning the *first research question*, we first provided a general description of the play observation. To this end, proportions were calculated of how long children were engaged in different types of behaviour (i.e., proportion of time spent in interaction, play, etc.) and several global scales (interference of parent, proximity, togetherness) were evaluated. Because both the assumptions of normality and equal variances were violated for several variables, parametric analyses were less valid. In addition, due to many zero values (complicating data transformation) and the fact that transforming the data complicates the interpretation of the data (e.g., Sainani 2012), we opted to use non-parametric analyses. Proportions and global ratings were compared between groups using the Mann-Whitney U test. Second, it was evaluated whether group status predicted social initiations and responses (positive and negative), accounting for sample characteristics that differed between groups (the age of the oldest sibling, day-care attendance, time spent together, MSEL, ADOS). Accordingly, regression models including 'group' (high-risk vs. low-risk) and these sample characteristics as predictors and sibling interaction characteristics as dependent variables were tested. Assumptions for multivariate regression analyses were met.

Regarding the *second research question*, it was evaluated whether group status predicted imitation of the youngest child. To this end, a regression model with group (high-risk vs. low-risk) and sample characteristics (age oldest child, day-care attendance, time spent together, MSEL, ADOS) as predictors was tested with imitation of the youngest sibling as dependent variable.

To answer the *third research question* and evaluate the association between sibling interactions and child development, regression models including the sibling interaction characteristics as predictors and language and social-communicative abilities at 24 months as dependents were evaluated. However, it is possible that pre-existing language abilities of HR-sibs influenced the association between the sibling interaction characteristics and language (MSEL, N-CDI) at 24 months. Therefore, scores on the MSEL and N-CDI at 14 months were added as predictors in the regression model to determine whether the sibling interaction characteristics would still significantly predict development at 24 months when taking development at 14 months into account.

Correlation analyses revealed high intercorrelations between several child interaction variables, leading to multicollinearity in the regression model. Especially positive initiations and positive responses of both children were significantly (p<.05) intercorrelated as well as negative initiations and negative responses. Correlations between positive behaviours ranged from r=.33 to r=.85 while correlations between negative behaviours ranged from r=.43 to r=.82. To address the problem of multicollinearity, a total interaction composite was first created by summing all behaviours, both positive and negative. This allowed us to evaluate whether more interaction, regardless of its nature, would predict development. The presence of both positive and negative exchanges can contribute to child development, not only separately but also combined. In addition, to evaluate the importance of the valence of these interactions, positive initiations/responses of both children on the one hand

and negative initiations/responses of both children on the other hand were summed to form two composite scores: *positive behaviour* and *negative behaviour*. Reliability analyses revealed a good internal consistency for both composite scores with Cronbach's alpha's of .81 for positive behaviour and .88 for negative behaviour.

Results

General description of the play observation

To get a general idea of the course of the play observations, it was evaluated how much time children spent in *direct* mutuality with their sibling (i.e., a bout of interaction characterized by initiations and responses, either positive or negative, and lasting at least a few seconds), in interaction with the parent/researcher, or engaged in non-interactive activities. These proportions are presented in Table 1 and did not significantly differ between groups.

Interaction. In both groups, children spent 16-20% of the play observation in interaction with another interaction partner (sibling/parent/researcher). Of the total play session, siblings only spent less than 5% in *mutual interaction* with each other. The overall feel of *togetherness* (i.e., global rating of the degree to which both children are enjoying the interaction together) was 1.85 in the LR group and 1.68 in the HR group, meaning that there were short instances of togetherness between both children, but not frequently. The difference between groups was not significant (U=270.50, p=.091). The average *proximity* between both children was 3.92 (frequent proximity) in the LR group and 3.46 (occasional to frequent proximity) in the HR group, but did not significantly differ between groups (U=272.50, p=.102). In addition to the interaction with each other, children also interacted with their parent(s) (4-8%) or with the researcher (7-9%).

Non-interaction. Although children were often in close proximity, the majority of the play observation consisted of solitary play (71-79%). Of the remaining time, children spent 4 to 9% of their time observing their sibling.

Parents were asked to stay in the room while the children were playing and to only intervene when absolutely necessary. In both groups, the average score on *interference of the parent* was around 2, meaning that parents only sporadically intervened during the play observation. *Interference of the parent* did not significantly differ between groups (U=306.50, p=.292). In addition, the majority of parents indicated that the observed play observation was representative for a typical play observation at home (LR: 83%; HR: 78%).

Group differences in social interaction and imitation

It was evaluated whether group status (high-risk vs. low-risk) predicted social initiations and responses as well as imitation of the youngest child while accounting for sample characteristics. Descriptives of the sibling interaction characteristics are shown in Table 3. Regression models and regression coefficients are presented in Table 4 (youngest sibling) and Table 5 (oldest sibling).

First, the regression models for positive behaviours of the youngest and oldest sibling were (marginally) significant. Group status significantly predicted positive initiations of the youngest child (β=-.429, t=-2.330, p=.024), responses of the youngest child (β=-.550, t=-3.255, p=.002), positive initiations of the oldest child (β=-.497, t=-3.190, p=.003), and positive responses of the oldest child (β=-.588, t=-3.538, p=.001). All four behaviours occurred more frequently in the LR group compared to the HR group. The regression models for negative behaviours were not significant.

Table 3. Descriptives (mean(standard deviation)) for sibling interaction characteristics

	LR	HR
	Frequency - Youngest sibling	
Negative initiations[a]	4.04(5.03)	2.44(2.66)
Positive initiations[a]	5.48(4.51)	3.38(3.52)
Negative responses[a]	6.73(5.93)	7.83(6.69)
Positive responses[a]	16.49(8.93)	12.14(10.83)
Mutuality[b]	48.08(45.74)	54.68(79.76)
Interaction with experimenter[b]	99.41(78.74)	83.18(66.51)
Interaction with parent[b]	75.82(75.49)	90.62(113.86)
Orientation to sibling[b]	81.37(50.93)	106.54(75.76)
Play[b]	849.71(128.73)	823.45(118.83)
	Frequency - Oldest sibling	
Negative initiations[a]	10.13(5.93)	9.48(6.16)
Positive initiations[a]	10.95(8.72)	9.75(14.06)
Negative responses[a]	5.48(5.99)	5.11(4.98)
Positive responses[a]	7.93(6.36)	5.70(6.86)
Mutuality[b]	46.42(42.18)	54.28(79.63)
Interaction with experimenter[b]	97.55(91.02)	77.22(86.84)
Interaction with parent[b]	47.20(48.52)	83.50(114.87)
Orientation to sibling[b]	48.18(65.12)	76.06(108.00)
Play[b]	927.82(129.52)	880.50(165.92)
	Global rating scales	
Togetherness[c]	1.85(.55)	1.68(.84)
Proximity[c]	3.92(.84)	3.46(1.04)
Imitation youngest[c]	1.54 (.62)	1.20 (.26)
Interference[c]	1.98(.62)	2.25(.87)

Note. LR=low-risk, HR=high-risk; [a]results reflect absolute frequencies; [b]results reflect total duration (in seconds); [c]results reflect global rating (1-5)

Second, the regression model for imitation of the youngest child was marginally significant. Group marginally significantly predicted imitation (β=-.350, t=-1.962, p=.056), with higher levels of imitation in LR-sibs than in HR-sibs.

Third, sample characteristics significantly predicted characteristics of the sibling interaction. *Age of the oldest sibling* significantly predicted positive initiations of the oldest child (β=.938, t=5.634, p<.001) and positive responses of both children (youngest: β=.733, t=4.057, p<.001;

oldest: β=.761, *t*=4.278, *p*<.001). All behaviours were more frequent in older children. In addition, *time spent together* positively predicted imitation of the youngest sibling (β=.363, *t*=2.550, *p*=.014). Day-care attendance, MSEL scores or ADOS scores did not significantly predict sibling interaction characteristics.

Table 4. *Prediction of sibling interaction characteristics: Regression coefficients (youngest sibling)*

		B	***SE B***	**β**
Positive initiations	**R^2=.279, F(8,44)=2.131, p=.053**			
	Group	-3.624	1.555	-.429*
	Age oldest	.051	.028	.361
	Day-care	.751	1.694	.067
	Time spent together	-.896	.803	-.167
	MSEL Receptive Language	.554	.342	.489
	MSEL Early Learning Composite	-.131	.083	-.470
	ADOS Social Affect	.795	1.021	.287
	ADOS Total Score	-1.188	1.019	-.449
Negative initiations	**R^2=.135, F(8,44)=.858, p=.558**			
	Group	-2.584	1.728	-.301
	Age oldest	.029	.031	.204
	Day-care	-.657	1.882	-.058
	Time spent together	-.177	.893	-.032
	MSEL Receptive Language	.485	.380	.422
	MSEL Early Learning Composite	-.125	.092	-.443
	ADOS-2 Social Affect	-1.123	1.135	-.399
	ADOS-2 Total Score	.795	1.132	.296
Positive responses	**R^2=.391, F(8,44)=3.527, p=.003**			
	Group	-11.103	3.411	-.550**
	Age oldest	.248	.061	.733***
	Day-care	.897	3.717	.034
	Time spent together	2.561	1.762	.200
	MSEL Receptive Language	.205	.750	.076
	MSEL Early Learning Composite	-.025	.182	-.038
	ADOS-2 Social Affect	2.268	2.240	.343
	ADOS-2 Total Score	-1.997	2.235	-.316
Negative responses	**R^2=.174, F(8,44)=1.162, p=.343**			
	Group	.088	2.400	.007
	Age oldest	.054	.043	.263
	Day-care	-2.968	2.615	-.184
	Time spent together	.270	1.240	.035
	MSEL Receptive Language	.576	.527	.352
	MSEL Early Learning Composite	-.102	.128	-.253
	ADOS-2 Social Affect	.650	1.577	.163
	ADOS-2 Total Score	-1.419	1.573	-.372

Imitation	**R^2=.330, *F*(8,44)=2.645, *p*=.019**			
	Group	-.373	.190	-.350⁺
	Age oldest	.003	.004	.177
	Day-care	-.064	.210	-.046
	Time spent together	.250	.098	.363*
	MSEL Receptive Language	.034	.042	.241
	MSEL Early Learning Composite	-.001	.010	-.036
	ADOS-2 Social Affect	.149	.128	.419
	ADOS-2 Total Score	-.044	.126	-.132

Note. **p<.05,* ***p*<.01, ****p*<.001; +*p*=.056; MSEL=Mullen Scales of Early Learning; ADOS-2=Autism Diagnostic Observation Schedule-2nd edition (Calibrated Severity Score)

Table 5. Prediction of sibling interaction characteristics: Regression coefficients (oldest sibling)

		B	***SE B***	**β**
Positive initiations	**R^2=.483, *F*(8,44)=5.147, *p*<.001**			
	Group	-11.311	3.546	-.497**
	Age oldest	.358	.064	.938***
	Day-care	3.524	3.864	.117
	Time spent together	1.533	1.832	.106
	MSEL Receptive Language	.208	.779	.068
	MSEL Early Learning Composite	-.095	.189	-.127
	ADOS-2 Social Affect	1.296	2.329	.174
	ADOS-2 Total Score	-1.385	2.324	-.194
Negative initiations	**R^2=.148, *F*(8,44)=.957, *p*=.481**			
	Group	1.267	2.419	.105
	Age oldest	-.030	.043	-.148
	Day-care	-3.301	2.636	-.207
	Time spent together	1.044	1.250	.136
	MSEL Receptive Language	.177	.532	.109
	MSEL Early Learning Composite	.090	.129	.227
	ADOS-2 Social Affect	1.503	1.589	.379
	ADOS-2 Total Score	-1.574	1.586	-.415
Positive responses	**R^2=.411, *F*(8,44)=3.832, *p*=.002**			
	Group	-7.870	2.224	-.588**
	Age oldest	.171	.040	.761***
	Day-care	.919	2.423	.052
	Time spent together	-.606	1.149	-.071
	MSEL Receptive Language	.384	.489	.214
	MSEL Early Learning Composite	-.110	.119	-.251
	ADOS-2 Social Affect	1.057	1.461	.241
	ADOS-2 Total Score	-1.159	1.457	-.277

Negative responses	**R^2=.161, *F*(8,44)=1.059, *p*=.408**			
	Group	-.494	2.227	-.044
	Age oldest	.015	.040	.081
	Day-care	-3.036	2.426	-.205
	Time spent together	-.306	1.150	-.043
	MSEL Receptive Language	.855	.489	.568
	MSEL Early Learning Composite	-.170	.119	-.461
	ADOS-2 Social Affect	-.596	1.462	-.162
	ADOS-2 Total Score	-.258	1.459	-.074

Note. ***p*<.01, ****p*<.001; MSEL=Mullen Scales of Early Learning; ADOS-2=Autism Diagnostic Observation Schedule-2nd edition (Calibrated Severity Score)

Association with social-communicative and language abilities

Next, regression models were tested including the three sibling interaction composites (positive, negative, and total interaction) and imitation (at 24 months) as predictors. For each dependent variable, three regression models were tested. In a first model, the predictive value of the total interaction was tested. In a second model, positive and negative behaviour were added as two separate variables to evaluate whether the valence of the interaction would predict development. In a third model, the predictive value of imitation of the youngest child was evaluated. Results for the dependent variables that are significantly predicted by sibling interaction variables are presented in Table 6. A more extensive overview of the regression models is added in the Appendix. In addition to the regression models, in Table 7 an overview is presented of the correlations between the sibling interaction and social-communicative and language abilities (N-CDI, MSEL, Q-Chat) that were associated with the sibling interaction.

In the LR group, *total interaction* negatively predicted N-CDI word comprehension, accounting for 18.5% of the variance. Imitation of LR-sibs positively predicted N-CDI word production, accounting for 22% of the variance. In the HR group, *total interaction* positively predicted both MSEL receptive language and MSEL expressive language, explaining 24% and

26% of the variance, respectively. In addition, *total interaction* positively predicted the Q-Chat total score, accounting for 32% of the variance.

Table 6. *Prediction of language and social-communicative functioning: Regression models and predictor coefficients*

	Low-risk group			
		B	***SE B***	**β**
N-CDI word comprehension	**1. R^2=.185, $F(1,24)$=5.448, p=.028**			
	Total interaction	-.221	.095	-.430*
	2. R^2=.189, $F(2,23)$=2.683, p=.090			
	Positive behaviour	-.191	.130	-.276
	Negative behaviour	-.289	.170	-.320
N-CDI word production	**1. R^2=.218, $F(1,24)$=6.683, p=.016**			
	Imitation	17.204	6.655	.467*
	High-risk group			
N-CDI word production	**1. R^2=.219, $F(1,14)$=3.916, p=.068**			
	Total interaction	.340	.172	$.468^{+}$
	2. R^2=.270, $F(2,13)$=2.411, p=.129			
	Positive behaviour	.205	.243	.210
	Negative behaviour	.677	.405	.416
MSEL receptive language	**1. R^2=.242, $F(1,22)$=7.031, p=.015**			
	Total interaction	.063	.024	.492*
	2. R^2=.248, $F(2,21)$=3.470, p=.050			
	Positive behaviour	.068	.035	$.389^{+}$
	Negative behaviour	.057	.055	.208
MSEL expressive language	**1. R^2=.255, $F(1,22)$=7.524, p=.012**			
	Total interaction	.054	.020	.505*
	2. R^2=.262, $F(2,21)$=3.721, p=.041			
	Positive behaviour	.055	.029	$.369^{+}$
	Negative behaviour	.059	.046	.252
Q-Chat	**1. R^2=.320, $F(1,11)$=.5.179, p=.044**			
	Total interaction	.088	.039	.566*
	2. R^2=.336, $F(2,10)$=.2.525, p=.129			
	Positive behaviour	.074	.058	.346
	Negative behaviour	.127	.095	.365

Note. ^{+}p<.10, $^{*}p$<.05

N-CDI=Dutch version of the MacArthur-Bates Communicative Development Inventory; MSEL=Mullen Scales of Early Learning; Q-Chat=Quantitative Checklist for Autism in Toddlers

Table 7. Correlation between the sibling interaction variables and the social-communicative and language abilities of the youngest sibling

	Q-Chat	MSEL Receptive Language	MSEL Expressive Language	N-CDI Word Comprehension	N-CDI Word Production
			LR group		
Positive Behaviour	.079	.255	-.017	-.295	-.098
Negative Behaviour	-.086	-.013	-.220	-.336	-.102
Total interaction	.001	.186	-.135	-.430*	-.140
Imitation	.246	.293	.104	.201	.467*
			HR group		
Positive Behaviour	.465	.458*	.453*	.136	.337
Negative Behaviour	.478	.337	.374	.248	.480
Total interaction	.566*	.492*	.505*	.211	.468
Imitation	.274	.277	.128	.156	.229

Note. *$p<.05$

Pre-existing language abilities: Language at 14 months

To determine whether sibling interaction characteristics would still predict language at 24 months when controlling for language at 14 months, pre-existing language abilities were taken into consideration for those models that significantly predicted child development at 24 months. Only the language variables at 14 months that showed an association with development at 24 months were added to the regression models. In the *high-risk group*, correlational analyses revealed significant positive correlations between MSEL receptive language at 14 months and MSEL receptive language as well as MSEL expressive language at 24 months. In addition, both N-CDI word production and N-CDI word comprehension at 14 months correlated significantly with N-CDI word comprehension and N-CDI word production at 24 months. In the *low-risk group*, there was a significant positive correlation between N-CDI word comprehension and N-CDI word production at 14 and N-CDI word comprehension at 24 months. In addition, N-CDI word comprehension at 14 months was associated with N-CDI word production at 24 months.

At step 1, the sibling interaction variables (model 1: total interaction, model 2: positive and negative behaviour, model 3: imitation) were added. At step 2, the MSEL or N-CDI scores at 14 months were added.

First, in the HR group, MSEL receptive language at 14 months was added to the models predicting MSEL receptive and expressive language. Both models were significant (receptive: R^2=.374, F(2,18)=5.378, p=.015; expressive: R^2=.605, F(2,18)=13.780, p<.001) with MSEL receptive language at 14 months as a significant predictor in both models (receptive: β=.430, t=2.123, p=.048; expressive: β=.662, t=4.117, p=.001). The *total interaction* composite was no longer a significant predictor (receptive: β=.298, t=1.472, p=.158; expressive: β=.224, t=1.391, p=.181). Second, in the LR group, N-CDI word comprehension and word production at 14 months were added to the model predicting N-CDI word comprehension at 24 months, and N-CDI word comprehension at 14 months was added to the model predicting N-CDI word production at 24 months. The model for N-CDI word comprehension was significant (R^2=.546, F(3,19)=7.629, p=.002) with N-CDI word comprehension at 14 months as a significant predictor (β=.613, t=2.865, p=.010). Again, the t*otal interaction* composite was no longer a significant predictor (β=-.233, t=-1.443, p=.165). The model for N-CDI word production was also significant (R^2=.333, F(2,20)=4.997, p=.017) with imitation of the youngest sibling as a marginally significant predictor (β=.413, t=2.074, p=.051).

Discussion

Sibling interaction: high-risk vs. low-risk group

The current study used a naturalistic, observational method to evaluate sibling interactions between 24-month-old children and their older sibling. With regard to the *first research question*, sibling interaction characteristics in the HR group (HR-sibs and their older sibling with ASD) were compared with those in the LR group (LR-sibs and their older typically developing sibling). On the one hand, sibling interactions in the HR and LR group were similar on important domains such as negative interactions, mutuality, togetherness and proximity between both siblings. Moreover, in both groups there were high levels of solitary play and low levels of mutual interaction. When parents were asked how frequent their children played together, they also often made a distinction between parallel play, which occurred frequently, and mutual play, which occurred only once in a while. Therefore, the finding that mutual interaction was low in both groups was not surprising. On the other hand, significant differences were observed. Consistent with previous studies (Knott et al. 1995, 2007; Walton & Ingersoll 2015), siblings interacted less frequently with each other in the HR group. More specifically, both siblings in HR-dyads showed lower levels of *positive* behaviour compared to LR-dyads. HR-sibs and children with ASD were less likely to positively initiate social interaction (e.g., sharing, helping, smiling) and showed fewer positive responses (e.g., following an instruction, giving a toy upon request, returning a smile). Levels of conflict or negative behaviour did not differ between groups. Next, to answer the *second research question*, imitation of the youngest child was evaluated. Even though the frequency of imitation was relatively low in both groups, there was a trend that HR-sibs imitated their older sibling less frequently than LR-sibs during sibling interactions. This is in line with previous studies suggesting low levels of imitation in younger siblings of children with ASD (Stone et al. 2007; Zwaigenbaum et al. 2005). After controlling for age of the oldest sibling, day-care attendance of the youngest sibling, the amount of time both children spent together at home, MSEL and ADOS scores, group status (high-risk vs. low-risk) remained a (marginally) significant predictor of both positive behaviour and imitation of the youngest child during the sibling interaction.

Previous studies have demonstrated the importance of (positive) sibling interactions for the development of both siblings (Brody 2004; Feinberg et al. 2012; Kuhl 2004; Tucker et al. 1999). However, when positive social approaches and responses of an older sibling with ASD are limited, possibly resulting in fewer bouts of positive interaction, younger HR-sibs might miss out on opportunities to practice adequate social behaviours. A decrease in social input may in turn contribute to the atypical developmental trajectories of HR-sibs (Dawson 2008). The degree to which atypical social behaviour of the older sibling affects the HR-sib's development might also depend on characteristics of the HR-sib. For example, Knott and colleagues (2007) found that typically developing HR-sibs compensated for the impairments of their sibling with ASD by taking over the leadership position. This was not found in the current study, but the children in our sample were on average younger compared to the sample of Knott and colleagues (2007). It is possible that toddlers are less inclined or less able to take over the dominant position compared to school-aged children. In addition, HR-sibs who show signs of the BAP or early ASD might experience social-communicative difficulties themselves. Therefore, lower levels of social input during sibling interactions might influence vulnerable HR-sibs differently than typically developing HR-sibs. Although positive sibling interactions occurred less frequently in the HR group, there was no difference in the frequency of negative sibling interactions or the general feeling of togetherness/mutuality. Having a sibling with ASD does therefore not necessarily lead to heightened levels of conflict or negativity, which is reassuring for many parents with children with ASD. In addition, at this age, the level of mutuality or closeness was similar in both groups, albeit similarly low. As both children grow older and opportunities for joint play increase, this might change. Further research is needed at later time points.

Association with language and social communication

Concerning the *third research question*, associations between sibling interaction characteristics and the youngest child's language and social-communicative abilities were evaluated. First, we found positive associations between the sibling interaction and language development at 24 months. In general, in the HR group but not in the LR group, a higher frequency of initiatives and responses was associated with better receptive and expressive language. In addition, it seemed that positive interactions more than negative interactions were associated with better language on the Mullen Scales of Early Learning (Mullen 1995). Even though positive interactions were less frequent in the HR group, these positive exchanges appear to benefit the language development of HR-sibs. Positive social exchanges such as demonstrating something or conversing provide learning opportunities for the HR-sib to practice their own language as well as observe the language of others. In contrast, surprisingly, in the LR group there was a *negative* association between the sibling interaction and language comprehension. It could be that younger siblings with lower scores on word comprehension ask more clarifying questions during social interaction (e.g. "what's that?", "ball?"), a key process during early language development. Given that the association between the sibling interaction and word comprehension is no longer significant after controlling for pre-existing language abilities, it seems more plausible that the language abilities of the younger sibling determine the course of the sibling interaction than that the sibling interaction has a direct influence on the younger sibling's word comprehension. Finally, in the LR group there was a positive association between imitation of the youngest sibling and language production, which is in line with existing research linking imitation to later expressive language (e.g., Charman et al. 2000). Due to the cross-sectional nature of these associations we cannot distinguish whether sibling interactions stimulate language development, or whether better language abilities lead to more (positive) sibling interactions. Nor can we exclude the possibility that other factors mediate the relationship between sibling interactions and language. Finally, it is noteworthy that associations between the sibling interaction and development differ between groups. We can therefore not assume that sibling interaction processes that impact development in the LR group also impact development in the HR group (and vice versa).

To conclude that sibling interaction characteristics promote development, we would not only expect a positive association between the sibling interaction and language, but we would also expect that this positive association remains significant after controlling for pre-existing language abilities at 14 months. To this end, the MSEL and N-CDI scores at 14 months were included. We could conclude that, for all significant regression models, language abilities at 14 months rather than sibling interaction characteristics at 24 months explained language development at 24 months. Therefore, based on these results, there is insufficient evidence to conclude that sibling interactions promoted language in this sample of participants. It is logical to assume that the language abilities of both interaction partners at the time of the observation have a significant impact on the quality and frequency of sibling interactions. For example, HR-sibs with better language abilities are more able to initiate positive interactions or to respond positively to an interaction of their sibling.

In addition to pre-existing abilities, future research should also take the broader social context into account when evaluating the association between sibling interactions and HR-sibs' developmental trajectories. Parent-child interactions can also influence the development of their children. For example, parental behaviours such as sharing attention or responsive verbal language are important for later social responsiveness and language development in children with ASD (Clifford & Dissanayake 2009; Haebig, McDuffie, & Weismer 2013). It is therefore possible that parental behaviours compensate for lower levels of social input from the sibling interaction. Next to the parents, other children in the family may also provide learning opportunities for the younger siblings included in this study. In the LR group, only 4 families included more than 2 siblings. In the HR group, however, 14 families consisted of the HR-sib, the ASD-sib and at least one other sibling. Thus, the family context and parent-child interactions could also influence the association between sibling interactions and outcome.

Second, higher levels of *total* interaction (positive and negative) at 24 months were positively associated with more parent-reported ASD characteristics as measured with the Q-Chat (Allison et al. 2008), but not with the ADOS scores (Lord et al. 2012). Although the level of immediate imitation during the sibling interaction was low in the HR group and not associated with the Q-Chat scores, this does not exclude the possibility that HR-sibs learn behaviours from their older sibling with ASD. In addition to *immediate* imitation, new behaviours are often acquired through deferred imitation, modelling or social learning and older siblings can be powerful models (Bandura 1977; Whiteman et al. 2011). Thus, social learning may be, among others, an important process to take into consideration when studying the development of HR-sibs. Consequently, in line with our expectations, HR-sibs might learn ASD-specific behaviours from their older sibling that are also measured by the Q-Chat (e.g., lining up toys, tip-toe walking, repetitive behaviours, echolalia). The correlations between the Q-Chat and ADOS scores were moderate, demonstrating a positive association between parent-report and a more comprehensive observation measure for ASD.

Nevertheless, sibling interaction characteristics only predicted *parent-reported* ASD characteristics. It is possible that parents observe different behaviours at home or that they interpret the behaviour of their child differently (e.g., exaggerating subtle behaviours) than researchers, resulting in differences between parent-report and observational methods.

Implications and strengths

The current study entails theoretical implications. Several studies have noted important differences between HR-sibs and siblings of typically developing children (e.g., Brian et al. 2014; Gamliel et al. 2007; Yirmiya et al. 2006), but sibling interactions have rarely been included in studies of HR-sibs. The current study was the first to assess both sibling interaction characteristics in sibling pairs with a child with ASD and the association with the language and social-communicative development of the youngest sibling. Not only were there significant differences between both groups in terms of positive initiations and responses, the association with the younger sibling's development was more pronounced in the HR group. The combination of early vulnerabilities and altered social interactions or social learning could contribute to the increased risk of ASD or the broader autism phenotype in HR-sibs. It needs to be noted however that in addition to the significant differences, there were also several similarities between groups. There were, for example, comparable levels of negative social interactions in the HR and LR group. Since conflict as well as positive interactions both contribute to child development, this means that the sibling interaction of HR-sibs also entails learning opportunities. Although future research is needed to better understand the interplay between environmental and genetic/biological factors, the current study shows that the early sibling interactions should be taken into account, including both differences and similarities between HR and LR groups.

A second implication relates to the choice of play materials. To observe the sibling interaction, different play materials were chosen to elicit different levels of play. Because group differences were largely similar in all contexts, the different play contexts were combined to present the results more clearly. However, the building blocks allowed for too much solitary or parallel play, discouraging mutual interaction, while the keyboard did not always allow for joint play and more frequently resulted in conflict. In contrast, the marble run seemed to lead to a good balance of both solitary and joint play and was probably best suited to observe the sibling interactions. Future research aiming to observe sibling interactions should consider play materials that allow for both parallel and joint/mutual play.

An (important) strength of this study is the use of a naturalistic, observational method. Compared to self-report or parent-report, observations in a naturalistic setting may provide more representative insights in sibling interactions (Hastings & Petalas 2014; Lobato, Miller, Barbour, Hall, & Pezzullo 1991; Senapati & Hayes 1988). In addition, the sample included a very young age group. Given that interactions early in life possibly have an impact on later development (Dawson 2008; Seibert, Hogan, & Mundy 1982), it is important to evaluate sibling interactions in younger populations.

Limitations and future research

There are some limitations that need further consideration. The small sample size imposes several restrictions on the current study. First, it limits the generalizability of the study and the likelihood of detecting significant results due to a decreased power. In addition, because a (Holm-)Bonferroni correction further reduces the statistical power (Nakagawa 2004; Perneger 1998), we opted not to correct for multiple comparisons. Due to the combination of a lower statistical power because of the small sample size and the fact that we expected to detect small differences, applying a Bonferroni correction would greatly reduce the possibility of finding relevant group differences while there are in fact real world differences. Second, only a limited number of predictors could be included in the regression model. As a result, we were restricted in the amount of regression models we could test. Third, the combination of the small sample size and the distribution of our data did not allow for more elaborate, parametric analyses. Future research should focus on replicating the current results in a larger sample, matched on sample characteristics.

The cross-sectional nature of the analyses at 24 months limits our conclusions in terms of causality. In addition, as we only included measures for the development of the youngest child, we were unable to evaluate the association between sibling interactions and the development of children with ASD. More research, including longitudinal studies, is needed to assess to what extent sibling interactions might contribute to the development of both children.

At this point, since the prospective study is still ongoing, we were unable to evaluate the diagnostic status of the HR-sibs (ASD/BAP vs. no ASD) and distinguish HR-sibs with and without later ASD/BAP. This impedes us to draw conclusions regarding the value of sibling interactions for later ASD outcome. When all HR- and LR-sibs reach the age of 36 months, evaluations in terms of diagnostic status will be possible.

Conclusion

This study provides new insights into the association between the social environment of HR-sibs and their social-communicative and language development. Sibling interactions in sibling pairs with a child with ASD differ from sibling interactions between typically developing children. In addition, sibling interaction characteristics are associated with the

HR-sib's ASD characteristics. Given that siblings are important interaction partners during early childhood, an evaluation of the role of sibling interactions in the developmental trajectories of HR sibs will be valuable to include in future research.

Appendix

Description of the global rating scales

Interference of the parent	The extent to which the parent is actively present during the play observation. This can be initiated by either the parent or the child, or can be triggered by the situation (e.g. marble run falls down). Observing the children is not taken into account. *Examples of child initiations*: complaining, seeking comfort, following the parent in the room, seeking physical contact. *Examples of parent initiations*: commenting on child behaviour, intervene during arguments, fights or aggressive behaviours.
Spatial proximity/closeness between both siblings	Spatial proximity refers to the distance between two people (important for social and emotional behaviour) or to the interpersonal distance between to people. For the current coding scheme, children are considered to be close to each other when they are within ca. 1-2 meters from each other. However, children can be further away and still in close interaction (e.g. when children are dancing together but are more than 2 meters apart). In this case, the interpersonal distance is low even though both children are further away from each other.
Repetitive, stereotyped and sensory behaviours	The child clearly shows repetitive, stereotyped or sensory/self-stimulating behaviours by using his/her voice, body or objects repeatedly in an unusual way. *Repetitive & stereotyped behaviours*: a broad range of behaviours including stereotypies, rituals, compulsions, obsessions, perseveration, and repetitive or stereotyped use of language. *Sensory behaviours*: a range of behaviours that are elicited from the presence of sensory stimuli. These behaviours may be present in any sensory modality and may include both sensory seeking behaviours – such as peering at an object, smelling objects, licking metal, and touching rough surfaces – and sensory avoiding behaviours, such as covering the ears to mute sound, refusing to eat foods of a certain texture, or intolerability for wearing certain fabrics.
Imitation	Child behaviour is coded as imitation when the behaviour is a direct and exact repetition of the other child's verbal communication (word, sentence), behaviour, actions, or body movements. Attempts to imitate the other child may also be coded here, but only when it's a clear and obvious attempt to imitate.
Togetherness	The degree to which both children are together in the interaction. Examples of togetherness are: observable signs of interpersonal warmth in the interaction (e.g., physical affection, expression of positive feelings, complementing), observable signs of positive affect (e.g., smiling due to an action of the other child), observable signs of joint pleasure (e.g., pleasure related to a joint activity, shared smiling), engagement in a joint activity, mutuality, sharing, etc.

Description of the frequency coding scheme

Social initiations	Initiations are clear, observable attempts (verbal or non-verbal) to initiate or continue/maintain an interaction. Initiations are only coded as initiations if the behaviour is directed towards the other person/child and if the behaviour is communicative. An initiation is either positive/prosocial (e.g., giving/sharing/ showing a toy, physical affection, praise, smiling) or negative/agonistic (e.g., physical or verbal aggression, snide comments or insults, object struggle). Social initiations are coded for each child separately.
Social responses	Responses are communicative behaviours (i.e., directed towards the other child) that follow the initiation of another child within 5 seconds and is related to this initiation. Responses can be either verbal or non-verbal and can be positive/prosocial (e.g., accepting a toy, responding to a question, returning a smile) as well as negative/agonistic (e.g., refusing to comply with a request, physical or verbal rejection, hitting back). 'No response' is coded when there are no changes in the child's ongoing behaviour as a result of a prosocial or agonistic act/initiation. Social responses are coded for each child separately
Mutuality	During mutuality, both children are oriented toward each other and have attention for each other (either actively involved with each other (e.g. initiation-response) or shared attention around a shared object/activity). Mutuality can be either positive (e.g., shared pleasure) or negative (e.g., conflict). This scale only reflects *sustained* mutuality, meaning that the mutuality has to last at least 2 seconds to be coded. Shorter social exchanges are captured by the initiation-response codes.
Interaction with the experimenter/parent	This scale includes any form of communicative behaviour (initiation or response) directed to the experimenter or the parent and should be coded for each child separately.
Orientation towards the sibling	This scale consists of all the child's behaviours that are directed towards the other child, but that aren't mutual or reciprocated. Tis includes for example initiations that aren't followed by a response or looking at the sibling or the sibling's activity.
Looking at a random object/doing nothing	The child clearly looks at an object (without the other child being close to that object or without the other child manipulating/playing with that object), the child is daydreaming, the child is seemingly doing nothing or the child isn't engaged in a purposeful activity.
Distress	The child shows clear signs of distress (e.g., crying, yelling, tantrum, wining).
Repetitive, Stereotyped or Sensory behaviour	The child clearly shows repetitive, stereotyped or sensory/self-stimulating behaviours by using his/her voice, body or objects repeatedly in an unusual way. *Repetitive & stereotyped behaviours*: a broad range of behaviours including stereotypies, rituals, compulsions, obsessions, perseveration, and repetitive or stereotyped use of language. *Sensory behaviours*: a range of behaviours that are elicited from the presence of sensory stimuli. These behaviours may be present in any sensory modality and may include both sensory seeking behaviours – such as peering at an object, smelling objects, licking metal, and touching rough surfaces – and sensory avoiding behaviours, such as covering the ears to mute sound, refusing to eat foods of a certain texture, or intolerability for wearing certain fabrics.
Solitary play	The child is engaged in a purposeful, useful activity with or without material (e.g. toys). When toys are used, the child at least attempts to use the toy in an adequate/appropriate way.

Prediction of child development - Low-risk group

		B	SE B	β
N-CDI word comprehension	**1. R^2=.185, F(1,24)=5.448, p=.028**			
	Total interaction	-.221	.095	-.430*
	2. R^2=.189, F(2,23)=2.683, p=.090			
	Positive behaviour	-.191	.130	-.276
	Negative behaviour	-.289	.170	-.320
	3. R^2=.040, F(1,24)=1.009, p=.325			
	Imitation	5.979	5.954	.201
N-CDI word production	**1. R^2=.020, F(1,24)=.483, p=.494**			
	Total interaction	-.089	.129	-.140
	2. R^2=.019, F(2,23)=.223, p=.802			
	Positive behaviour	-.079	.177	-.093
	Negative behaviour	-.108	.232	-.097
	3. R^2=.218, F(1,24)=6.683, p=.016			
	Imitation	17.204	6.655	.467*
MSEL receptive language	**1. R^2=.035, F(1,30)=1.078, p=.307**			
	Total interaction	.013	.013	.186
	2. R^2=.066, F(2,29)=1.023, p=.372			
	Positive behaviour	.025	.018	.257
	Negative behaviour	-.003	.022	-.028
	3. R^2=.086, F(1,30)=2.807, p=.104			
	Imitation	1.155	.689	.293
MSEL expressive language	**1. R^2=.018, F(1,30)=.553, p=.463**			
	Total interaction	-.008	.011	-.135
	2. R^2=.049, F(2,29)=.741, p=.485			
	Positive behaviour	.000	.015	-.004
	Negative behaviour	-.023	.019	-.220
	3. R^2=.011, F(1,30)=.326, p=.572			
	Imitation	.352	.617	.104
Q-Chat	**1. R^2=.000, F(1,25)=.000, p=.996**			
	Total interaction	.000	.036	.001
	2. R^2=.014, F(2,24)=.176, p=.840			
	Positive behaviour	.020	.049	.084
	Negative behaviour	-.029	.064	-.091
	3. R^2=.061, F(1,25)=1.611, p=.216			
	Imitation	2.525	1.989	.246

*Note. *p<.05; N-CDI=Dutch version of the MacArthur-Bates Communicative Development Inventory; MSEL=Mullen Scales of Early Learning; Q-Chat=Quantitative Checklist for Autism in Toddlers*

Prediction of child development controlling for development at 14 months - Low-risk group

		B	SE B	β
N-CDI word comprehension	**1. R^2=.546, F(3,19)=7.629, p=.002**			
	Total interaction	-.119	.083	-.233
	N-CDI word comprehension 14 months	.436	.152	.613*
	N-CDI word production 14 months	.067	.337	.043
	2. R^2=.553, F(4,18)=5.571, p=.004			
	Positive behaviour	-.157	.109	-.229
	Negative behaviour	-.061	.15	-.069
	N-CDI word comprehension 14 months	.451	.157	.634*
	N-CDI word production 14 months	.073	.345	.046
	3. R^2=.497, F(3,19)=6.250, p=.004			
	Imitation	-.121	5.702	-.004
	N-CDI word comprehension 14 months	.458	.188	.644*
	N-CDI word production 14 months	.135	.381	.086
N-CDI word production	**1. R^2=.190, F(2,20)=2.342, p=.122**			
	Total interaction	.004	.134	.006
	N-CDI word comprehension 14 months	.391	.186	.437*
	2. R^2=.197, F(3,19)=1.550, p=.0234			
	Positive behaviour	-.037	.177	-.043
	Negative behaviour	.085	.243	.077
	N-CDI word comprehension 14 months	.411	.196	.460*
	3. R^2=.333, F(2,20)=4.997, p=.017			
	Imitation	15.394	7.421	.413^{+}
	N-CDI word comprehension 14 months	.242	.178	.271
MSEL receptive language	**1. R^2=.029, F(2,26)=.384, p=.685**			
	Total interaction	.011	.014	.161
	MSEL receptive language 14 months	-.089	.248	-.070
	2. R^2=.065, F(3,25)=.582, p=.632			
	Positive behaviour	.023	.018	.246
	Negative behaviour	-.006	.023	-.053
	MSEL receptive language 14 months	-.090	.248	-.071
	3. R^2=.069, F(2,26)=.969, p=.393			
	Imitation	1.008	.741	.258
	MSEL receptive language 14 months	-.085	.242	-.066
MSEL expressive language	**1. R^2=.032, F(2,26)=.425, p=.658**			
	Total interaction	-.007	.012	-.111
	MSEL receptive language 14 months	.162	.212	.149
	2. R^2=.062, F(3,25)=.548, p=.654			
	Positive behaviour	.001	.016	.013
	Negative behaviour	-.021	.020	-.206
	MSEL receptive language 14 months	.162	.212	.148
	3. R^2=.039, F(2,26)=.525, p=.597			
	Imitation	.467	.644	.140
	MSEL receptive language 14 months	.146	.210	.134

Note. $^{+}p<.10$, $^{*}p<.05$; *N-CDI=Dutch version of the MacArthur-Bates Communicative Development Inventory; MSEL=Mullen Scales of Early Learning; Q-Chat=Quantitative Checklist for Autism in Toddlers*

Prediction of child development - High-risk group

N-CDI word comprehension	**1. R^2=.045, F(1,14)=.654, p=.432**			
	Total interaction	.135	.167	.211
	2. R^2=.066, F(2,13)=.456, p=.644			
	Positive behaviour	.057	.242	.067
	Negative behaviour	.326	.404	.228
	3. R^2=.024, F(1,14)=.348, p=.565			
	Imitation	15.234	25.815	.156
N-CDI word production	**1. R^2=.219, F(1,14)=3.916, p=.068**			
	Total interaction	.340	.172	.468$^+$
	2. R^2=.271, F(2,13)=2.411, p=.129			
	Positive behaviour	.205	.243	.210
	Negative behaviour	.677	.405	.416
	3. R^2=.052, F(1,14)=.774, p=.394			
	Imitation	25.408	28.879	.229
MSEL receptive language	**1. R^2=.242, F(1,22)=7.031, p=.015**			
	Total interaction	.063	.024	.492*
	2. R^2=.248, F(2,21)=3.470, p=.050			
	Positive behaviour	.068	.035	.389$^+$
	Negative behaviour	.057	.055	.208
	3. R^2=.077, F(1,21)=1.746, p=.201			
	Imitation	5.491	4.155	.277
MSEL expressive language	**1. R^2=.255, F(1,22)=7.524, p=.012**			
	Total interaction	.054	.020	.505*
	2. R^2=.262, F(2,21)=3.721, p=.041			
	Positive behaviour	.055	.029	.369$^+$
	Negative behaviour	.059	.046	.252
	3. R^2=.016, F(1,21)=.352, p=.559			
	Imitation	2.087	3.518	.128
Q-Chat	**1. R^2=.320, F(1,11)=.5.179, p=.044**			
	Total interaction	.088	.039	.566*
	2. R^2=.336, F(2,10)=2.525, p=.129			
	Positive behaviour	.074	.058	.346
	Negative behaviour	.127	.095	.365
	3. R^2=.075, F(1,11)=.891, p=.365			
	Imitation	7.099	7.519	.274

Note. $^+$*p<.10, *p<.05; N-CDI=Dutch version of the MacArthur-Bates Communicative Development Inventory; MSEL=Mullen Scales of Early Learning; Q-Chat=Quantitative Checklist for Autism in Toddlers*

Prediction of child development controlling for development at 14 months - High-risk group

		B	SE B	β
N-CDI word comprehension	**1. R^2=.672, F(3,8)=5.473, p=.024**			
	Total interaction	-.170	.176	-.214
	N-CDI word comprehension 14 months	1.278	.461	.962*
	N-CDI word production 14 months	-.367	1.110	-.109
	2. R^2=.721, F(4,7)=4.525, p=.040			
	Positive behaviour	-.282	.202	-.320
	Negative behaviour	.391	.542	.156
	N-CDI word comprehension 14 months	1.503	.498	1.131*
	N-CDI word production 14 months	-.950	1.217	-.281
	3. R^2=.688, F(3,8)=5.877, p=.020			
	Imitation	-29.537	25.119	-.280
	N-CDI word comprehension 14 months	1.187	.426	.894*
	N-CDI word production 14 months	.174	1.128	.051
N-CDI word production	**1. R^2=.674, F(3,8)=5.526, p=.024**			
	Total interaction	-.067	.177	-.084
	N-CDI word comprehension 14 months	1.019	.464	.758+
	N-CDI word production 14 months	.382	1.120	.112
	2. R^2=.689, F(4,7)=3.884, p=.057			
	Positive behaviour	-.126	.216	-.141
	Negative behaviour	.260	.578	.103
	N-CDI word comprehension 14 months	1.143	.531	.851+
	N-CDI word production 14 months	.050	1.299	.015
	3. R^2=.705, F(3,8)=6.362, p=.016			
	Imitation	-24.422	24.717	-.229
	N-CDI word comprehension 14 months	1.009	.419	.751*
	N-CDI word production 14 months	.768	1.110	.225
MSEL receptive language	**1. R^2=.374, F(2,18)=5.378, p=.015**			
	Total interaction	.037	.025	.298
	MSEL receptive language 14 months	.995	.469	.430*
	2. R^2=.381, F(3,17)=3.483, p=.039			
	Positive behaviour	.045	.034	.275
	Negative behaviour	.021	.053	.083
	MSEL receptive language 14 months	1.004	.484	.434+
	3. R^2=.329, F(2,17)=4.176, p=.033			
	Imitation	3.941	3.979	.199
	MSEL receptive language 14 months	1.174	.467	.506*
MSEL expressive language	**1. R^2=.605, F(2,18)=13.780, p<.001**			
	Total interaction	.025	.018	.224
	MSEL receptive language 14 months	1.417	.344	.662**
	2. R^2=.609, F(3,17)=8.822, p=.001			
	Positive behaviour	.032	.025	.208
	Negative behaviour	.014	.039	.060
	MSEL receptive language 14 months	1.424	.356	.666**

	3. R^2=.566, *F*(2,17)=11.091, *p*=.001			
	Imitation	1.481	2.862	.084
	MSEL receptive language 14 months	1.523	.336	.734***

Note. +p<.10, *p<.05, ***p<.01,***p<.001; N-CDI=Dutch version of the MacArthur-Bates Communicative Development Inventory; MSEL=Mullen Scales of Early Learning; Q-Chat=Quantitative Checklist for Autism in Toddlers*

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: Informed consent was obtained from all individual participants included in the study.

References

Adamson, L. B., McArthur, D., Markov, Y., Dunbar, B., & Bakeman, R. (2001). Autism and joint attention: Young children's responses to maternal bids. *Journal of Applied Developmental Psychology*, 22(4), 439–453.

Allison, C., Baron-Cohen, S., Wheelwright, S., Charman, T., Richler, J., Pasco, G., & Brayne, C. (2008). The Q-CHAT (Quantitative CHecklist for Autism in Toddlers): a normally distributed quantitative measure of autistic traits at 18–24 months of age: preliminary report. *Journal of Autism and Developmental Disorders*, 38(8), 1414–1425.

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

Bandura, A. (1977). *Social learning theory*. Englewood Cliffs, NJ: Prentice Hall.

Bank, L., Patterson, G. R., & Reid, J. B. (1996). *Negative sibling interaction patterns as predictors of later adjustment problems in adolescent and young adult males*. Ablex Publishing.

Barbaro, J., & Dissanayake, C. (2012). Developmental profiles of infants and toddlers with autism spectrum disorders identified prospectively in a community-based setting. *Journal of Autism and Developmental Disorders*, 42(9), 1939–1948.

Bedford, V. H., Volling, B. L., & Avioli, P. S. (2000). Positive consequences of sibling conflict in childhood and adulthood. *International Journal of Aging & Human Development*, 51(1), 53–69.

Bijou, S. W., & Ghezzi, P. M. (1999). The behavior interference theory of autistic behavior in young children. *Autism: Behavior Analytic Perspectives*, 33–43.

Boucher, J. (2012). Research review: Structural language in autistic spectrum disorder - characteristics and causes. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, 53(3), 219–233.

Brian, A. J., Roncadin, C., Duku, E., Bryson, S. E., Smith, I. M., Roberts, W., … Zwaigenbaum, L. (2014). Emerging cognitive profiles in high-risk infants with and without autism spectrum disorder. *Research in Autism Spectrum Disorders*, 8(11), 1557–1566.

Brody, G. H. (2004). Siblings' direct and indirect contributions to child development. *Current Directions in Psychological Science*, 13(3), 124–126.

Brody, G. H., Stoneman, Z., & Mackinnon, C. E. (1982). Role asymmetries in interactions among school-aged children, their younger siblings, and their friends. *Child Development*, 53(5), 1364–1370.

Bryson, S. E., Zwaigenbaum, L., Brian, J., Roberts, W., Szatmari, P., Rombough, V., & McDermott, C. (2007). A prospective case series of high-risk infants who developed autism. *Journal of Autism and Developmental Disorders*, 37(1), 12–24.

Buist, K. L., & Vermande, M. (2014). Sibling relationship patterns and their associations with child competence and problem behavior. *Journal of Family Psychology*, 28(4), 529–537.

Charman, T., Baron-Cohen, S., Swettenham, J., Baird, G., Cox, A., & Drew, A. (2000). Testing joint attention, imitation, and play as infancy precursors to language and theory of mind. *Cognitive Development*, 15(4), 481–498.

Cicchetti, D. V. (1994). Guidelines, criteria, and rules of thumb for evaluating normed and standardized assessment instruments in psychology. *Psychological Assessment*, 6(4), 284.

Clifford, S., & Dissanayake, C. (2009). Dyadic and triadic behaviours in infancy as precursors to later social responsiveness in young children with autistic disorder. *Journal of Autism and Developmental Disorders*, 39(10), 1369–1380.

Constantino, J. N., & Gruber, C. P. (2012). *Social Responsiveness Scale, second Edition (SRS-2)*. Torrance, CA: Western Psychological Services.

Dawson, G. (2008). Early behavioral intervention, brain plasticity, and the prevention of autism spectrum disorder. *Development and Psychopathology*, 20(3), 775–803.

Elsabbagh, M., & Johnson, M. H. (2010). Getting answers from babies about autism. *Trends in Cognitive Sciences*, 14(2), 81–87.

Feinberg, M. E., Solmeyer, A. R., & McHale, S. M. (2012). The third rail of family systems: Sibling relationships, mental and behavioral health, and preventive intervention in childhood and adolescence. *Clinical Child and Family Psychology Review*, 15(1), 43–57.

Fenson, L., Dale, P. S., Reznick, J. S., Thal, D., Bates, E., Hartung, J. P., … Reilly, J. S. (1993). *The MacArthur Communicative Developmental Inventories: User's guide and technical manual*. Baltimore: Paul H. Brookes Publishing Co.

Gamliel, I., Yirmiya, N., & Sigman, M. (2007). The development of young siblings of children with autism from 4 to 54 months. *Journal of Autism and Developmental Disorders*, 37(1), 171–183.

Gammer, I., Bedford, R., Elsabbagh, M., Garwood, H., Pasco, G., Tucker, L., … Pickles, A. (2015). Behavioural markers for autism in infancy: Scores on the Autism Observational Scale for Infants in a prospective study of at-risk siblings. *Infant Behavior and Development*, 38, 107–115.

Gotham, K., Pickles, A., & Lord, C. (2009). Standardizing ADOS scores for a measure of severity in autism spectrum disorders. *Journal of Autism and Developmental Disorders*, 39(5), 693–705.

Gottlieb, G. (2007). Probabilistic epigenesis. *Developmental Science*, 10(1), 1–11.

Haebig, E., McDuffie, A., & Weismer, S. E. (2013). Brief report: Parent verbal responsiveness and language development in toddlers on the autism spectrum. *Journal of Autism and Developmental Disorders*, 43(9), 2218–2227.

Harrist, A. W., Achacoso, J. A., John, A., Pettit, G. S., Bates, J. E., & Dodge, K. A. (2014). Reciprocal and complementary sibling interactions: Relations with socialization outcomes in the kindergarten classroom. *Early Education and Development*, 25(2), 202–222.

Hastings, R. P., & Petalas, M. A. (2014). Self-reported behaviour problems and sibling relationship quality by siblings of children with autism spectrum disorder. *Child: Care, Health and Development*, 40(6), 833–839.

Hendriksen, J. G. M., & Hurks, P. P. M. (2009). *Technische handleiding WPPSI-III-NL*. Amsterdam: Pearson Assessment and Information B.V.

Hollingshead, A. B. (1975). *Four factor index of social status.* Yale University Press, New Haven, CT.

Hudry, K., Chandler, S., Bedford, R., Pasco, G., Gliga, T., Elsabbagh, M., … Charman, T. (2014). Early language profiles in infants at high-risk for autism spectrum disorders. *Journal of Autism and Developmental Disorders*, 44(1), 154–167.

Hus, V., Gotham, K., & Lord, C. (2014). Standardizing ADOS Domain Scores: Separating Severity of Social Affect and Restricted and Repetitive Behaviors. *Journal of Autism and Developmental Disorders*, 44(10), 2400–2412.

Kaminsky, L., & Dewey, D. (2001). Siblings relationships of children with autism. *Journal of Autism and Developmental Disorders*, 31(4), 39–410.

Knott, F., Lewis, C., & Williams, T. (1995). Sibling interaction of children with learning disabilities: A comparison of autism and Down's syndrome. *Journal of Child Psychology and Psychiatry*, 36(6), 965–976.

Knott, F., Lewis, C., & Williams, T. (2007). Sibling interaction of children with autism: Development over 12 months. *Journal of Autism and Developmental Disorders*, 37(10), 1987–1995.

Kort, W., Schittekatte, M., Dekker, P. H., Verhaeghe, P., Compaan, E. L., Bosmans, M., & Vermeir, G. (2005). *WISC-III-NL: Wechsler Intelligence Scale for Children. Derde Editie NL. Handleiding en Verantwoording.* Amsterdam: Harcourt Test Publishers/Nederlands Instituut voor Psychologen.

Kuhl, P. K. (2004). Early language acquisition: cracking the speech code. *Nature Reviews Neuroscience*, 5(11), 831–843.

Lamb, M. E. (1978). Interactions between eighteen-month-olds and their preschool-aged siblings. *Child Development*, 49(1), 51–59.

Lobato, D. J., Miller, C. T., Barbour, L., Hall, L. J., & Pezzullo, J. (1991). Preschool siblings of handicapped children: Interactions with mothers, brothers, and sisters. *Research in Developmental Disabilities*, 12(4), 387–399.

Lord, C., Rutter, M., DiLavore, P. C., Risi, S., Gotham, K., & Bishop, S. L. (2012). *Autism diagnostic observation schedule: ADOS-2*. Los Angeles, CA: Western Psychological Services.

Luyster, R., Lopez, K., & Lord, C. (2007). Characterizing communicative development in children referred for autism spectrum disorders using the MacArthur-Bates Communicative Development Inventory (CDI). *Journal of Child Language*, 34(3), 623–654.

Mandy, W., & Lai, M. C. (2016). Annual Research Review: The role of the environment in the developmental psychopathology of autism spectrum condition. *Journal of Child Psychology and Psychiatry*, 57(3), 271–292.

Meulen, B. F., van der Ruiter, S. A. J., Spelberg, H. C., & Smrkovský, M. (2004). *Bayley Scales of Infant Development-II, Nederlandse Versie. Handleiding.* Amsterdam: Harcourt Test Publishers.

Mitchell, S., Brian, J., Zwaigenbaum, L., Roberts, W., Szatmari, P., Smith, I., & Bryson, S. (2006). Early language and communication development of infants later diagnosed with autism spectrum disorder. *Journal of Developmental and Behavioral Pediatrics*, 27(2), S69–S78.

Mullen, E. (1995). *Mullen Scales of Early Learning*. Circle Pines, MN: American Guidance Services.

Noldus. (2013). *The Observer XT: The next generation of observation software. Reference manual, version XT 11.5*. Wageningen, The Netherlands: Noldus.

Osterling, J. A., Dawson, G., & Munson, J. A. (2002). Early recognition of 1-year-old infants with autism spectrum disorder versus mental retardation. *Development and Psychopathology*, 14(2), 239–251.

Ozonoff, S., Young, G. S., Belding, A., Hill, M., Hill, A., Hutman, T., … Iosif, A. M. (2014). The broader autism phenotype in infancy: When does it emerge. *Journal of the American Academy of Child and Adolescent Psychiatry*, 53(4), 398–407.

Ozonoff, S., Young, G. S., Carter, A., Messinger, D., Yirmiya, N., Zwaigenbaum, L., … Stone, W. L. (2011). Recurrence risk for autism spectrum disorders: A Baby Siblings Research Consortium study. *Pediatrics*, 128(3), e488–e495.

Pettit, G. S., & Arsiwalla, D. D. (2008). Commentary on special section on “bidirectional parent–child relationships”: The continuing evolution of dynamic, transactional models of parenting and youth behavior problems. *Journal of Abnormal Child Psychology*, 36(5), 711–718.

Rutter, M., Bailey, A., & Lord, C. (2003). *Social Communication Questionnaire*. Los Angeles, CA:Western Psychological Services.

Sainani, K. L. (2012). Dealing With Non-normal Data. *PM and R*, 4(12), 1001–1005.

Samango-Sprouse, C. A., Stapleton, E. J., Aliabadi, F., Graw, R., Vickers, R., Haskell, K., … Gropman, A. L. (2015). Identification of infants at risk for autism spectrum disorder and developmental language delay prior to 12 months. *Autism*, 19(3), 327–337.

Seibert, J. M., Hogan, A. E., & Mundy, P. C. (1982). Assessing interactional competencies: The early social-communication scales. *Infant Mental Health Journal*, 3(4), 244–258.

Senapati, R., & Hayes, A. (1988). Sibling relationships of handicapped children: A review of conceptual and methodological issues. *International Journal of Behavioral Development*, 11(1), 89–115.

Shephard, E., Milosavljevic, B., Pasco, G., Jones, E. J. H., Gliga, T., Happé, F., … BASIS Team. (2016). Mid-childhood outcomes of infant siblings at familial high-risk of autism spectrum disorder. *Autism Research*, 10(3), 546–557.

Stone, W. L., McMahon, C. R., Yoder, P. J., & Walden, T. A. (2007). Early social-communicative and cognitive development of younger siblings of children with autism spectrum disorders. *Archives of Pediatrics & Adolescent Medicine*, 161(4), 384.

Sucksmith, E., Roth, I., & Hoekstra, R. A. (2011). Autistic traits below the clinical threshold: Re-examining the broader autism phenotype in the 21st century. *Neuropsychology Review*, 21(4), 360–389.

Tellegen, P., Winkel, M., Wijnberg-Williams, B. J., & Laros, J. A. (1998). *Snijders-Oomen Niet-verbale Intelligentietest, SON-R 2½-7. Handleiding*. Lisse: Swets & Zeitlinger, B.V.

Tick, B., Bolton, P., Happé, F., Rutter, M., & Rijsdijk, F. (2016). Heritability of autism spectrum disorders: A meta-analysis of twin studies. *Journal of Child Psychology and Psychiatry*, 57(5), 585–595.

Toth, K., Dawson, G., Meltzoff, A. N., Greenson, J., & Fein, D. (2007). Early social, imitation, play, and language abilities of young non-autistic siblings of children with autism. *Journal of Autism and Developmental Disorders*, 37(1), 145–157.

Tucker, C. J., Updegraff, K. A., McHale, S. M., & Crouter, A. C. (1999). Older siblings as socializers of younger siblings' empathy. *The Journal of Early Adolescence*, 19(2), 176–198.

Van Baar, A. L., Steenis, L. J. P., Verhoeven, M., & Hessen, D. (2014). *Bayley-III-NL. Technische Handleiding.* Amsterdam: Pearson Assessment and Information B.V.

Walton, K. M., & Ingersoll, B. R. (2015). Psychosocial adjustment and sibling relationships in siblings of children with autism spectrum disorder: Risk and protective factors. *Journal of Autism and Developmental Disorders*, 45(9), 2764–2778.

Wetherby, A. M., Watt, N., Morgan, L., & Shumway, S. (2007). Social communication profiles of children with autism spectrum disorders late in the second year of life. *Journal of Autism and Developmental Disorders*, 37(5), 960–975.

Whiteman, S. D., Bernard, J. M. B., & McHale, S. M. (2010). The nature and correlates of sibling influence in two-parent African American families. *Journal of Marriage and Family*, 72(2), 267–281.

Whiteman, S. D., McHale, S. M., & Soli, A. (2011). Theoretical perspectives on sibling relationships. *Journal of Family Theory & Review*, 3(2), 124–139.

Yirmiya, N., Gamliel, I., Pilowsky, T., Feldman, R., Baron-Cohen, S., & Sigman, M. (2006). The development of siblings of children with autism at 4 and 14 months: Social engagement, communication, and cognition. *Journal of Child Psychology and Psychiatry*, 47(5), 511–523.

Zink, I., & Lejaegere, M. (2002). *N-CDI: Lijsten voor communicatieve ontwikkeling*. Leuven: Acco.

Zink, I., & Lembrechts, D. (2000). *De Nederlandstalige Nonspeech Test (NNST)*. Leuven: Acco.

Zwaigenbaum, L., Bryson, S., Rogers, T., Roberts, W., Brian, J., & Szatmari, P. (2005). Behavioral manifestations of autism in the first year of life. *International Journal of Developmental Neuroscience*, 23(2–3), 143–152.