



# 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.

**Keywords** Autism spectrum disorder · High-risk siblings · Sibling interaction · Language · Social communication

## Introduction

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 2 years of life (Bryson et al. 2007; Osterling et al. 2002; Wetherby et al. 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 and 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 et al. 2011). This includes delays in social communication such as the use of eye contact, gestures, and orientation to name (Gamliel et al. 2007; Gammer et al. 2015; Mitchell et al. 2006; Toth et al. 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 3 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 et al. 2016). In addition, when studying ASD, environmental factors and the gene-environment interaction need to be considered as well (Mandy and Lai 2016), particularly at a young age when brain plasticity is high and social communication and language develop rapidly (Barbaro and Dissanayake 2012; Elsabbagh and 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

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impact (Mandy and 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 and 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 and 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 and 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 and 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 and Vermande 2014; Feinberg et al. 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 et al. 1999). Conversely, negative sibling interactions can lead to poorer developmental outcomes (Bank et al. 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 and Vermande 2014). However, some level of conflict, in balance with warmth, can promote the development of anger management and conflict resolution skills (Brody et al. 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 et al. 2011). In typically developing sibling dyads, younger siblings are more likely to imitate their older brother or sister than vice versa (Whiteman et al. 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 and 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 and 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 et al. (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 2 years of life (e.g., Barbaro and 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 et al. 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 et al. 2000; Buist and 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 and Gruber 2012), and the Social Communication Questionnaire (SCQ; Rutter et al. 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 and 115). Of the other 13 children, three scored very low (IQ < 55), nine children scored below average (IQ between 55 and 85), and one 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 [ $F(1,54) = 23.498, p < .001$ ]. 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),

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

	Low-risk ( <i>n</i> = 32)	High-risk ( <i>n</i> = 24)	
<i>Sibling pair</i>			
Family SES [M (SD)]	51.81 (7.00)	45.67 (11.39)	<i>U</i> = 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	$\chi^2(1) = .219$
<i>Youngest sibling</i>			
Chronological age			
M(SD)	24.75 (.77)	24.69 (.77)	<i>F</i> (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	<i>U</i> = 383.00
Mutuality	4.2	4.6	<i>U</i> = 332.00
Interaction with parent	6.6	7.8	<i>U</i> = 382.00
Interaction with experimenter	8.6	7.2	<i>U</i> = 342.00
Non-interaction (%)	80.6	80.4	<i>U</i> = 383.00
Orientation to sibling	7.1	9.3	<i>U</i> = 316.00
Solitary play	73.5	71.1	<i>U</i> = 330.00
<i>Oldest sibling</i>			
Chronological age			
M(SD)	55.69 (13.91)	87.85 (34.00)	<i>F</i> (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	<i>U</i> = 339.00
Mutuality	4.1	4.7	<i>U</i> = 333.00
Interaction with parent	4.1	7.1	<i>U</i> = 372.00
Interaction with experimenter	8.3	6.6	<i>U</i> = 318.50
Non-interaction (%)	83.5	81.6	<i>U</i> = 339.00
Orientation to sibling	4.2	6.5	<i>U</i> = 309.50
Solitary play	79.3	75.1	<i>U</i> = 324.50

Chronological age is reported in months; \**p* < .05, \*\*\**p* < .001; *M* mean, *SD* standard deviation

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 and 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 min. 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

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

	Low-risk ( <i>n</i> = 32)	High-risk ( <i>n</i> = 24)	
<i>MSEL</i>			
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)	$F(1,54) = 4.475^*$
<i>N-CDI</i>			
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)	$F(1,40) = 3.596$
<i>ADOS-2</i>			
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)	$U = 247.50^*$
<i>Q-Chat</i>	24.81 (6.53)	22.15 (7.09)	$F(1,38) = 1.379$

*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

\* $p < 0.05$ ; \*\* $p < 0.01$

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.

## 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 and 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 and 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 et al. 2001; Luyster et al. 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 et al. 2009; Hus et al. 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 min, the middle 8 min were selected and coded using The Observer XT, version 11.5 (Noldus 2013). For play with keyboard, lasting 5 min, the middle 4 min 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 and .74 reflect good interrater agreement and ICC's between .75 and 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  $\pm$  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  $\pm$  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  $.85$  while correlations between negative behaviours ranged from  $r = .43$  to  $.82$ . 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 4–9% 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 ( $\beta = -.429$ ,  $t = -2.330$ ,  $p = .024$ ), responses of the youngest child ( $\beta = -.550$ ,  $t = -3.255$ ,  $p = .002$ ), positive initiations of the oldest child ( $\beta = -.497$ ,  $t = -3.190$ ,  $p = .003$ ), and positive responses of the oldest child ( $\beta = -.588$ ,  $t = -3.538$ ,  $p = .001$ ). All four behaviours occurred more frequently in the LR group compared to the HR group. The regression models for negative behaviours were not significant.

Second, the regression model for imitation of the youngest child was marginally significant. Group marginally significantly predicted imitation ( $\beta = -.350$ ,  $t = -1.962$ ,  $p = .056$ ), 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

**Table 3** Descriptives [mean (SD)] for sibling interaction characteristics

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

LR low-risk, HR high-risk

<sup>a</sup>Results reflect absolute frequencies

<sup>b</sup>Results reflect total duration (in seconds)

<sup>c</sup>Results reflect global rating (1–5)

child ( $\beta = .938, t = 5.634, p < .001$ ) and positive responses of both children (youngest:  $\beta = .733, t = 4.057, p < .001$ ; oldest:  $\beta = .761, t = 4.278, p < .001$ ). All behaviours were more frequent in older children. In addition, *time spent together* positively predicted imitation of the youngest sibling ( $\beta = .363, t = 2.550, p = .014$ ). Day-care attendance, MSEL scores or ADOS scores did not significantly predict sibling interaction characteristics.

### 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

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

	B	SE B	$\beta$
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			
$R^2 = .174, R^2(8,44) = 1.162, p = .343$			
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			
$R^2 = .330, R^2(8,44) = 2.645, p = .019$			
Group	-.373	.190	-.350 <sup>+</sup>
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

MSEL Mullen Scales of Early Learning; ADOS-2 Autism Diagnostic Observation Schedule-2nd edition (Calibrated Severity Score)

\* $p < .05$ , \*\* $p < .01$ , \*\*\* $p < .001$ ; <sup>+</sup> $p = .056$



**Table 5** Prediction of sibling interaction characteristics: regression coefficients (oldest sibling)

	<i>B</i>	<i>SE B</i>	$\beta$
<b>Positive initiations</b>			
$R^2 = .483, F(8,44) = 5.147, p < .001$			
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
<b>Negative initiations</b>			
$R^2 = .148, F(8,44) = .957, p = .481$			
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
<b>Positive responses</b>			
$R^2 = .411, F(8,44) = 3.832, p = .002$			
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
<b>Negative responses</b>			
$R^2 = .161, F(8,44) = 1.059, p = .408$			
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

MSEL Mullen Scales of Early Learning; ADOS-2 Autism Diagnostic Observation Schedule-2nd edition (Calibrated Severity Score)

\*\* $p < .01$ , \*\*\* $p < .001$

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 Tables 8, 9, 10, 11, 12, 13. 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.

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

	<i>B</i>	<i>SE B</i>	$\beta$
<b>Low-risk group</b>			
<b>N-CDI word comprehension</b>			
$R^2 = .185, F(1,24) = 5.448, p = .028$			
Total interaction	-.221	.095	-.430*
$R^2 = .189, F(2,23) = 2.683, p = .090$			
Positive behaviour	-.191	.130	-.276
Negative behaviour	-.289	.170	-.320
<b>N-CDI word production</b>			
$R^2 = .218, F(1,24) = 6.683, p = .016$			
Imitation	17.204	6.655	.467*
<b>High-risk group</b>			
<b>N-CDI word production</b>			
$R^2 = .219, F(1,14) = 3.916, p = .068$			
Total interaction	.340	.172	.468 <sup>+</sup>
$R^2 = .270, F(2,13) = 2.411, p = .129$			
Positive behaviour	.205	.243	.210
Negative behaviour	.677	.405	.416
<b>MSEL receptive language</b>			
$R^2 = .242, F(1,22) = 7.031, p = .015$			
Total interaction	.063	.024	.492*
$R^2 = .248, F(2,21) = 3.470, p = .050$			
Positive behaviour	.068	.035	.389 <sup>+</sup>
Negative behaviour	.057	.055	.208
<b>MSEL expressive language</b>			
$R^2 = .255, F(1,22) = 7.524, p = .012$			
Total interaction	.054	.020	.505*
$R^2 = .262, F(2,21) = 3.721, p = .041$			
Positive behaviour	.055	.029	.369 <sup>+</sup>
Negative behaviour	.059	.046	.252
<b>Q-Chat</b>			
$R^2 = .320, F(1,11) = .5179, p = .044$			
Total interaction	.088	.039	.566*
$R^2 = .336, F(2,10) = .2525, p = .129$			
Positive behaviour	.074	.058	.346
Negative behaviour	.127	.095	.365

<sup>+</sup> $p < .10$ , \* $p < .05$

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
<b>LR group</b>					
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*
<b>HR group</b>					
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

\* $p < .05$ 

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.

### 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:  $\beta = .430$ ,  $t = 2.123$ ,  $p = .048$ ; expressive:  $\beta = .662$ ,  $t = 4.117$ ,  $p = .001$ ). The *total interaction* composite was no longer a significant predictor (receptive:  $\beta = .298$ ,  $t = 1.472$ ,  $p = .158$ ; expressive:  $\beta = .224$ ,  $t = 1.391$ ,  $p = .181$ ). 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 ( $\beta = .613$ ,  $t = 2.865$ ,  $p = .010$ ). Again, the *total interaction* composite was no longer a significant predictor ( $\beta = -.233$ ,  $t = -1.443$ ,  $p = .165$ ). 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 ( $\beta = .413$ ,  $t = 2.074$ ,  $p = .051$ ).

## Discussion

### Sibling Interaction: High-Risk versus 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 and 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 et al. (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 et al. (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 and Dissanayake 2009; Haebig et al. 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 and Petalas 2014; Lobato et al. 1991; Senapati and 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 et al. 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.

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**Author Contributions** CB set up the study design, was responsible for data collection/measurements and statistical analyses, and drafted the manuscript; PW participated in the study design, assisted in statistical analyses and interpretation of the data, and helped to draft the manuscript; ED participated in the study design, performed measurements and helped to draft the manuscript; EB performed measurements and helped to draft the manuscript. SB performed measurements and helped draft the manuscript. HR participated in the study design and coordinated the study, assisted in statistical analyses and interpretation of the data, and helped to draft the manuscript. All authors read and approved the final version of the manuscript.

### Compliance with Ethical Standards

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical Approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the insti-



tutional 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.

## Appendix

See Tables 8, 9, 10, 11, 12 and 13.

**Table 8** 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 m 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 m 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 intolerance 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

**Table 9** 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 s 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 <i>sustained</i> mutuality, meaning that the mutuality has to last at least 2 s 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. This 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. <i>Repetitive &amp; stereotyped behaviours</i> : a broad range of behaviours including stereotypies, rituals, compulsions, obsessions, perseveration, and repetitive or stereotyped use of language. <i>Sensory behaviours</i> : 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 intolerance 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

**Table 10** Prediction of child development—low-risk group

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

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

\* $p < .05$

**Table 11** Prediction of child development controlling for development at 14 months—low-risk group

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

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

+ $p < .10$ , \* $p < .05$

**Table 12** Prediction of child development—high-risk group

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

<sup>+</sup> $p < .10$ , <sup>\*</sup> $p < .05$ ; 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 13** Prediction of child development controlling for development at 14 months - High-risk group

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

**Table 13** (continued)

	B	SE B	$\beta$
MSEL receptive language 14 months	1.417	.344	.662**
$R^2 = .609, F(3,17) = 8.822, p = .001$			
Positive behaviour	.032	.025	.208
Negative behaviour	.014	.039	.060
MSEL receptive language 14 months	1.424	.356	.666**
$R^2 = .566, F(2,17) = 11.091, p = .001$			
Imitation	1.481	2.862	.084
MSEL receptive language 14 months	1.523	.336	.734***

*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

<sup>+</sup> $p < .10$ , \* $p < .05$ , \*\* $p < .01$ , \*\*\* $p < .001$

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