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Parent-child interaction and developmental outcomes in children with typical and elevated likelihood of autism

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ABSTRACT

Background: Early parent-child interactions have a critical impact on the developmental outcomes of the child. It has been reported that infants with a family history of autism and their parents may engage in different patterns of behaviours during interaction compared to those without a family history of autism. This study investigated the association of parent-child interactions with child developmental outcomes of those with typical and elevated likelihood of autism.
Method: This longitudinal study investigated the relationship between global attributes of parent-child interaction and the developmental outcomes of infant siblings with elevated likelihood (EL: n = 29) or typical likelihood (TL: n = 39) of developing autism. Parent-child interactions were recorded during a session of free-play when the infants were six months of age. Developmental assessments were carried out when the children were 12 and 24 months of age.
Results: The intensity of mutuality was significantly higher in the TL group than in the EL group, and developmental outcomes were poorer in the EL group when compared to the TL group. Positive associations between parent-child interaction scores at six months and developmental outcomes at 12 months were observed only in the TL group. However, in the EL group, higher levels of infant positive affect and attentiveness paid to the caregiver is associated with lower autism symptoms. Due to the sample size and design of the study, the findings must be viewed as indicative.
Conclusion: This preliminary investigation demonstrated differences in the association between parent-child interaction quality and developmental outcomes for children with typical and elevated likelihood for autism. Future studies should combine micro-analytic and macro-analytic approaches to parent-child interaction to further examine the nature of this relationship.

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1. Introduction

Autism is a neurodevelopmental condition characterised by delays in communication and social interaction, alongside restrictive interests and repetitive behaviours (American Psychiatric Association, 2013). Children with autism often experience developmental delay, predominantly affecting language and social-emotional development (Bellman et al., 2013; Delehanty et al., 2018; Raza et al., 2020). Autism is a highly heritable condition (Rosenberg et al., 2009), therefore an increased likelihood of developing autism could be determined by assessing family history of psychiatric and neurodevelopmental problems. Those with a first-degree relative, such as a biological parent or sibling diagnosed with autism, have an Elevated Likelihood (EL) of developing the disorder. Individuals with no family history of neurodevelopmental disorders have Typical Likelihood (TL) of developing autism (Ozonoff et al., 2011). The use of "high-risk and "low-risk" is often used when investigating early signs of autism in infants. Advocates have suggested that the use of risk has negative connotations. The preferred terminology now uses "increased or elevated likelihood" and "low or typical likelihood" (Fletcher-Watson et al., 2017).

The Transactional Model of Child Development (Sameroff, 2009) describes parent-child interaction as a reciprocal process that involves the parent's response to the child and in turn the child's response to the parent. The observation of parent-child interactions allows us to understand a child's social, relational, and communicative abilities in a dynamic transaction shaped by the social opportunities and environments provided by their caregivers. The quality of parent-child interactions is a significant mediator in the relationship between neurobiological risk factors and child development (Beaudoin et al., 2019). Higher quality parent-child interactions, indicated by reciprocal and engaging dyadic interactions, are associated with improved developmental outcomes in domains such as cognitive (Evans & Porter, 2009; Feldman, 2007), social-emotional (Cerezo et al., 2008) and language development (Topping et al., 2013). The heritable nature of autism, combined with its impact on communication and social development, means children with an EL of developing autism and their parents are susceptible to lower quality interactions when compared to parent-child dyads with TL for autism.

Global and microanalytic observational tools have been used to measure qualities of parent-child interactions in parent-infant dyads where the infant is at EL of autism (Wan et al., 2018). Global rating tools are used to assess general constructs of interest. The behavioural quality is typically scored on a scale and indicate whether high levels of the behaviour are present during the interaction or low levels of the behaviour are observed. Microanalytic tools are used to code clearly defined behaviours during parent-child interactions by coding behavioural constructs on a second-by-second basis (Morawska et al., 2015).

1.1. Elevated likelihood for autism and infant behaviours

The investigation of parent-child interaction in infants with an 'EL' of autism is of particular interest as it allows an exploration of the emergence of early characteristics that relate to the autism phenotype. Children on the autism spectrum exhibit behaviours that may impact the quality of parent-child interactions, for example, they have been shown to display fewer social interests and reduced social engagement (Campbell et al., 2015; Wimpory et al., 2000) compared to children who are typically developing. Studies utilising microanalytic coding schemes have identified that EL infants display lower levels of prosocial behaviours (Russell et al., 2012) and communicative gestures (Delehanty & Wetherby, 2021), less positive facial expressions (Cassel et al., 2007) and limited joint attention (Adamson et al., 2019). When observing parent-child interactions on a global level, infants with EL show fewer and less clear initiations of interaction (Pijl et al., 2021). They are also found to display lower levels of positive affect and attention towards their parent when compared to infants with TL (Wan et al., 2013).

Infants primarily learn through the interactions they have with their caregivers. During typical development, learning is facilitated through communicative and affective cues provided by the parent. The infant takes notice, learns and responds to such cues, but this process is observed to be disrupted in those with autism (Vivanti & Nuske, 2017). Instances of learning that occur during parent-child interactions may be interrupted if infants display lower levels of positive affect or pay less attention their caregivers. This in turn may have a negative impact on child developmental outcomes in those with an EL for autism.

Autism symptoms are being identified in children at an increasingly young age. Behavioural differences between those with EL and TL of developing autism have been reported in infants as young as six months of age (Cassel et al., 2007; Gangi et al., 2021), although these differences are not clearly established until they are 12 months of age (Ozonoff et al., 2010; Rozga et al., 2011). Additional studies investigating the early emergence of autism traits during naturalistic parent-child interactions in infants six months and younger are required.

1.2. Elevated likelihood for autism and maternal behaviours

It is important to consider parental behaviours during instances of interaction. As parents are aware of the heritability of autism, mothers of infants with an EL for autism may adjust their behaviours if they believe their infant is at an increased risk of developing autism. Additionally, the parent may have adapted their parenting in response to their older children with autism. Studies investigating parent behaviours using global measures of parent-child interaction demonstrate that mothers of infants with EL of autism are more likely to display different levels of sensitivity (Wan et al., 2013) and higher levels of directive behaviour during parent-child interaction, perhaps as a response to their infant's behaviours (Meirsschaut et al., 2011; Quigley & McNally, 2013; Wan et al., 2012). Parental directive behaviour coded during interaction using microanalytic coding schemes, is characterised by increased gesture use (Talbott et al., 2015), closer physical proximity (Srinivasan & Bhat, 2020) and a greater amount of verbal instruction directed to the infant (Harker et al., 2016; Patterson et al., 2014).

Different patterns of associations have been observed between directive parental behaviours and child outcomes. Some studies have found directiveness to be associated with reduced infant engagement and slower development in both typically developing children and those with an EL for autism (Saint-Georges et al., 2011). When mothers exhibit directive behaviours higher levels of negative affect is observed in infants with an EL for autism (Steiner et al., 2018). This impacts the frequency and duration of the interaction that may otherwise promote learning in children. However, other studies consider directiveness to be adaptive and contribute functional value to child development. Doussard-Roosevelt and colleagues (2003) found children with autism to be responsive towards maternal directive behaviours. Although intrusive behaviours often disrupt children's play, directives are often preceded with high levels of joint engagement in the activity prompted by the caregiver assuming that it is sensitive to the infant's state and interests (Bottema-Beautel et al., 2018; Masur et al., 2013).

Caregiver sensitivity describes the ability to detect and interpret the infant's behavioural signals and to respond to them with attentiveness, warmth, appropriate engagement and support. Whilst Wan et al. (2012, 2013) did report lower levels of sensitivity in mothers of EL infants, many studies have provided evidence of similar levels of sensitivity for caregivers of EL and TL cohorts (Baker et al., 2010; Harker et al., 2016).

1.3. Elevated likelihood for autism and dyadic behaviours

Dyadic mutuality describes the general amount of engagement shared between the mother and infant. It considers the degree of reciprocity, attunement and synchrony shared in the dyad. Mutuality is expressed through the infant's acceptance of the caregiver's involvement and is represented in togetherness through cooperative play, flow and body orientation (Deater-Deckard & Pentrill, 2004; Wan et al., 2017). Dyad engagement intensity refers to the quality of the mutual activity between the mother and infant. It is characterised by the level of interest and positivity the dyad expresses towards one another or through mutual focus on an object. Dyadic mutuality and engagement intensity are global constructs that have been directly linked to favourable outcomes in children such as positive, reciprocal relationships (Ensor et al., 2011) and a reduction in child behaviour problems (Pasiak & Menna, 2015). Features of parent-child mutuality and engagement intensity coded microanalytically such as synchrony and joint attention have been linked to improved cognitive and language outcomes in children (Provenzi et al., 2018; Salo et al., 2018). Mutual interactions allow the parent and infant to take part in shared opportunities that facilitate infant learning. The parent can provide experiences that are informative, the infant can learn from these cues, respond to them and increase their proficiency through back and fourth interaction (Edmunds et al., 2019). Therefore, it is expected that higher levels of dyadic mutuality and engagement intensity will contribute to improved developmental outcomes in children.

When compared to dyads of infants with TL of developing autism, mother-infant dyads where the infant is at EL of autism have been observed to exhibit lower interactive reciprocity, dyadic mutuality and engagement during parent-child interactions (Campbell et al., 2015; Wan et al., 2013). Parent-child dyads of typically developing children spend more time in mutual engagement compared to dyads where the child has a diagnosis of autism (Rozenbaltt-Perkel & Zaidman-Zait, 2020). Infants with EL of developing autism tend to display lower levels of synchrony (Kellerman et al., 2020), joint attention (Adamson et al., 2019) and social interest (Killmeyer et al., 2019) when compared to infants with TL. Such behaviours are important when eliciting mutual engagement with their parent and lower levels of these behaviours may therefore contribute to lower levels of engagement intensity.

A study on children with a developmental language disorder found attuned dyadic behaviour to be associated with improved receptive language ability, while parent behaviours alone were not associated with child language abilities (Jokihaka et al., 2022). This suggests that it is important not only to consider the behaviours of the parent and child, but also of the dyad. Other scales measuring global qualities of parent-child interactions (Biringen, 2000) have been used to measure parent-child interactions where the child has a diagnosis of autism (Dolev et al., 2009). But such scales only consider qualities of the parent and the child separately and do not take into account the cooperation between the pair of individuals.

1.4. Investigating the quality of parent-child interaction and child outcomes in autism

The majority of studies that investigate play behaviours in relation to child developmental outcomes in those with an EL of developing autism have observed associations with behaviours coded microanalytically (Northrup & Iverson, 2015; Salo et al., 2018; Talbott et al., 2015) but research has yet to establish the relationship between global constructs of parent-child interaction and developmental outcomes. Morawska and colleagues (2015) found global measures of parent-child interactions to be more sensitive when coding behaviours during play. In a study of infants with EL or TL of developing autism, Wan et al., (2013) examined whether the quality of parent-child interactions at 12–15 months predicted autism classification at three years of age. Using the Manchester Assessment of Caregiver and Infant Interaction (MACI; Wan et al., 2017) to rate the quality of parent-child interactions, Wan et al. (2013) found that lower levels of dyadic mutuality, infant positive affect and attentiveness were associated with autism symptom severity at three years.

The current study is a preliminary investigation examining the relationship between global qualities of parent-child interaction and developmental outcomes in infants at EL for autism. While previous studies (e.g. Wan et al., 2013) focussed on predicting autism outcomes, the current study investigated the relationship between parent-child interactions and domain-specific developmental outcomes using standardised assessments.

1.5. The current study

The current study investigated the longitudinal relationship between emerging parent-child interaction qualities at six months of age, and the child's developmental functioning at 12 and 24 months. Repeated measures were carried out on an independent sample of children with EL or TL of developing autism. Parent-child interactions at six months were rated using the MACI (Wan et al., 2017) and developmental outcomes were assessed using the Mullen Scales of Early Learning (MSEL; Mullen, 1995). Symptoms of autism were also assessed at 24 months of age using the Autism Diagnostic Observation Schedule-Generic (ADOS-G; Lord et al., 2000). The study examined whether the association between parent-child interaction qualities and developmental outcomes was differentially impacted by autism likelihood status. For the purpose of this study, high quality parent-child interactions will be characterised by higher levels of sensitive responding from the mother, attentiveness to their caregiver, liveliness and positive affect from the child, and higher levels of mutuality and engagement intensity observed between the parent and child.

The following hypotheses were investigated.

(1) Compared with the TL group, infants at EL of developing autism would display distinct interactions characterised by lower levels of attentiveness towards their mother, reduced liveliness and less positive affect. Mothers of EL infants would display similar levels of sensitivity but more directive behaviours. EL dyads are predicted to display lower levels of mutuality and the intensity of the engagement will be lower.
(2) For the relationship between parent-child interaction variables and developmental outcomes tested within each group, it was expected that higher quality parent-child interactions would be positively associated with developmental outcome scores in the EL and TL groups. High quality parent-child interactions will be negatively associated with child autism symptoms in those in the EL group.

2. Method

The study is based on longitudinal data collected as part of the PRegnancy Investigation of Siblings and Mothers of children with autism (PRISM) study, conducted in Perth, Western Australia (Unwin et al., 2016). Expectant mothers of TL infants were recruited through advertisements in local newspapers. Those expecting EL infants were recruited through referrals from obstetricians, gynaecologists, and via advertisements in local newspapers. Mothers and their children were invited for participation at three separate time points, specifically, when the child was 6, 12 and 24 months of age.

2.1. Participants

Sixty-eight mothers and their infants enrolled in the study. The sample was categorised into two groups depending on the infant's autism likelihood status. Twenty-nine infants (42.65 %) were considered at elevated likelihood (EL) of developing autism, and 39 infants (57.35 %) were considered as having typical likelihood (TL) for autism. Infants who had an older biological sibling with a clinical diagnosis of Autism or Pervasive Developmental Disorder – Not Otherwise Specified (PDDNOS) were defined as "EL". The standard diagnostic procedure for autism in Western Australia during the time of this study followed the DSM-IV guidelines (American Psychological Association, 1994). Clinical protocols at the time required a multidisciplinary healthcare team to assess each case and comprised a paediatrician, clinical psychologist and a speech and language pathologist. For each EL family, the mother participating in the study was the biological mother of both the EL child and the older sibling with autism. Infants were defined as "TL" if they had no known developmental risk factors and also had one or more biological siblings of at least three years of age without a diagnosis of a neurodevelopmental disorder. The appropriate local ethics committees granted ethical approval for this study. Participating caregivers gave informed consent on behalf of themselves and their infant to participate in the study. Before completing each stage of the study, all participants were reminded that they could withdraw from the study if they wished and were debriefed at the end of the study.

2.1.1. Sample characteristics

Demographic information collected from participating mothers included the child's age, gender, gestational age and number of

Table 1
Sample characteristics of Typical and Elevated Likelihood groups.

Characteristics	TL (n = 39)	EL (n = 29)	*df*	Test Statistic
Gestational Age (weeks; *M, SD*)	38.54 (1.19)	38.59 (1.18)	66	$t = 0.16$, $p = .870$
Gender			1	$X^2 = 0.10$, $p = .751$
Male (%)	20 (51.28)	16 (55.17)		
Female (%)	19 (48.72)	13 (44.83)		
Number of Siblings (*Mdn, Range*)	1.00 (4.00)	2.00 (5.00)		$U = 177.00$, $p = .000$**
Maternal Age (Years; *M, SD*)	33.29 (3.25)	35.71 (4.54)	65	$t = 2.55$, $p = .013$**
Household Income (*Mdn, Range*)	12.00 (3.00)	11.00 (8.00)		$U = 309.00$, $p = .002$*
Maternal AQ Score (*M, SD*)	11.42 (4.64)	13.18 (6.18)	64	$t = 1.45$, $p = .191$

Note. Maternal AQ Score measured using Autism-Spectrum Quotient Questionnaire.
*$p < 0.05$; **$p < 0.01$.

siblings, maternal age, household income and maternal autistic traits. Demographic characteristics are displayed according to group in Table 1. The sample of children participating in the study did not differ significantly in gestational age or gender when comparing the two groups. The number of siblings however was higher in the EL group compared to the TL group. Household income was classified into 12 categories starting from $1 to $8000 per year up to $104,001 or more per year. The TL group was found to have a significantly higher household income than the EL group. The median household income of the TL group was $104,001 or more per year (income category 12), whereas the median income of the EL group was $78,001 to $104,000 per year (income category 11). Autistic traits were measured in mothers using the Autism Spectrum Quotient (AQ) questionnaire (Baron-Cohen et al., 2001). Neither group exhibited significant levels of autistic traits (i.e., no mother obtained a score of 32 or above) and there was no statistical difference in maternal AQ scores between the EL group and TL group (see Table 1).

2.2. Procedure

When the infants were six months of age, both mother and infant were invited to the laboratory at the Telethon Kids Institute (The University of Western Australia) and a session of parent-child interaction was video recorded. A selection of developmentally appropriate toys was provided for this interaction. The mother was instructed to play with their infant, just as they do at home. The interaction was video-recorded for six minutes commencing as soon as the research assistant left the room. At 12 months of age, children and their parents were invited back to the lab and the child's developmental functioning was assessed using the MSEL (Mullen, 1995). At 24-months, the child's developmental functioning was once again assessed using the MSEL and the children were assessed for symptoms of autism using the ADOS-G (Lord et al., 2000).

Within the EL sample, 20.7 % was lost to follow-up by the time of the ADOS-G assessment at 24 months, compared with 12.8 % of TL participants. A chi-square test demonstrated a significantly greater loss of participants from the EL group in comparison to the TL group ($X^2(1) = 4.22, p = 0.04$). Table 2 indicates the number of participants who returned for assessment at each time point according to group. Analyses were conducted to investigate whether there were any characteristic differences between the completers (participants who returned and took part in every phase of the study) and non-completers (participants who did not take part in every phase of the study) in the TL and EL groups. The quality of parent-child interactions was compared across the completers and non-completers. Where the infant had a TL of developing autism, a Mann-Whitney *U* test indicated that there were no differences in the quality of parent-child interactions on any domain of the MACI. In the EL group, there was a significant difference in infant affect observed between the two groups. The infants who were in the non-completer group ($M\,dn = 1.00$) had significantly lower scores on the positive affect domain of the MACI compared to those in the completer group ($M\,dn = 3.00$) $U = 14.00, Z = -3.33, p = .001$.

2.3. Materials

2.3.1. The Manchester Assessment of Caregiver-Infant Interaction (MACI)

The parent-child interaction videos were rated by a trained research assistant using the global analytic rating scheme, MACI (Wan et al., 2017). The MACI is designed to assess the quality of seven domains of parent-child interaction: caregiver sensitivity, caregiver non-directiveness, the infant's attentiveness to caregiver, infant positive affect, infant liveliness, dyad mutuality and dyad engagement intensity. Each domain is rated on a seven-point Likert scale and each parent-child interaction video is given one rating for each domain on the scale, giving a total of seven scores for each video. A score on the higher end of the scale (i.e. scores closer to 7) indicate high levels of the quality specified.

Caregiver sensitivity describes the parent's response to infant behaviour. Caregivers demonstrating high sensitivity respond to their infants with an attentive attitude, warmth, appropriate engagement and support. A score of 1 indicates minimal sensitive responsiveness and a score of 7 indicates high sensitive responsiveness. When a caregiver exhibits non-directiveness they follow the lead of the infant during play and provide feedback that relates to the infant's focus of attention. A caregiver demonstrating high levels of directiveness will exhibit demanding and intrusive behaviours and use negative comments during the interaction with their infant. A score of 1 indicates highly directive caregiver behaviour and a score of 7 indicates a highly nondirective caregiver. The infant's attentiveness to their caregiver refers to the infant's use of direct eye contact, body orientation, and joint activity in relation to their caregiver. The infant may reference caregiver activity through acts such as imitation. A score of 1 indicates that the infant was minimally attentive and a score of 7 indicates that the infant was highly attentive to their caregiver. Infant positive affect measures the infant's use of positive behaviours, vocalisations and expression during the parent-child interaction. Negative affect is demonstrated through the use of negative expressions, vocalisations and gestures. A score of 1 indicates that the infant exhibited high negative affect and a score of 7 indicates high positive affect. Infant liveliness measures the amount and level of physical activity the infant partakes in during the interaction and considers behaviours that are spontaneously initiated by the infant. A score of 1 indicates that the infant was

Table 2
Group attrition rates.

Group	n at 6 m	n at 12 m	n at 24 m	n at ADOS-G
TL	39	39 (0.00 %)	36 (7.69 %)	34 (12.82 %)
EL	29	26 (10.34 %)	24 (17.24 %)	23 (20.70 %)
Full Sample	68	65 (4.41 %)	60 (11.76 %)	57 (16.18 %)

Note. % = Attrition Rate.

not at all lively during the interaction and a score of 7 indicates that the infant was extremely lively. Dyadic mutuality measures the general amount of engagement shared between the parent and infant. It considers the level of reciprocity, attunement and togetherness exhibited during the interaction. The domain considers the level of shared attention, mutual play, flow and body orientation of the dyad. A score of 1 indicates that the dyad exhibited very low mutuality, a score of 7 indicates consistently high mutuality. Engagement intensity measures the quality of the mutual interaction during periods of engagement such as mutual object focus. The domain considers the degree of interest, arousal and positivity/excitement exhibited by both parties during the period of mutuality. A score of 1 indicates almost no engagement and a score of 7 indicates a very intense engagement.

The psychometric utility, validity and reliability of the MACI have been established in a normative sample of children aged 3–14 months (Wan et al., 2017). In the current study, inter-rater reliability (IRR) of the MACI coding was established through blinded independent double coding of 15 (22.06 %) randomly selected parent-child interaction recordings. Good to high inter-rater agreement was demonstrated on each single measure of the MACI with intra-class correlations ranging from $r = 0.63$–0.95.

2.3.2. Mullen scales of early learning (MSEL)

The MSEL (Mullen, 1995) is a standardised assessment tool used to measure development in children aged 0–68 months. In this study, the MSEL was administered when the children were 12 and 24 months of age, it took 15–35 min to administer depending on the child's age and ability. The MSEL was used to assess children's visual reception, fine motor skills, and receptive and expressive language. Visual reception is a measurement of cognitive functioning that incorporates visual discrimination, memory, organisation and spatial awareness. Tasks include placing block set shapes onto a puzzle board, producing object associations and looking for missing objects. The MSEL assesses fine motor skills such as motor planning and control, object manipulation and writing readiness. The use of pincer grip, grasping, and object transference is assessed by instructing the child to play with toy blocks. Tasks such as turning pages in a book and the imitation of crayon lines are also observed. Receptive language skills, such as auditory comprehension, auditory memory and auditory sequencing, are assessed. Children are tested to see if they understand familiar names, words and instructions and can identify their own body parts and pictures in a book. Expressive language abilities assessed include speaking, language formation and verbal conceptualisation. The production of babbling, consonant sounds and two-syllable sounds is observed in younger children. The naming of objects and use of two-word phrases is assessed during the 24-month assessment. Visual reception, fine motor and language scores are combined to calculate the Early Learning Composite Score (ELC). The ELC provides a measure of general intellectual functioning and is used to avoid truncation in the case of extreme scores on singular domains. The raw score of each subdomain is converted into a T-score, where 20 is the minimum score and represents a score that is three standard deviations below the mean. A score of 50 is considered average with a standard deviation equal to 10. The MSEL has an internal validity between 0.75 and 0.80 dependent on the domain, and a test re-test coefficient of 0.70 in children aged one to twenty-four months (Mullen, 1995).

2.3.3. Autism diagnostic observation schedule-generic (ADOS-G)

Module one of the ADOS-G (Lord et al., 2000) was administered to measure autism symptoms in the children when they reached 24 months of age. A trained administrator carried out the play-based assessment designed to elicit social interaction, communication skills, imagination and creativity (flexible thinking) and stereotyped behaviours. Upon assessment, individuals are rated with an ADOS-G classification that includes non-spectrum, autism or autism-spectrum, dependant on their scoring on the four assessed domains. A higher score on the ADOS-G indicates increased autism symptom severity. A score of at least 14 on the social and communication scales indicates an autism classification. A score of at least 7 on these domains is required for an autism-spectrum classification. A score below 7 yields a non-spectrum classification. The ADOS-G demonstrates excellent inter-rater reliability coefficients (kappas exceeding 0.60) and test re-test coefficients ranging from 0.59 to 0.82. Overall, seven children across the cohort exhibited high levels of autism symptoms by receiving a score of 7 or more, six from the EL group and one child from the TL group. Due to the small number of those displaying autism symptoms, any group differences that might emerge as early signs of autism may not be detected.

2.3.4. Autism-spectrum quotient (AQ)

Due to the heritable nature of autism, the AQ (Baron-Cohen et al., 2001) was used to measure traits of autism in the mothers in this sample. The AQ is a self-report questionnaire that comprises fifty statements that positively or negatively relate to traits of autism in adults. It measures five traits of autism including social skills, imagination, communication, attention switching and attention to detail. Examples of statements include "I notice patterns in things all the time" and "I enjoy social chitchat". The mothers were asked to rate each statement using a four-point scale ranging from "definitely agree" to "definitely disagree". A score of 32 or above on the AQ is indicative of significant autism traits; 80 % of individuals with a score above this threshold received a clinical diagnosis of high functioning autism (Baron-Cohen et al., 2001). The AQ demonstrates good test re-test and interrater reliability. When administered twice within a two-week time period, scores from the first and second administration of the AQ did not differ at the group level, and were strongly correlated. The AQ yielded Cronbach alpha coefficients between 0.62 and 0.77, indicating moderate to high internal consistency (Baron-Cohen et al., 2001).

2.4. Statistical analysis

Statistical analyses for this study were conducted using SPSS (Version 26), with alpha criterion set to $p < 0.05$ unless stated otherwise. Data were checked for normality to meet the assumptions of parametric statistics using Shapiro Wilk's test and homogeneity of variance was checked using Levene's test. Log transformations were applied to non-normal data and non-parametric tests were used

when such transformations did not produce normality. Group differences in demographic characteristics, autism symptoms (using the ADOS-G) and the quality of parent-child interaction (using the MACI) were analysed using independent samples t-tests, Mann-Whitney *U* or Chi-square tests as appropriate. A 2×2x4 ANOVA was conducted to test for group differences in developmental outcomes using the four MSEL domain scores from assessments at 12 and 24 months. Kendall's Tau correlation coefficients were calculated to analyse the relationship between individual domains of the MACI, the MSEL and ADOS-G.

3. Results

3.1. Developmental functioning and autism symptoms

MSEL scores of children collected at 12 and 24 months were compared by group. Table 3 presents descriptive statistics and group differences for these developmental outcome scores. A 2×2x4 analysis of variance (ANOVA) was used to test differences in MSEL scores for the four domains (visual reception, fine motor skills, and receptive and expressive language) assessed at two time points (12 and 24 months) according to group (TL and EL). Due to heterogeneity of variance within the data, the significance level for this analysis was adjusted to $p < 0.01$ to ensure the robustness of the findings using this parametric test. The sphericity assumption was met for the effect of each domain as indicated by Mauchly's test, $X^2(5) = 8.02$, $p = 0.155$. Interaction effects from the ANOVA were not significant, the EL and TL groups did not differ significantly in MSEL scores when factoring in age of assessment. There was a significant effect of autism group, with the EL group scoring significantly lower than the TL group on each domain of the MSEL, $F(3,174) = 4.91$, $p = 0.003$. There was also a significant main effect of age of assessment, with MSEL scores lower for assessment at 12 months compared to assessment at 24 months for both groups $F(3,174) = 5.53$, $p = 0.001$.

Symptoms of autism in the children were measured when they were 24 months of age using module one of the ADOS-G (Lord et al., 2000). Mann-Whitney *U* tests were conducted to compare ADOS-G domain scores between the EL and TL groups. Children in the EL group received higher scores (indicative of more pronounced autistic symptoms) on the communication, flexible behaviour and stereotyped thinking domains of the ADOS-G when compared to the TL group (see Table 4 for descriptive statistics for the two groups and outcomes of the Mann-Whitney *U* tests).

3.2. Comparing parent-child interaction quality at 6 months in TL and EL groups

In order to test hypothesis 1, the quality of parent-child interaction was compared between the EL and TL groups. Shapiro Wilk's tests and histograms indicated that the MACI data were not normally distributed. Therefore, the groups were compared for each of the seven domain scores using a Mann-Whitney *U* test. Descriptive statistics are presented in Table 5 and tests of group differences in MACI scores are presented in Table 6. A Mann-Whitney *U* test indicated that the level of engagement intensity in the EL group was significantly lower compared to the TL group. There were no significant group differences on any of the other MACI variables (see Table 6) but a number of domains demonstrated a pattern of non-significant trends where the EL group displayed lower levels of caregiver sensitivity, infant attentiveness to caregiver and dyadic mutuality compared to the TL group.

3.3. Associations between parent-child interaction variables at 6 months and child outcome variables at 12 & 24 months

In order to test hypothesis 2, Kendall's Tau correlations were computed to analyse the relationship between the quality of parent-child interactions and developmental outcomes in children with TL and EL of developing autism. Parent-child interactions were observed when the infants were 6 months of age, MSEL scores were acquired across the 12- and 24-month collection points and ADOS-G scores were obtained when the children were 24 months of age. The patterns of relationships in the two groups are distinct and multiple significant associations were observed between MACI scores and MSEL scores collected at 12 months in the TL group; these correlations are displayed in Table 7 for the TL group and in Table 8 for the EL group.

Table 3
Descriptive statistics for MSEL scores at 12 and 24 months for each group.

		Group					
		Typical Likelihood			*Elevated Likelihood*		
Child age	Domain	Mean	SD	Range	Mean	SD	Range
12 Months	Visual Rec	51.15	7.25	28.00	47.31	8.85	36.00
	Fine Motor	57.33	9.50	38.00	52.77	8.07	30.00
	Rec Lang	52.95	4.81	21.00	49.23	6.94	30.00
	Exp Lang	52.26	5.59	20.00	50.00	8.28	32.00
	ELC	106.46	10.24	44.00	99.92	11.32	43.00
24 Months	Visual Rec	63.06	8.45	37.00	56.13	15.97	60.00
	Fine Motor	52.89	8.45	36.00	46.79	10.09	45.00
	Rec Lang	59.89	6.22	23.00	52.08	13.20	51.00
	Exp Lang	62.36	9.72	41.00	51.58	11.31	40.00
	ELC	119.17	12.09	47.00	103.54	21.16	77.00

Note. Visual Rec = Visual Reception; Rec Lang = Receptive Language; Exp Lang = Expressive Language; ELC = Early Learning Composite.

Table 4
ADOS-G scores at 24 months by group.

	TL (n = 34)		*EL (n = 23)*		*Group Difference*			
ADOS-G Domain	Median	IQR	Median	IQR	*U*	*Z*	Cohen's d	*p*
Communication	0.50	1.25	1.00	3.00	328.50	-2.10	0.52	.040*
Social	0.00	1.00	1.00	3.75	338.50	-1.72	0.48	.090
Flexible Thinking	0.00	1.00	0.50	2.00	344.50	-2.04	0.46	.041*
Stereotyped Behaviours	0.00	0.00	0.00	0.25	371.00	-2.52	0.36	.012*

Note. Higher scores on the ADOS-G reflect higher levels of autism symptoms
*$p < 0.05$.

Table 5
Descriptive statistics for MACI scores at 6 months for each group.

	Group					
	Typical Likelihood			*Elevated Likelihood*		
	Mean	SD	Range	Mean	SD	Range
Infant Age (in months)	6.13	0.24	1.27	6.10	0.27	1.10
Interaction Domain						
Caregiver Sensitivity	3.79	1.24	5.00	3.28	1.00	3.00
Caregiver Non-directiveness	4.18	1.34	4.00	3.62	1.45	5.00
Infant Attentiveness to Caregiver	3.97	1.22	5.00	3.41	1.21	5.00
Infant Positive Affect	2.82	1.59	6.00	2.52	1.60	5.00
Infant Liveliness	3.95	1.05	4.00	4.14	0.99	3.00
Dyadic Mutuality	3.33	1.32	5.00	2.83	1.00	4.00
Engagement Intensity	3.79	0.77	4.00	3.41	0.95	4.00

Note. Interaction domains are scored on a scale from 1 to 7; low scores indicate poor interactions (for example, lower levels of sensitivity).

Table 6
Comparison of MACI scores at 6 months by group.

	Typical Likelihood (n = 39)		*Elevated Likelihood (n = 29)*		*Group Difference*			
Interaction Domain	Median	IQR	Median	IQR	*U*	*Z*	Cohen's d	*p*
Caregiver Sensitivity	4.00	2.00	3.00	2.00	433.50	-1.70	0.41	.090
Caregiver Non-Directiveness	4.00	2.00	4.00	3.00	445.50	-1.52	0.37	.128
Infant Attentiveness to Caregiver	4.00	2.00	4.00	2.00	429.50	-1.76	0.42	.079
Infant Positive Affect	3.00	3.00	2.00	2.50	498.50	-0.86	0.20	.389
Infant Liveliness	4.00	2.00	4.00	2.00	515.00	-0.65	0.15	.514
Dyadic Mutuality	3.00	2.00	3.00	1.50	434.50	-1.68	0.40	.093
Engagement Intensity	4.00	1.00	3.00	1.00	415.00	-2.01	0.47	.045*

Note. Interaction domains are scored on a scale from 1 to 7; low scores indicate poor interactions (for example, lower levels of sensitivity).
*$p < 0.05$.

In the TL group, caregiver sensitivity, caregiver non-directiveness, infant attentiveness to caregiver, infant positive affect, dyadic mutuality and engagement intensity positively correlated with performance on visual reception. Caregiver sensitivity and dyadic mutuality positively correlated with performance on the fine motor domain. Engagement intensity scores were positively associated with expressive language skills. Higher levels of caregiver sensitivity, dyadic mutuality and engagement intensity were positively related to ELC scores. For the relationship between MACI and ADOS-G scores, higher levels of engagement intensity were associated with improved social functioning and flexible thinking.

Fewer significant associations were observed in the EL group. Surprisingly, higher levels of engagement intensity were associated with lower ELC scores at 12 months among the EL group. However, as expected, infants who showed less attention to their mother scored higher (i.e., displayed more pronounced symptoms) on the communication and flexible thinking domains of the ADOS-G. Infant positive affect scores were also negatively associated with flexible thinking domain scores (i.e., less positive affect was associated with greater inflexibility in thinking).

No significant associations were observed between any MACI scores at six months and MSEL scores in any domain in either the TL or EL group at 24 months.

4. Discussion

When the quality of parent-child interaction at six months was compared between the TL and EL groups, the level of engagement intensity was significantly lower in the EL group in comparison to the TL group. This finding partially supports the first hypothesis,

Table 7
Correlations among the study variables in the Typical Likelihood Group.

	MACI Variables						
	Caregiver Sensitivity	Caregiver Non-directiveness	Infant Attentiveness to Caregiver	Infant Positive Affect	Infant Liveliness	Dyadic Mutuality	Engagement Intensity
MSEL Variables							
Visual Reception	.28*	.26*	.25*	.25*	.14	.30**	.28*
Fine Motor	.20	.09	.04	.14	.14	.20	.06
Receptive Language	.00	-.02	.05	-.07	.02	.05	.09
Expressive Language	.16	.17	.15	.05	.19	.20	.32*
ELC	.24*	.19	.15	.15	.14	.29**	.20
ADOS-G Variables							
Communication	-.05	-.14	.07	.15	.03	.04	.09
Social	.00	-.20	-.21	-.09	.24	.12	-.43**
Flexible Thinking	.06	.04	-.24	-.18	.13	.03	-.29*
Stereotyped Behaviour	-.13	-.24	-.24	.05	.20	-.25	-.21

Note. MACI scores were collected when the children were 6 months of age, MSEL scores were acquired at 12 months of age and ADOS-G scores were obtained when the children were 24 months of age.
*$p < 0.05$; **$p < 0.01$. (One-tailed).

Table 8
Correlations among the study variables in the Elevated Likelihood group.

	MACI Variables						
	Caregiver Sensitivity	Caregiver Non-directiveness	Infant Attentiveness to Caregiver	Infant Positive Affect	Infant Liveliness	Dyadic Mutuality	Engagement Intensity
MSEL Variables							
Visual Reception	.00	.25	-.09	-.12	-.14	-.13	-.20
Fine Motor	-.02	.09	-.10	-.08	.11	-.04	-.05
Receptive Language	-.03	.05	.03	-.11	-.11	-.16	-.19
Expressive Language	-.26	-.14	.14	-.04	.19	-.25	-.11
ELC	-.13	.13	-.07	-.18	.03	-.21	-.28*
ADOS-G Variables							
Communication	-.15	.08	-.36*	-.17	-.10	-.12	-.07
Social	.03	.07	-.08	-.02	-.04	.07	.05
Flexible Thinking	-.04	.11	-.32*	-.33*	-.01	-.02	-.18
Stereotyped Behaviour	.01	-.01	-.09	-.02	-.24	.15	-.01

Note. MACI scores were collected when the children were 6 months of age, MSEL scores were acquired at 12 months of age and ADOS-G scores were obtained when the children were 24 months of age.
*$p < 0.05$. (One-tailed).

which posited that infants with EL of developing autism and their parents would engage in lower quality interactions, characterised by lower levels of reciprocity and less engaging dyadic interactions. Engagement intensity describes the degree of mutual interest, arousal, positivity and excitement expressed by both the mother and infant (Wan et al., 2017). Consistent with the literature, a study by Wan et al. (2013) found engagement intensity at 12 months to predict autism outcomes in children at 36 months of age. It could be that children with an EL of autism found the interaction to be less interesting or rewarding, thus decreasing the intensity of the engagement. Children with autism tend to display lower levels of social behaviour, therefore mothers may adjust their behaviours to ensure they are not overbearing or intense. An engagement that is overly intense may overwhelm the infant causing them to disengage from the interaction (Segars et al., 2020). Conversely, children with an EL for autism may exhibit hypo-reactive patterns of behaviour that lead to a decrease in the number of opportunities for parents to respond to their child and can delay early learning (Grzadzinski et al., 2021). Infants who display hypo-reactive patterns of behaviour may benefit from more intense engagement as long as the parent is sensitive to the interests of the infant (Haebig et al., 2013).

Whilst engagement intensity differed between the TL and EL groups, the groups did not differ significantly on other domains of parent-child interaction including caregiver and infant qualities. Previous studies have demonstrated differences in caregiver qualities in EL groups, such as lower levels of sensitive responding and higher levels of directive behaviour (Wan et al., 2012). However, other studies have found parental sensitivity to be similar between TL and EL cohorts (Baker et al., 2010; Harker et al., 2016; Schwichtenberg

et al., 2019). Infants with EL for autism tend to exhibit fewer and less clear social initiations during episodes of parent-child interaction, but these tendencies are more pronounced in the case of older children in interaction (Pijl et al., 2021). It is possible that the global measure of parent-child interaction used in the present study (MACI; Wan et al., 2017) was not sensitive enough to detect fine-grained differences in interactions at six months of age. Previous studies comparing groups with EL and TL of developing autism measured the quality of parent-child interaction using the MACI when children were 6–10 and 12–15 months of age (Wan et al., 2012; Wan et al., 2013). Parent-child interaction measured at 12–15 months (but not at 6–10 months) was found to significantly predict autism diagnosis at three years of age (Wan et al., 2013). This suggests that the MACI may be more sensitive to the quality of parent-child interaction in older children with EL for autism. Alternatively, when infants are 6–10 months old, they may not be displaying symptoms that affect the quality of the parent-child interaction. In turn, this may affect the child's developmental outcome. Wan et al. (2012) identified a larger number of group differences in parent-child interactions when comparing the interactions of those in an TL and EL group using the MACI. The study had a larger sample size and thus increased statistical power compared to the current study. The MACI scores were normally distributed and therefore treated as interval data and infant age was controlled for in their analysis. If the sample size and statistical power of the current study was increased, more differences in parent-child interactions may be observed. Indeed, a number of domains demonstrated borderline effects and the EL group displayed lower levels of caregiver sensitivity, infant attentiveness to caregiver and dyadic mutuality compared to the TL group. It is possible that increased statistical power, and the inclusion of more children displaying high levels of autism symptoms within the EL group could increase the likelihood of detecting significant group effects on these domains of the MACI. Alternatively, the trends might disappear.

The results of the study indicate that infants in the EL group are susceptible to poorer developmental outcomes compared to those in the TL group. Furthermore, the current study found children with an EL for autism and their parents display characteristically different behaviours during parent-child interaction compared to dyads where the child has a TL of autism. This suggests that changes in behaviour in the EL group can be identified as early as 6 months of age. The detection of emerging autism symptoms at a young age is critical, as early intervention is likely to be the most effective in decreasing impairments (Landa, 2018).

The second hypothesis concerned the relationship between the quality of parent-child interactions at six months and outcome measures at 12 and 24 months and whether this relationship differed between the TL and EL groups. Different patterns of relationships were observed in the TL and EL groups. The findings indicate that parent-child interactions do not impact the developmental outcomes of those in the EL group in the same way as they do for the TL group. In the TL group, multiple positive associations were identified where higher quality parent-child interactions at six months were associated with better developmental outcomes 6 months later and lower ADOS-G scores 18 months later. In the EL group, the infant MACI scores including higher levels of infant positive affect and infant attentiveness to the caregiver were associated with lower levels of autism symptoms, as hypothesised. Our findings are consistent with the trajectory of the autism phenotype (Filliter et al., 2015), as infants who were less attentive to their mother and displayed lower levels of positive affect displayed higher levels of autism symptoms.

No positive associations were observed between MACI and MSEL scores in the EL group. Instead the opposite effect was found and higher levels of engagement intensity at 6 months was associated with lower ELC scores at 12 months of age. The literature suggests that higher quality parent-child interactions are associated with improved developmental outcomes in children. Wan et al. (2013) found lower levels of engagement intensity to be associated with autism outcome at 36 months. Therefore, this finding is unexpected and runs counter to the study's hypothesis. Engagement intensity describes the quality of the engagement and mutual focus that the parent and child share directly or through focus on a mutual object. Certain qualities of parent-child interactions may have different effects on those with EL and TL of developing autism. In the context of these findings, it could be that higher levels of engagement intensity shared in the parent-child dyad could be less rewarding for children in the EL group, whereas children in the TL group may find the level of intensity to be engaging and enjoyable. However more definitive explanations for this unexpected finding awaits replication by further studies.

Mothers of infants with an EL for autism may have adapted their parenting in response to their older children with autism. Mothers may exhibit more structured and routine-based behaviours in order to accommodate less flexible and more demanding behaviours observed in children on the autism spectrum. Thus, even if engaged in positive mutual activity, this mutual engagement might exhibit different characteristics which may be associated with different domains of development for those on the spectrum. For example, differences in the properties of language used by the mother during the dyadic interaction might be observed. There may be variation in the use of child directed speech addressed to the infant such as prosody, which in turn has been found to impact child language development and social responsiveness (Cohen et al., 2013; Quigley et al., 2016). Future studies might incorporate microanalytic approaches (Morawska et al., 2014) to explore fine grained characteristics of engagement intensity such as the composition of caregiver speech input, levels of synchrony, joint attention and social reciprocity. The use of microanalytic techniques in conjunction with global measurements of parent-child interaction can increase the precision and sensitivity of the observation of parent-child interaction.

In the literature various measures are used to code parent-child interactions (Lotzin et al., 2015). The lack of standardisation brings into question the reliability of these coding schemes, particularly measures that code global behavioural constructs. A variety of definitions are used to describe specific constructs of parent-child interaction. For instance, directiveness has been negatively associated with favourable interaction styles such as sensitivity and responsiveness. However, recent literature suggests that directiveness can be impacted by different types of verbal directiveness such as follow-in directives (Haebig et al., 2013). Follow-in directives are statements that relate to an activity or object that the child is already focused on and conveys an expectation that the child changes their activity. The use of follow-in directives is linked to improved language outcomes in children with autism one year later (Haebig et al., 2013). Thus, directiveness has distinct effects on child outcomes depending on the definition of directiveness employed. This raises a question of whether directiveness should be considered as a single construct and highlights the importance of how global

variables are defined.

Limitations of the study design must be considered when interpreting these findings. The study sample was affected by attrition at multiple time points of assessment and participants in the EL group were more likely to withdraw. The infant's gestational age, gender, number of siblings, and the mother's age, household income and maternal AQ scores were observed and compared between the completer and non-completer groups. No significant differences were found in any of the sample demographics when comparing the completers to the non-completers. This suggests that demographics and autism traits in mothers had no impact on whether the family would return to participate in the study at a later stage. The parent was less likely to return to take part in the later stages of the study if their infant displayed a distressed or negative state during participation. It could be that some element of the study such as the tasks or being in a laboratory environment prompted negative emotional responses in this group of infants.

A measure of development was not taken at the baseline period when the children were 6 months of age, only parent-child interactions were observed during this phase of data collection. Future research should ensure a baseline assessment is conducted at the time of the parent-child interaction.

The findings of this study are based on a relatively small sample. The use of non-parametric statistics decreases the statistical power of the study and possible covariates such as number of siblings cannot be controlled for. The results are therefore susceptible to false negatives and any sampling effect biases may be amplified, thus the findings must only be viewed as indicative. Due to the heterogeneous nature of autism, studies investigating infant sibling groups require relatively large sample sizes in order to sufficiently represent this cohort (Lombardo et al., 2019). Despite this limitation, the study's prospective repeated measures design helped elevate the statistical power of this study (Bakeman, 2005).

There were significant differences in the family demographics between the EL and TL groups such as maternal age, number of siblings and household income. These differences may have influenced the results. In this study, mothers of children with EL were on average 2.42 years older than mothers of TL children. Findings from previous studies suggest that older mothers display higher levels of maternal supportiveness and closeness with their child (Barnes et al., 2014). Despite these differences, it is unlikely that this age gap is significant enough to elicit these characteristics, which were between mothers in their teens and early twenties and older mothers in their thirties in the Barnes et al. study. One factor likely linked to elevated maternal age is the difference in the number of siblings between groups. In this study mothers of EL infants had more children than mothers of TL infants. A greater number of siblings has been found to influence how mothers interact with their infant, and in turn has an effect on their children's development. The amount of parent-child quality time the mother can offer to each child decreases as the size of the family expands. This has been linked to lower scores on cognitive tests in younger siblings (Lehmann et al., 2018). Additionally, infants with EL of autism could learn maladaptive behaviours from their diagnosed older sibling, such as non-functional repetitive behaviours (Christensen et al., 2010). Despite significant differences in household income, the median income for EL and TL groups both fall into high income brackets. The families participating in the study generally come from high resource households, which limits the generalisability of results.

Only a small number of children in this sample exhibited high levels of autism symptoms and received a score of 7 or more on the ADOS-G at 24 months of age. None of the children had a formal clinical diagnosis of autism. Seven out of 57 (12.28 %) children had high levels of autism symptoms identified using the ADOS-G, with six of the children from the EL group and one child from the TL group. Due to the small number in the high autism symptom group, any group differences that emerge as early signs of autism may have been dampened in the EL group. Further analyses could not be carried out to see if parent-child interactions and developmental outcomes could predict membership in high versus low autism symptom groups. An explanation for the low level of autism symptoms found could be attributed to relatively equal numbers of males and females in the study. Boys are three times more likely to be diagnosed with autism, and it is harder to measure autism symptoms in girls at a young age (Loomes et al., 2017). It may have been too early to measure autism symptoms using the ADOS-G assessment at 24 months of age, particularly among girls. Given the period of recruitment for the study was before the publication of the ADOS-2 (Lord et al., 2012) and DSM-5 (APA, 2013), the ADOS-G (Lord et al., 2000) was used to measure the level of autism symptoms in the sample and the siblings diagnosed with autism were diagnosed with reference to the DSM-IV(APA, 1994). Future studies should make use of the most up to date measures to ensure the evaluation of autism symptoms and autism diagnosis in sibling probands is reliable.

Despite these limitations, the study has many strengths including its longitudinal design, the assessment of development at two time points, and the observation of developmental outcomes by subdomain. The majority of studies that observe the relationship between parent-child interactions and developmental outcomes report only the ELC score of the MSEL. To our knowledge, this study is one of the first to examine global qualities of parent-child interaction and their relationship to specific developmental subdomains in children with an EL or TL of developing autism.

CRediT authorship contribution statement

Chelo Del Rosario: Conceptualization, Formal analysis, Writing. **Elizabeth Nixon:** Conceptualization, Writing, Supervision. **Jean Quigley:** Conceptualization, Writing, Supervision. **Andrew J.O. Whitehouse:** Conceptualization, Resources, Funding acquisition. **Murray T. Maybery:** Conceptualization, Resources, Writing, Supervision.

Declaration of Competing Interest

The authors have no conflicts of interest to declare.

Data Availability

The authors do not have permission to share data associated with this research.

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