Is level of prematurity a risk/plasticity factor at three years of age?

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Children born preterm have poorer outcomes than children born full-term, but the caregiving environment can ameliorate some of these differences. Recent research has proposed that preterm birth may be a plasticity factor, leading to better outcomes for preterm than full-term infants in higher quality environments. This analysis uses data from two waves of an Irish study of children (at 9 months and 3 years of age, *n*=11,134 children) and their caregivers (*n*=11,132 mothers, *n*=9,998 fathers) to investigate differences in how caregiving affects social, cognitive, and motor skills between full-term, late preterm, and very preterm children. Results indicate that parental emotional distress and quality of attachment are important for child outcomes. Both being born very preterm and late preterm continue to be risk factors for poorer outcomes at 3 years of age. Only fathers' emotional distress significantly moderated the effect of prematurity on infants' cognitive and social outcomes – no other interactions between prematurity and environment were significant. These interactions were somewhat in line with diathesis stress, but the effect sizes were too small to provide strong support for this model. There is no evidence that preterm birth is a plasticity factor.

Keywords: preterm, caregiving, diathesis stress, differential susceptibility, prematurity, parenting stress

1. Introduction

Preterm birth (≤ 36 weeks gestation) is a growing public health concern, accounting for more than 11% of live births worldwide (Blencowe et al., 2012) and for 6% of live births in Ireland (Economic and Social Research Institute, 2013). While there are different definitions, level of prematurity is often split into three categories: very preterm (≤33 weeks), late preterm (34-36 weeks) and full-term (≥37 weeks), with children born earlier tending to have less positive developmental outcomes (National Institute of Child Health and Human Development [NICHD], 2014; Saigal & Doyle, 2008; Sullivan & Hawes, 2007). Preterm children have a greater frequency of behavioural issues (Anderson, Doyle, & the Victorian Infant Collaborative Study Group, 2003; Delobel-Ayoub et al., 2009), poorer performance on cognitive assessments (Anderson et al., 2003; Baron et al., 2014; Ionio et al., 2016), and a greater likelihood of fine and gross motor skill impairment (Baron et al., 2014; Foulder-Hughes & Cooke, 2003; Sullivan & Hawes, 2007). These effects continue into adolescence (de Kieviet, Piek, Aarnoudse-Moens, & Oosterlaan, 2009; Gardner et al., 2004; Johnson, 2007).

Because of the well-documented adverse consequences associated with preterm birth (Cheong et al., 2017; NICHD, 2014; Saigal & Doyle, 2008), it has typically been characterized as a vulnerability factor. In other words, preterm birth makes one more likely to be adversely affected by environmental stressors (Belsky & Pluess, 2009). However, recent research has suggested that preterm birth may, instead, be a plasticity factor (e.g. Gueron-Sela, Atzaba-Poria, Meiri, & Marks, 2015; Shah, Robbins, Coelho, & Poehlmann, 2013) – that is, a factor that makes one more sensitive to both negative *and* positive environmental influences (Belsky & Pluess, 2009).

If preterm birth acts as a continuing plasticity factor into toddlerhood, this would have important implications for interventions aiming to improve developmental functioning of preterm infants. Given the growing numbers of preterm births and the lack of consensus in the literature, it is critical to examine this area further. The current analysis used data from a nationally representative study of infants and their families (Growing Up in Ireland, GUI), to test whether the effects of mothers' and fathers' emotional distress and quality of attachment on child outcomes differed by level of prematurity. We hypothesized that early and late preterm status would be associated with less positive social, cognitive, and motor skills outcomes, but did not make a prediction of whether prematurity was a risk or plasticity factor.

1.1. Parenting of Preterm Infants

Parenting influences emotional, social, and linguistic development (e.g. Landry, Smith, & Swank, 2003; Shah et al., 2013) as well as executive function (Bernier, Carlson, & Whipple, 2010), and academic achievement (Steinberg, 2001). Preterm birth tends to have a negative psychosocial and emotional effect on families, which may impact the caregiving environments where preterm children are raised (Saigal & Doyle, 2008, although see Bilgin & Wolke, 2015). It may disrupt normal parental roles, cause emotional distress, and lead to an altered parent-child relationship (Miles & Holditch-Davis, 1997). Two aspects of the parent-preterm infant relationship that are likely to affect infant wellbeing are parent-infant attachment and parent stress.

Parental attachment is an aspect of parents' emotional bonds with their infants and is strongly related to the quality of the parent-infant relationship (Slade, Belsky, Aber, & Phelps, 1999). Compared to full-term infants, preterm infants and their mothers have higher rates of insecure attachment during the first twelve months after birth (Korja, Latva, & Lehtonen, 2012), particularly when infants have severe perinatal risks (Borghini et al., 2006). Parent-child attachment may influence child outcomes by compromising the affective communication system, providing fewer opportunities for a child to engage in positive social and learning interactions with their parents, and affecting how children organize their behaviour towards others (Ainsworth, 1979; Tronick, 1989). Similarly, parents of preterm children have higher levels of stress and depression than parents of full-term children (Sansavini et al., 2015; Treyvaud, 2014). There is an association between gestational age and stress even within preterm infants, where mothers and fathers of children born earlier experience greater stress (Schappin, Wijnroks, Uniken Venema, & Jongmans, 2013). Parents who are highly emotionally distressed are less sensitive, less affirming, and more negating of their infants (Murray, Fiori-Cowley, Hooper, & Cooper, 1996), all of which affect a child's functioning. Some well-established differences in outcomes between preterm and full-term infants may be related to such differences in caregiving environments.

1.2. Effects of Parenting on Preterm Infants' Social, Cognitive, and Motor Skills

There are two primary theories of how environmental factors – such as parenting – may affect developmental outcomes: diathesis stress and differential susceptibility. Both models posit an interaction between preterm birth and environment, but differ in their predictions for the nature of that interaction. The diathesis stress model (Monroe & Cummins, 2015; Monroe & Simons, 1991) proposes that children born with vulnerabilities are *more susceptible to negative* environmental influences than children who were not born with those vulnerabilities. The diathesis stress model predicts that when faced with a similarly adverse environment, preterm children will have fewer positive outcomes than full-term children, because their prematurity acts as a diathesis. By contrast, the differential susceptibility model (Bakermans-Kranenburg & van IJzendoorn, 2015; Belsky, Bakermans-Kranenburg, & van IJzendoorn, 2007) suggests that some aspects have been incorrectly characterized as vulnerabilities when they are actually plasticity factors, making children *more susceptible to either negative or positive* environmental influences. The differential susceptibility model would predict that preterm children are more vulnerable to adverse environments than full-term children, but that they may also experience greater benefit from positive environments than full-term children. Preterm birth may act as a plasticity factor due to cerebral structural abnormalities such as reduced volume of cortical and deep nuclear gray matter (Inder, Warfield, Wang, Hüppi, & Volpe, 2005). Preterm infants might depend more on their environment to regulate behaviour because of this neurobiological variation, which may lead to better functioning for preterm infants exposed to high quality parental environments.

Research examining the interaction between caregiving and gestational age has produced mixed findings as to whether effects on social outcomes are best explained by differential susceptibility or diathesis stress. Gueron-Sela et al.'s (2015) study comparing infants born between 28 and 33 weeks gestation and full-term infants showed that preterm infants exposed to higher levels of maternal distress or low quality triadic family interactions demonstrated lower social competence than full-term infants at 12 months of age, while those exposed to low maternal distress or high quality family interactions outperformed the full-term infants on measures of social competence. Because biological risk factors affect social abilities to a smaller degree than cognitive abilities (Bendersky & Lewis, 1994), the social abilities of children born preterm may have more space to be positively impacted by high quality caregiving than their cognitive abilities. In contrast, research by Shah et al. (2013) found no interaction between preterm status and parenting quality on 3 year olds' behavioural outcomes. It is possible that Gueron-Sela et al. and Shah et al.'s results differed due to the age at follow-up: 12 months compared to 36 months. Given these conflicting findings, it remains unclear if prematurity acts as a plasticity factor for social outcomes.

Research on which model best explains the interaction between biological risk and the caregiving environment as they affect cognitive outcomes has also produced conflicting results. In line with differential susceptibility, Shah et al. (2013) found that children born under 30 weeks of gestation were more likely than full-term children to have poorer cognitive outcomes when experiencing negative parenting, but more likely to have better cognitive outcomes when parenting was less negative. Additionally, in Poehlmann et al.'s (2012) study on a group of solely preterm infants, the cognitive outcomes of an easily-distressed subgroup of infants were in line with differential susceptibility. However, in Gueron-Sela et al.'s (2015) study – which had a control group of full-term infants – diathesis stress best explained the interaction between prematurity and maternal emotional distress for children born between 28 and 33 weeks. Recent studies of low birth weight infants – who are often, but not exclusively preterm – also found that children's cognitive and academic outcomes are consistent with diathesis stress (Camerota, Willoughby, Cox, Greenberg, & the Family Life Project Investigators, 2015; Jaekel, Pluess, Belsky, & Wolke, 2015).

Finally, findings are mixed regarding the influence of children's caregiving environment on the development of motor skills. Some studies indicate that the quality of caregiving and the parent-child relationship has an influence on motor development (e.g. Nasreen, Nahar Kabir, Forsell, & Edhborg, 2013) while others have found no relationship (Piteo, Yelland, & Makrides, 2012). As far as the authors found, there has not been a study explicitly testing whether quality of caregiving and prematurity interact to affect children's motor skills development. However, Wu and Chiang (2016) examined this relationship for low birthweight children who were not necessarily preterm, and found low birthweight was a risk factor: low birthweight infants were more vulnerable to low-quality environments than full birthweight infants.

1.3. Current Study

Using the GUI infant cohort, the current study explored whether the diathesis stress or differential susceptibility model best explains the interaction between children's caregiving environment at age 9 months and level of prematurity on social, cognitive, and motor skills outcomes at age 3 years. This research expands on previous work in four primary ways. First, a large, nationally representative sample of children was used, as opposed to sampling participants from neonatal intensive care units (NICUs) as is common in other research in this area. Second, previous research has largely been restricted to infants with low medical or neurological risk, despite relatively high levels of such risks in preterm populations (Saigal & Doyle, 2008) and has not tended to include children living in high-risk social conditions. The current study addressed this gap by including children at varying degrees of risk: because the sample is nationally representative, it includes children with more severe medical and neurological issues, as well as those raised in households with risk factors such as substance abuse, domestic violence, and parental psychiatric conditions. This inclusivity has been explicitly called for in recent studies (e.g. Gueron-Sela et al., 2015). Third, despite the association between being born preterm and difficulties in motor skill development (Moster, Lie, & Markestad, 2008), this outcome has often been overlooked when investigating processes underlying the developmental outcomes of being born preterm. To address this, our study included an objective measure of fine and gross motor skills. Finally, based on work that has indicated that very preterm and late preterm children may be affected differently by their caregiving environment (Baron et al., 2014; Shah et al., 2013), the current analysis included three groups: very preterm (≤33 weeks), late preterm (34-36 weeks), and full-term (≥37 weeks) infants. This builds on related work which has either not included a full-term group (Poehlmann et al., 2012; Shah et al., 2013) or not included a late preterm group (Gueron-Sela et al., 2015), prohibiting comparison across the range of gestational ages.

Specifically, this study attempted to answer the following questions:

1. Do mothers' and fathers' emotional distress and quality of attachment to their children interact with the children's level of prematurity (very preterm, late preterm, and full-term) to influence children's social, cognitive, and motor skills outcomes?

2. If so, are these interactions better explained by a differential susceptibility or diathesis stress?

There are conflicting findings – even within the preterm population – about which model provides a better explanation of interactions between biological risk and environmental influences on cognitive and social outcomes (e.g. Gueron-Sela et al., 2015; Shah et al., 2013). Given the lack of consensus about whether caregiving has any influence on motor skills, we were not confident there would be an interaction at all: neither model may apply. As such, this was an exploratory study, where we hypothesized that early and late preterm status would be associated with less positive social, cognitive, and motor skills outcomes, but did not make a prediction about which model would best explain the results.

2. Method

2.1. Participants

The data in this study were from the first two waves of the GUI infant cohort. GUI aimed to explore the factors that affect wellbeing of children in Ireland (Quail, Williams, McCrory, Murray, & Thornton, 2011a). Participants were sampled from the Child Benefit Register, which is an administrative register for administering financial benefits available to all children in Ireland up to age of 16. Comparisons with representative measures of 9-month-olds in Ireland indicate a discrepancy of less than 3% (Quail, Williams, McCrory, Murray, & Thornton, 2011b). Stratified sampling was used, with pre-stratification by variables included in the Child Benefit Register: marital status, county of residence, nationality of children, and number of children in the claim.

The final sample for the first wave included 11,134 9-month-olds, their 11,134 primary caregivers and 10,183 secondary caregivers. The 11,134 participating households comprised 27% of all households of 9-month-old infants in Ireland (see Quail et al., 2011a for additional information). Children and their families were re-contacted in the month after the child's third birthday, resulting in a sample of 9,793 3-year-olds, their 9,793 primary caregivers and 8,837 secondary caregivers at wave 2 (see Murray, Quail, McCrory, & Williams, 2013 for additional information on this wave).

The current study included three groups of children based on the gestational age at which they were born: very preterm (≤33 weeks, *n*=231), late preterm (34-36 weeks, *n*=513), and full-term (≥37 weeks, *n*=10,390; see Table 1). The 11,132 mothers (M_{age}= 31.5, *SD*=5.4, at wave 1) tended to be the primary caregivers of the children participating in the study, both at wave 1 (99.6%) and at wave 2 (99.0%). The 9,998 fathers were an average of 34.9 years at wave 1 (*SD*=5.5).

2.2. Procedure

To ensure data collection was smooth, GUI was pre-piloted (*n* = 22 families), then piloted (*n* = 359 families), and finally a dress rehearsal was conducted (*n* = 413 families). Both the pilot and the main study underwent a thorough ethical review from a dedicated Research Ethics Committee set up by the Department of Health and Children. Participants were contacted by mail, followed by a face-to-face home visit with a trained and vetted interviewer – at which time any queries parents had about participation were answered and the interview date was set. At the agreed-upon interview date, interviewers administered questionnaires using computer assisted interviewing software and conducted direct assessments of children's cognitive and motor abilities. Signed consent was obtained from a parent/guardian in each household, and all participants were informed of the voluntary nature of the study. No remuneration was provided. Interviewers were never left alone with the child participating in the study; when conducting direct assessments of the child, this was done in the presence of an adult from the household. Interviewers were trained in child welfare in research and attempted to ensure that participation from the children was voluntary by not pressuring the children or their parents to take part and by vigilantly monitoring the children for signs of fatigue. Wave 1 data were collected from September 2008 to April 2009 and wave 2 data were collected from December 2010 to July 2011.

2.3. Measures

2.3.1. Control variables.

2.3.1.1. Infant medical risk at birth.

Infant medical risk at birth was assessed at wave 1 using four questions asked of the primary caregiver: "How many days was [baby] in hospital after the birth?" (0 = ≤ 3 days in hospital, 1 = ≥ 4 days in the hospital), "Did [baby] have to go to the NICU or special care nursery?" (0 = no, 1 = yes), "Did [baby] need any help with his/her breathing from a ventilator?" (0 = no, 1 = yes), and "Were there any complications during [baby's] birth?" (0 = no, 1 for each of these four complications: "foetal distress - abnormal heart tracing", "foetal distress - meconium or other sign", "foetal blood sample taken in labour", or "nerve injury/fracture/bruising"). These scores were summed for a combined possible score ranging from 0 to 7 (*M*=0.5, *SD*=0.9).

2.3.1.2. Child health issues.

Children's health at wave 2 was assessed using three questions to the primary caregiver: "In general, how would you describe [child's] current health?" (0 = "very healthy, no problems", 1 = "healthy, but with a few minor problems", "sometimes quite ill", or "almost always unwell"), "Does [child] have any long-standing illness, condition, or disability?" (0 = no, 1 = yes), and "Since the time of the last interview, approximately how many nights has [child] spent in hospital?" (0 = ≤ 6 nights in the hospital, 1 = ≥ 7 nights in the hospital). These scores were summed for a possible score ranging from 0 to 3 (*M*=0.4, *SD*=0.7).

2.3.1.3. Household socioeconomic status.

Socioeconomic status (SES) was calculated by averaging the standardized scores for household equivalised annual income (Quail et al., 2011a) and the number of years of education that had been completed by the primary caregiver for both wave 1 and wave 2. Due to the high correlation between SES across the waves (r=.80), only the wave 2 SES variable was retained in analyses.

2.3.2. Predictors.

2.3.2.1. Level of prematurity.

At wave 1, primary caregivers were asked "after how many weeks of pregnancy was the baby born?" This was used to classify babies as very preterm (≤33 weeks), late preterm (34-36 weeks), or full-term (≥37 weeks).

2.3.2.2. Quality of attachment.

Primary and secondary caregiver's quality of attachment to their infant was assessed at wave 1 with the 9-item Quality of Attachment subscale of the Maternal Postnatal Attachment Scale (Condon & Corkindale, 1998) for the mothers (range 9-45) and the 5-item paternal version of the same measure for the fathers (range 5-25, see Table 1). This subscale relates to caregivers' feelings toward their infants and about themselves as parents. It has been shown to be consistent and reliable (Condon & Corkindale, 1998).

2.3.2.3. Parental emotional distress.

Parental emotional distress was assessed by a combination of the 18-item Parental Stress Scale (Berry & Jones, 1995) and the 8-item Centre for Epidemiological Studies Depression Scale (CES-D, Radloff, 1977), completed by both primary and secondary caregivers. Caregivers' scores on the Parental Stress Scale and CES-D were standardized and averaged to create a parental emotional distress score for both mothers and fathers, with higher scores indicating greater emotional distress (see Table 1). Internal consistency for both scales has been shown to be acceptable (Berry & Jones, 1995; Radloff, 1977).

We combined these two to bring our emotional distress scale in line with Gueron-Sela et al.'s (2015), which included the CES-D, the Difficult Child subscale of the Parenting Stress Index (Abidin, 1990), and an anxiety measure. Maternal parental distress and maternal depression were positively correlated ($r = .34$), as were paternal parental distress and paternal depression ($r = .25$); Spearman correlations were conducted for both because of skewness in depression scores. Although these correlations are medium-to-small, they are relatively consistent with Gueron-Sela et al.'s (2015) correlations when combining similar measures to create an emotional distress variable. Factor analyses revealed that the mother and father measures each compounded onto 1 factor which explained 67% of the variance in maternal emotional distress and 62% of the variance in paternal emotional distress, respectively.

2.3.3. Outcomes.

2.3.3.1. Socioemotional skills at age 3.

Children's socioemotional skills were assessed using the Strengths and Difficulties Questionnaire (Goodman, 1997), which was completed by the primary caregiver. This scale consists of four negative subscales: emotional symptoms, conduct problems, hyperactivity, and peer problems. Higher scores indicate poorer functioning.

2.3.3.2. Cognitive ability at age 3.

Children were administered the Picture Similarities and Naming Vocabulary subscales from the British Abilities Scales (Elliott, Smith, & McCullough, 1996). These subscales measure reasoning/problem solving and vocabulary, respectively. The subscales were standardized and summed to create a total cognitive ability score.

2.3.3.3. Motor skills at age 3.

Field interviewers asked the child participating in the study to carry out the following tasks: stand on one leg, throw a ball overhand, copy a vertical line, and use a pincer grip. Children received 1 point for each task they carried out successfully. The scores were summed to create a total motor skills score, ranging from 0 to 4. These measures of fine and gross motor skills were informed by other neurodevelopmental batteries (McCrory, Williams, Murray, Quail, & Thornton, 2013).

2.4. Analysis

The data were weighted prior to analysis to ensure they were representative of all 9-month-olds in Ireland (Quail et al., 2011a). We tested whether the data were missing completely at random (Little, 1988). Because the data were not missing completely at random (Little & Rubin, 2014), listwise deletion was inappropriate and missing values were imputed using chained equations (van Buuren & Groothuis-Oudshoorn, 2011). Results in reported regression models were pooled from 30 imputed datasets. After imputation, we carried out a series of stacked regression analyses. The first step included child sex, SES at wave 2, child health at wave 1 and wave 2, and level of prematurity (very preterm and late preterm) as covariates, and then included either the two mother variables (maternal emotional distress and maternal quality of attachment) or the two father variables (paternal emotional distress and paternal quality of attachment). The second step added interactions between level of prematurity and either the two mothering variables or the two fathering variables. The models also varied based on whether the outcome was the children's socioemotional, cognitive, or motor skills outcomes. Preterm status was included in each model as an indicator variable, with the full-term group as a baseline.

An interaction alone does not indicate whether an effect is best predicted by differential susceptibility or diathesis stress. To explore this, significant interactions were subjected to a regions of significance analysis (ROS; Roisman et al., 2012), which is a kind of parameterized simple slopes test (e.g., Aiken, West, & Reno, 1991), providing estimates of the point an interaction is statistically significant. ROS can be thought of as providing error bands on an interaction diagram – denoting in what configurations the interaction holds. ROS analyses were carried out for models in which a significant interaction between preterm status and a caregiving variable was found. When the significant regions of the interaction are skewed to the negative side of the moderator, the evidence supports diathesis stress. Alternatively, if the regions are centred on either side of the crossover point, which is itself within +/- 2 *SD* of the mean, the evidence is supportive of differential susceptibility. When the bounds of an interaction's significant regions with respect to the moderator are far from the mean (typically beyond +/- 2 *SD*), then the interaction itself – even when significant – is not strongly characterized by either diathesis stress or differential susceptibility. In addition to the ROS, we computed the Proportion of the Interaction (POI; Roisman et al., 2012), which expresses the percent of the interaction represented on either side of the crossover point. POI values near 0.5 constitute evidence for differential susceptibility whereas values closer to 0.0 or 1.0 suggest diathesis stress. For examples of ROS and POI analyses, see Manuck and McAffrey (2014) or Wu and Chiang (2016).

3. **Results**

3.1. Preliminary Analysis

Because very preterm and late preterm status are indicator variables derived from the same variable (weeks of gestation), they did not covary with one another, nor did their corresponding interactions. Accordingly, all of the models contained both early and late preterm and their interactions. With an *N* of 11,134 households, the ANOVAs associated with all models were significant and are not reported, though an adjusted R^2 statistic is reported in each case. Including children's status as a singleton or non-singleton did not affect the pattern of results so, for parsimony, this variable was not included.

3.2. Socioemotional functioning

The multiple regression model predicting child socioemotional functioning from maternal emotional distress and quality of attachment had an adjusted R^2 of .14, as did the same model including the interactions (Table 3). Maternal emotional distress (β = .20) was associated with better socioemotional functioning, as was maternal quality of attachment (β = .09). There were no effects of being either very preterm or late preterm and the interactions of those variables with maternal emotional distress and maternal quality of attachment were also non-significant.

The model predicting child social functioning from paternal emotional distress and quality of attachment had an adjusted R^2 of .08 as did the same model that included the interactions (Table 4). Neither being very preterm nor being late preterm predicted a difference in social functioning as compared to full-term children. Paternal emotional distress was associated with better socioemotional functioning (β = .12). There was no association between fathers' quality of attachment to their 9-month-olds and the children's later socioemotional functioning. There was a significant interaction between fathers' emotional distress and very preterm status on social functioning (β = .03). The lower and upper bounds of the ROS for Paternal Emotional Distress*Very Preterm were -4.38 and 1.65, respectively, indicating the model's fit for very preterm children compared to full-term was significant for Paternal Emotional Distress values outside this range (Figure 1a). The POI with respect to children's social functioning as a product of the Paternal Emotional Distress*Very Preterm interaction was 0.60, suggesting a differential susceptibility effect. However, the ROS bounds suggested that differential susceptibility was unlikely because the lower bound was beyond Roisman et al.'s (2012) recommended +/- 2 *SD* limit. Moreover, none of the observed fathers' emotional distress scores were below the range, while 5.7% (*n*=634 imputed; *n*=600 observed) were above, which provides some support for a diathesis stress effect. These results are not in line with differential susceptibility and, while they offer some support for diathesis stress, the evidence is supporting this model is limited. There was no interaction between paternal quality of attachment and being very preterm or late preterm.

3.3. Cognitive functioning.

The model predicting child cognitive functioning at wave 2 using mothers' emotional distress and quality of attachment had an adjusted R^2 of .06 (Table 3). Being very preterm (β = -.04) and late preterm (β = -.04) were both associated with poorer cognitive skills. Greater maternal emotional distress was associated with worse cognitive outcomes (β = -.04). There was no association between maternal quality of attachment and later child cognitive outcomes. There were no interactions between being very preterm or late preterm for either maternal emotional distress or maternal quality of attachment.

The multiple regression model predicting child cognitive functioning at wave 2 using fathers' emotional distress and quality of attachment had an adjusted R^2 of .06 (Table 4). Being very preterm (β = -.04) or late preterm (β = -.03) were both associated with reduced cognitive functioning. Paternal emotional distress was associated with poorer cognitive skills (β = -.04) but paternal quality of attachment had no effect. There was a significant interaction between paternal emotional stress and very preterm status on cognitive functioning (β = -.03). The Paternal Emotional Distress*Very Preterm interaction was submitted to the same ROS and POI analyses described above. The lower and upper significant regions began at -6.50 and 0.91, respectively (Figure 1b), providing evidence that this relationship is not consistent with differential susceptibility. The POI was 0.54, but the lower bound of the ROS with respect to paternal distress were well outside the recommended +/- 2 *SD* limit. Because none of the observed values for paternal distress were below the ROS bound and 9.1% (*n*=1,013 imputed; *n*=926 observed) were above, diathesis stress effects are more plausible. Like social outcomes, the results were relatively weak, providing limited support for the diathesis stress model. The interactions between paternal quality of attachment and very preterm or late preterm status were non-significant.

4. Motor functioning.

Both the multiple regression model predicting child motor functioning at wave 2 using mothers' emotional distress and quality of attachment and the model using father's emotional distress and quality of attachment were quite weak ($R^2 = .04$ for all four models). There were no interaction effects associated with either parent's emotional distress or quality of attachment and very preterm or late preterm status (see Tables 3-4). Being very preterm was associated with significantly poorer motor skills outcomes in both models ($\beta = -.03$ in maternal model, $\beta = -.04$ in paternal model). Neither maternal emotional distress, maternal quality of attachment, nor paternal quality of attachment were related to children's motor skills at age 3. Paternal emotional distress was associated with poorer motor functioning ($\beta = -.04$).

5. Discussion

This study examined whether the developmental outcomes of children born premature were more dependent on family environment than for children born full-term and, if so, whether differential susceptibility or diathesis stress best explained the relationship. The results indicated that preterm children were more susceptible to some environmental influences: fathers' emotional distress had a greater effect on the cognitive and socioemotional outcomes of very preterm as compared with full-term children. Although these interactions were statistically significant, they explained a very limited proportion of the variance in children's socioemotional and cognitive development. Taken together, these findings supported the conclusion that being born preterm generally leads to less positive outcomes but not for the notion that such prematurity is a plasticity factor.

Gueron-Sela et al.'s (2015) study of Israeli very preterm and full-term infants found that the interaction between caregiving and gestational age on social outcomes fit best with differential susceptibility, and that differences in cognitive outcomes were best explained by diathesis stress. By contrast, we found the effect of very preterm*fathers' emotional distress interactions on both social and cognitive outcomes were more in line with diathesis stress than differential susceptibility. However, support for diathesis stress was very weak, with a small effect size and a low proportion of observed cases in the significant regions. Gueron-Sela et al.'s (2015) models also predicted much more of the observed variance in outcomes than our models (by R^2). Because our sample was significantly larger, the difference in fit may be due to model specification as opposed to power. The differences could also be due to the older age of our sample: their study followed children up to 12 months and it is possible that these effects simply diminish by age 3.

One possible explanation for why we did not find evidence of differential susceptibility and Gueron-Sela et al. (2015) did is that caregiving of preterm infants may be more important to their outcomes than caregiving of full-term infants, whereas the caregiving of pre-school aged children born preterm and full-term may be of similar importance. However, Landry et al. (2003) found that very low birth weight preterm infants are more susceptible than those born full-term to maternal warmth through 8 years of age. Further, Shah et al. (2013) found evidence of differential susceptibility for very preterm children at 3 years of age. Another possible explanation is the composition of our data. Using the GUI data gave us a nationally representative sample, as opposed to sampling children entirely from NICUs (e.g. Gueron-Sela et al., 2015; Shah et al., 2013) or exclusively using preterm infants ≤1600 grams at birth who were from low-income families (e.g. Landry et al., 2003). Perhaps certain subgroups of preterm infants are more susceptible to environmental influences over time than full-term infants, but this does not appear to be the case in the overall population of preterm infants.

In contrast to Gueron-Sela et al.'s (2015) study, which found maternal emotional distress interacted with prematurity status to influence social and cognitive outcomes at the age of 12 months, no such interaction on children's outcomes was found at 3 years in our data. Given the large sample size, our study has sufficient power to detect even weak interactions between maternal caregiving and prematurity. One explanation for this contradiction is that mothers may spend more time with their very preterm infants in the first year of life *because* these infants required extra care, and thus, maternal caregiving may be particularly important to very preterm infants' outcomes at age 12 months. Whereas by age 3, mothers of very preterm and full-term infants spend a similar amount of time with their children and, as such, their outcomes are similar with respect to the very preterm*maternal caregiving interaction. Future research that tracked maternal interactions more closely, perhaps by using time diaries, could help clarify this difference in results.

Like other studies that found differences between outcomes of children born late preterm and full-term (e.g. Woythaler, McCormick, & Smith, 2011), being born late preterm was associated with poorer cognitive functioning in our models. It was not, however, associated with less positive socioemotional or motor skills outcomes. Compared to full-term, late preterm status did not interact with any maternal or paternal caregiving variables to affect any of child outcomes. This builds on Shah et al.'s (2013) research comparing late preterm to very preterm infants. They found being born late preterm did not significantly interact with maternal parenting to affect children's outcomes at age 3 years. Together, these results suggest that being born late preterm does not make children more susceptible to environmental influences than full-term or very preterm children or, at least, that any additional susceptibility dissipates by age 3.

Although there were no interactions between prematurity and caregiving on motor skills outcomes, the findings point to the importance of fathers' emotional state when it comes to children's motor development (see Table 4). There was a main effect for paternal emotional distress, with fathers' greater distress when their children are 9 months old predicting poorer motor skills for children at 3 years old. This further supports work indicating that the quality of infants' early caregiving is important to the development of their motor skills (e.g. Nasreen et al., 2012). Interventions designed to bolster development of children's motor skills may be strengthened by focusing on fathers' mental health and stress levels, in addition to occupational and physical therapy for the infants directly (Spittle, Orton, Anderson, Boyd, & Doyle, 2012). Few trials to improve preterm infants' motor include a specific focus on fathers' mental health or stress (Hughes, Redsell, & Glazebrook, 2017; van Wassenaer-Leemhuis et al., 2016).

5.1. Limitations

This study fills a number of gaps in the literature due to the large sample size and nationally representative nature of the data. Not only does the GUI represent Ireland, it also included children with significant medical, neurological, and social risks and allowed us to compare infants born very preterm, late preterm, and full-term. However, there remain some limiting factors. First, participants were only tested at two time points more than two years apart. While the findings of Gueron-Sela et al. (2015) underscore the importance of maternal caregiving at 9 months of age to infant outcomes at 12 months of age, we did not find this interaction at 3 years of age. It was not possible to test the age at which (or how quickly) the effect dissipates because of the longitudinal resolution of the GUI data. Further, caregiving variables and children's socioemotional outcomes were reported by the primary caregiver, which can result in shared method variance. Future work could directly test children's socioemotional outcomes, similarly to how cognitive ability and motor skills were tested in this study. Lastly, Ireland experienced the onset of a financial crisis during the collection of wave 1 data; the economic effects of this recession deepened considerably by wave 2. A quarter of the primary caregivers in the GUI sample indicated that the economic recession had a very significant effect on their lives, with a further 38% stating that it had a significant effect on their lives. This impact was most strongly felt by caregivers in the lowest income quintile (Williams, Murray, McCrory, & McNally, 2013). The additional stress put on families due to increased economic hardships may have influenced the relationship between our measure of stress at wave 1 and functioning at wave 2 (Fahey & Nixon, 2014; Shelleby et al., 2014).

Finally, our measures were somewhat different than those used in previous studies, which may account for some differences in findings. Parents' quality of attachment and emotional distress levels were assessed through self-report. Other similar studies have exclusively used direct observation, or a combination of observation and self-report (e.g. Gueron-Sela et al., 2015; Poehlmann et al., 2011; Shah et al., 2013). It would be helpful to use either observations of interactions or biomarkers, in addition to questionnaires, to better assess these constructs. It is also possible that we did not find the same effects as similar studies because of measurement differences. Gueron-Sela et al.'s (2015) measure of socio-emotional development focused on joint attention, responses to behavioural requests, responding to social interactions, and adaptive behaviours, whereas we measured behaviour problems (cf. Shah et al., 2013). These two distinct aspects of social development may be differentially affected by and related to parenting. Similarly, Gueron-Sela et al. (2015) measured family alliance using the Lausanne Trilogue Play scenario (Corboz-Warnery, Fivaz-Depeursinge, Gertsh Bettens, & Favez, 1993), which measures the appropriateness of affect sharing, family warmth, and validation of a child's emotional experience in the triad, whereas our measure of quality of attachment was a survey measure. Although family alliance and attachment are related (Tissot, Favez, Udry-Jorgensen, Frascarolo, & Despland, 2015), this might explain some of the variation in our findings as compared to previous studies. However, we used a similar emotional distress measure to that of Gueron-Sela et al. (2015) and did not find the same parental emotional distress results, suggesting the differences are not entirely due to differences in measurement.

6. **Conclusions.**

This research used a nationally representative sample of Irish children, followed from age 9 months to 3 years and their parents, and found that children born very preterm are slightly more affected by the emotional distress of their fathers than are children born full-term. However, these effects were extremely weak for both cognitive and socioemotional outcomes and nonexistent for motor outcomes. Further, they were not in line with differential susceptibility and provided only weak support for diathesis stress. These findings call into question whether preterm birth acts as a continuing plasticity factor as children reach toddlerhood.

References

Abidin, R. (1990). *Parenting Stress Index*. Odessa, FL: Psychological Assessment Resources.

Aiken, L. S., West, S. G., & Reno, R. R. (1991). *Multiple regression: Testing and interpreting interactions.* Newbury Park, CA: Sage.

Ainsworth, M. S. (1979). Infant–mother attachment. *American Psychologist, 34*(10), 932-937. DOI: 10.1037/0003-066X.34.10.932

Anderson, P., Doyle, L.W., & the Victorian Infant Collaborative Study Group (2003). Neurobehavioral outcomes of school-age children born extremely low birth weight or very preterm in the 1990s. *Journal of the American Medical Association*, *289*(24), 3264-3272. DOI: 10.1001/jama.289.24.3264

Bakermans-Kranenburg, M. J., & Van IJzendoorn, M. H. (2015). The hidden efficacy of interventions: Gene× environment experiments from a differential susceptibility perspective. *Annual Review of Psychology, 66*, 381-409. DOI: 10.1146/annurev-psych-010814-015407

Baron, I.S., Weiss, B.A., Baker, R., Khoury, A., Remsburg, I., Thermolice, J.W. … Ahronovich, M.D. (2014). Subtle adverse effects of late preterm birth: A cautionary note. *Neuropsychology, 28*(1), 11-18. DOI: 10.1037/neu0000018

Belsky, J., Bakermans-Kranenburg, M.J., & van IJzendoorn, M.H. (2007). For better and for worse: Differential susceptibility to environmental influences. *Current Directions in Psychological Science, 16*(6), 300-304. DOI: 10.1111/j.1467-8721.2007.00525.x

Belsky, J. & Pluess, M. (2009). Beyond diathesis stress: Differential susceptibility to environmental influences. *Psychological Bulletin, 135*(6), 885-908. DOI: 10.1037/a0017376

Bendersky, M., & Lewis, M. (1994). Environmental risk, biological risk, and developmental outcome. *Developmental Psychology, 30*(4), 484-494. DOI: 10.1037/0012-1649.30.4.484

Bernier, A., Carlson, S.M., & Whipple, N. (2010). From external regulation to self-regulation: Early parenting precursors of young children's executive functioning. *Child Development, 81*(1), 326-339. DOI: 10.1111/j.1467-8624.2009.01397.x

Berry, J.O. & Jones, W.H. (1995). The Parental Stress Scale: Initial psychometric evidence. *Journal of Social and Personal Relationships, 12*(3), 463-472. DOI: 10.1177/0265407595123009

Bilgin, A. & Wolke, D. (2015). Maternal sensitivity in parenting preterm children: A meta-analysis. *Pediatrics, 139*(1), 1-19. DOI: 10.1542/peds.2014-3570.

Blencowe, H., Cousens, S., Oestergaard, M.Z., Chou, D., Moller, A., Narwal, R … Lawn, J.E. (2012). National, regional, and worldwide estimates of preterm birth rates in the year 2010 with time trends since 1990 for selected countries: A systematic analysis and implications. *The Lancet, 379*(9832), 2162–2172. DOI: 10.1016/S0140-6736(12)60820-4

Borghini, A., Pierrehumbert, B., Miljkovitch, R., Muller-Nix, C., Forcada-Guex, M., & Ansermet, F. (2006). Mother's attachment representations of their premature infant at 6 and 18 months after birth. *Infant Mental Health Journal, 27*(5), 494-508. DOI: 10.1002/imhj.20103

Camerota, M., Willoughby, M. T., Cox, M., Greenberg, M. T., & Family Life Project Investigators. (2015). Executive function in low birth weight preschoolers: The moderating effect of parenting. *Journal of Abnormal Child Psychology, 43*(8), 1551-1562. DOI: 10.1007/s10802-015-0032-9

Cheong, J. L., Doyle, L. W., Burnett, A. C., Lee, K. J., Walsh, J. M., Potter, C. R., ... & Spittle, A. J. (2017). Association between moderate and late preterm birth and neurodevelopment and social-emotional development at age 2 years. *JAMA Pediatrics*. Advance online publication. DOI: 10.1001/jamapediatrics.2016.4805.

Condon, J.T. & Corkindale, C.J. (1998). The assessment of parent-to-infant attachment: Development of a self-report questionnaire instrument. *Journal of Reproductive and Infant Psychology, 16*(1), 57-76. DOI: 10.1080/02646839808404558

Corboz-Warnery, A., Fivaz-Depeursinge, E., Bettens, C. G., & Favez, N. (1993). Systemic analysis of father-mother-baby interactions: The Lausanne triadic play. *Infant Mental Health Journal, 14*(4), 298-316.

de Kieviet, J.F., Piek, J.P., Aarnoudse-Moens, C.S., & Oosterlaan, J. (2009). Motor development in very preterm and very low-birth-weight children from birth to adolescence: A meta-analysis. *The Journal of the American Medical Association, 302*(20), 2235-2242. DOI: 10.1001/jama.2009.1708

Delobel-Ayoub, M., Arnaud, C., White-Koning, M., Casper, C., Pierrat, V., Garel, M … Larroque, B. (2009). Behavioral problems and cognitive performance at 5 years of age after very preterm birth: The EPIPAGE study. *Pediatrics, 123*(6), 1485 -1492. DOI: 10.1542/peds.2008-1216

Economic and Social Research Institute. (2013). *Perinatal statistics report 2012*. Dublin, Ireland: Health Research and Information Division.

Elliott, C.D., Smith, P., & McCulloch, K. (1996). *British Ability Scales Second Edition (BAS II): Administration and Scoring Manual.* London, England: NFER-Nelson.

Fahey, T., & Nixon, E. (2014). Family policy in Ireland. In M. Robila (Ed.) *Handbook of family policies across the globe* (pp. 125-136). New York, NY: Springer.

Foulder-Hughes, L.A., & Cooke, R.W.I. (2003). Motor, cognitive, and behavioural disorders in children born very preterm. *Developmental Medicine and Child Neurology, 45*, 97-103. DOI: 10.1017/S0012162203000197

Gardner, F., Johnson, A., Yudkin, P., Bowler, U., Hockley, C., Mutch, L., & Wariyar, U. (2004). Behavioral and emotional adjustment of teenagers in mainstream school who were born before 29 weeks' gestation. *Pediatrics, 114*(3), 676-682. DOI: 10.1542/peds.2003-0763-L

Goodman, R. (1997). Strengths and Difficulties Questionnaire: A research note. *The Journal of Child Psychology and Psychiatry, 38*(5), 581-586. DOI: 10.1111/j.1469-7610.1997.tb01545.x

Gueron-Sela, N., Atzaba-Poria, N., Meiri, G., & Marks, K. (2015). The caregiving environment and developmental outcomes of preterm infants: Diathesis stress or differential susceptibility effects? *Child Development, 86*(4), 1014-1030. DOI: 10.1111/cdev.12359

Hughes, A. J., Redsell, S. A., & Glazebrook, C. (2017). Motor development interventions for preterm infants: A systematic review and meta-analysis. *Pediatrics.* Advanced online publication. DOI: 10.1542/peds.2016-0147

Ionio, C., Riboni, E., Confalonieri, E., Dallatomasina, C., Mascheroni, E., Bonanomi, A., ... & Comi, G. (2016). Paths of cognitive and language development in healthy preterm infants. *Infant Behavior and Development, 44*, 199-207. DOI: 10.1016/j.infbeh.2016.07.004

Inder, T. E., Warfield, S. K., Wang, H., Hüppi, P. S., & Volpe, J. J. (2005). Abnormal cerebral structure is present at term in premature infants. *Pediatrics, 115*(2), 286-294. DOI: 10.1542/peds.2004-0326

Jaekel, J., Pluess, M., Belsky, J., & Wolke, D. (2015). Effects of maternal sensitivity on low birth weight children's academic achievement: A test of differential susceptibility versus diathesis stress. *Journal of Child Psychology and Psychiatry, 56*(6), 693-701. DOI: 10.1111/jcpp.12331

Johnson, S. (2007). Cognitive and behavioural outcomes following very preterm birth. *Seminars in Fetal and Neonatal Medicine, 12*(5), 363-373. DOI: 10.1016/j.siny.2007.05.004

Korja, R., Latva, R., & Lehtonen, L. (2012). The effects of preterm birth on mother–infant interaction and attachment during the infant's first two years. *Acta Obstetricia et Gynecologica Scandinavica, 91*(2), 164-173. DOI: 10.1111/j.1600-0412.2011.01304.x

Landry, S.H., Smith, K.E., & Swank, P.R. (2003). The importance of parenting during early childhood for school-age development. *Developmental Neuropsychology, 24*(2&3), 559-591. DOI: 10.1080/87565641.2003.9651911

Little, R. J. (1988). A test of missing completely at random for multivariate data with missing values. Journal of the American Statistical Association, 83(404), 1198-1202. DOI: 10.1080/01621459.1988.10478722

Little, R. J., & Rubin, D. B. (2014). *Statistical analysis with missing data*. Hoboken, NJ: John Wiley & Sons.

Manuck, S.B. & McCaffery, J.M. (2014). Gene-environment interaction. *Annual Review of Psychology, 65*, 41-70. DOI: 10.1146/annurev-psych-010213-115100

Miles, M. S., & Holditch-Davis, D. (1997, June). Parenting the prematurely born child: Pathways of influence. *Seminars in Perinatology, 21*(3), 254-266. DOI: 10.1016/S0146-0005(97)80067-5

Monroe, S. M., & Cummins, L. F. (2015). Diathesis-stress models. In *The Encyclopedia of Clinical Psychology*. Hoboken, NJ: John Wiley & Sons. DOI: 10.1002/9781118625392.wbecp466

Monroe, S.M. & Simons, A.D. (1991). Diathesis stress theories in the context of life stress research: Implications for the depressive disorders. *Psychological Bulletin, 110*(3), 406-425. DOI: 10.1037/0033-2909.110.3.406

Moster, D., Lie, R.T., & Markestad, T. (2008). Long-term medical and social consequences of preterm birth. *The New England Journal of Medicine, 359*, 262-273. DOI: 10.1056/NEJMoa0706475

Murray, L., Fiori-Cowley, A., Hooper, R., & Cooper, P. (1996). The impact of postnatal depression and associated adversity on early mother-infant interactions and later infant outcome. *Child Development, 67*(5), 2512-2526. DOI: 10.2307/1131637

Murray, A., Quail, A., McCrory, C., & Williams, J. (2013). *Summary data dictionary for wave 2 of the infant cohort (at 3 years) of Growing Up in Ireland.* Dublin, Ireland: Economic and Social Research Institute.

Nasreen, H-E., Nahar Kabir Z., Forsell, Y., & Edhborg, M. (2013). Impact of maternal depressive symptoms and infant temperament on early infant growth and motor development: Results from a population based study in Bangladesh. *Journal of Affective Disorders, 146*(2), 254-261. DOI: 10.1016/j.jad.2012.09.013

National Institute of Child Health and Human Development (NICHD) (2014). *Preterm labor and birth: Condition information*. Retrieved May 21, 2015, from https://www.nichd.nih.gov/health/topics/preterm/conditioninfo/Pages/default.aspx

Piteo, A.M., Yelland, L.N., & Makrides, M. (2012). Does maternal depression predict developmental outcome in 18 month old infants? *Early Human Development, 88*(8), 651-655. DOI: 10.1016/j.earlhumdev.2012.01.013

Poehlmann, J., Hane, A., Burnson, C., Maleck, S., Hamburger, E., & Shah, P. E. (2012). Preterm infants who are prone to distress: differential effects of parenting on 36-month behavioral and cognitive outcomes. *Journal of Child Psychology and Psychiatry, 53*(10), 1018-1025. DOI: 10.1111/j.1469-7610.2012.02564.x

Poehlmann, J., Schwichtenberg, A.J.M., Shlafer, R.J., Hahn, E., Bianchi, J-P., & Warner, R. (2011). Emerging self-regulation in toddlers born preterm or low birth weight: Differential susceptibility to parenting? *Development and Psychopathology, 23*(1), 177-193. DOI: 10.1017/S0954579410000726

Quail, A., Williams, J., McCrory, C., Murray, A., & Thornton, M. (2011a). *A summary guide to wave 1 of the Infant Cohort (at 9 months) of Growing Up in Ireland*. Dublin, Ireland: Economic and Social Research Institute.

Quail, A., Williams, J., McCrory, C., Murray, A., & Thornton, M. (2011b). *Sample design and response in wave 1 of the infant cohort (at 9 months) of Growing Up in Ireland*. Dublin, Ireland: Economic and Social Research Institute.

Radloff, L.S. (1977). The CES-D Scale: A self-report depression scale for research in the general population. *Applied Psychological Measurement, 1*(3), 385-401. DOI: 10.1177/014662167700100306

Roisman, G.I., Newman, D.A., Fraley, R.C., Haltigan, J.D., Groh, A.M., & Haydon, K.C. (2012). Distinguishing differential susceptibility from diathesis–stress: Recommendations for evaluating interaction effects. *Development and Psychopathology, 24*, 389-409. DOI: 10.1017/S0954579412000065

Saigal, S. & Doyle, L.W. (2008). An overview of mortality and sequelae of preterm birth from infancy to adulthood. *The Lancet, 371*, 261-269. DOI: 10.1097/01.aoa.0000344668.20582.5b

Sansavini, A., Zavagli, V., Guarini, A., Savini, S., Alessandroni, R., & Faldella, G. (2015). Dyadic co-regulation, affective intensity and infant's development at 12 months: A comparison among extremely preterm and full-term dyads. *Infant Behavior and Development, 40,* 29-40. DOI: 10.1016/j.infbeh.2015.03.005

Schappin, R., Wijnroks, L., Uniken Venema, M.M.A.T., & Jongmans, M.J. (2013). Rethinking stress in parents of preterm infants: A meta-analysis. *PloS ONE, 8*(2), 1-19. DOI: 10.1371/journal.pone.0054992

Shah, P.E., Robbins, N., Coelho, R.B., & Poehlmann, J. (2013). The paradox of prematurity: The behavioral vulnerability of late preterm infants and the cognitive susceptibility of very preterm infants at 36 months post-term. *Infant Behavior and Development, 36*(1), 50-62. DOI: 10.1016/j.infbeh.2012.11.003

Shelleby, E. C., Votruba-Drzal, E., Shaw, D. S., Dishion, T. J., Wilson, M. N., & Gardner, F. (2014). Income and children's behavioral functioning: A sequential mediation analysis. *Journal of Family Psychology, 28*(6), 936-946. DOI: 10.1037/fam0000035

Slade, A., Belsky, J., Aber, J. L., & Phelps, J. L. (1999). Mothers' representations of their relationships with their toddlers: links to adult attachment and observed mothering. *Developmental Psychology, 35*(3), 611-619. DOI: 10.1037/0012-1649.35.3.611

Spittle, A., Orton, J., Anderson, P., Boyd, R., & Doyle, L.W. (2012). Early developmental intervention programmes post-hospital discharge to prevent motor and cognitive impairments in preterm infants. *The Cochrane Library*, *12*. DOI: 10.1002/14651858.CD005495.pub3

Steinberg, L. (2001). We know some things: Parent-adolescent relationships in retrospect and prospect. *Journal of Research on Adolescence, 11*(1), 1-19. DOI: 10.1111/1532-7795.00001

Sullivan, M.C. & Hawes, K. (2007). A decade comparison of preterm motor performance at age 4. *Research in Nursing and Health, 30*(6), 641-654. DOI: 10.1002/nur.20220

Tissot, H., Favez, N., Udry-Jorgensen, L., Frascarolo, F., & Despland, J. N. (2015). Mothers' and fathers' sensitive parenting and mother–father–child family alliance during triadic interactions. *The Family Journal, 23*(4), 374-380. DOI: 10.1177/1066480715601110

Treyvaud, K. (2014). Parent and family outcomes following very preterm or very low birth weight birth: A review. *Seminars in Fetal and Neonatal Medicine, 19*(2), 131-135. DOI: 10.1016/j.siny.2013.10.008

Tronick, E. Z. (1989). Emotions and emotional communication in infants. *American Psychologist, 44*(2), 112-119. DOI: 10.1037/0003-066X.44.2.112

van Buuren, S. & Groothuis-Oudshoorn, K. (2011). Mice: Multivariate imputation by chained equations in R. *Journal of Statistical Software, 45*(3), 1-67.

van Wassenaer-Leemhuis, A. G., Jeukens-Visser, M., van Hus, J. W., Meijssen, D., Wolf, M.-J., Kok, J. H., ... & Koldewijn, K. (2016). Rethinking preventive post-discharge intervention programmes for very preterm infants and their parents. *Developmental Medicine & Child Neurology, 58*(S4), 67-73. DOI: 10.1111/dmcn.13049

Williams, J., Murray, A., McCrory, C., & McNally, S. (2013). *Development from birth to three years: Executive summary.* Dublin, Ireland: The Stationery Office.

Woythaler, M.A., McCormick, M.C., & Smith, V.C. (2011). Late preterm infants have worse 24-month neurodevelopmental outcomes than term infants. *Pediatrics, 127*(3), e622-e629. DOI: 10.1542/peds.2009-3598

Wu, J. C-L. & Chiang, T-L. (2016) Differential susceptibility to effects of the home environment on motor developmental outcomes of preschool children: Low birthweight status as a susceptibility factor, *Early Child Development and Care, 186*(8), 1227-1242. DOI: 10.1080/03004430.2015.1085862

Table 1. *Sample characteristics*

	Very Preterm (25-33 weeks)	Late Preterm (34-36 weeks)	Full-term (≥37 weeks)
Infants			
n	231	513	10390
W1 Male (%)	56.9	50.9	51.3
W1 Gestational age (weeks)	30.7 (2.5)	35.3 (0.8)	39.9 (1.4)
W1 Medical risk at birth	2.7 (1.0)	1.5 (1.2)	0.4 (0.8)
W1 Weight at birth (grams)	2230.8 (632.0)	2791.1 (423.3)	3539.8 (482.9)
W1 Length at birth (cms)	43.5 (10.4)	46.8 (7.4)	51.0 (6.0)
W1 Non-singleton (%)	29.6	21.2	2.0
W2 Health issues	0.8 (1.0)	0.5 (0.8)	0.4 (0.7)
W2 English as first language (%)	90.7	91.4	92.6
W2 Irish as first language (%)	0.0	0.7	0.4
Mothers			
n	231	512	10389
W1 Maternal quality of attachment	42.3 (3.6)	42.5 (2.7)	42.5 (2.8)
W1 Maternal emotional distress	0.2 (0.9)	0.1 (0.9)	0.0 (0.8)
W2 Irish ethnicity (%)	81.3	84.0	84.8
W2 Roman Catholic (%)	85.7	87.3	89.8
W2 Age left education	18.3 (2.7)	18.7 (2.7)	19.0 (2.6)
Fathers			
n	197	450	9351
W1 Paternal quality of attachment	24.8 (2.7)	24.1 (1.7)	24.2 (1.9)
W1 Paternal emotional distress	0.0 (0.9)	0.1 (0.9)	0.0 (0.8)
W2 Irish ethnicity (%)	82.9	81.2	85.5
W2 Roman Catholic (%)	85.2	87.5	89.4
W2 Age left education	18.3 (2.9)	18.9 (2.9)	18.8 (2.8)
Household			
W1 Equivalised annual income (€)[a]	18759.4	18957.0	21701.68
W2 Equivalised annual income (€)[a]	16141.1	17832.1	18139.7
W2 People in household	4.3 (1.2)	4.3 (1.2)	4.3 (1.1)
W2 Two-parent household (%)	83.5	84.4	86.6

Note. Unless otherwise stated, values represent means, with standard deviations in parentheses. Infant and household information is based on primary caregiver report.
W1 = Data was collected at wave 1; W2 = Data was collected at wave 2.
[a] Equivalised income is the annual household disposable income, equivalised for the number of adults and children in the household, so that different-sized households can be compared (for additional information, see Quail et al., 2011).

Table 2. *Correlations between study variables for samples separated by the different gestational age groups*

	Mother		Father		Child	
	Emotional distress	Quality of attachment	Emotional distress	Quality of attachment	Cognitive	Socio-emotional
Very preterm						
Mother quality of attachment	-.42**					
Father emotional distress	.65**	-.25*				
Father quality of attachment	.03	-.56**	-.13†			
Child cognitive	-.20*	.07	-.33**	-.12		
Child socio-emotional	.38**	-.31**	.42**	.12	-.29**	
Child motor skills	-.08	.03	-.16*	.03	.36**	-.26**
Late preterm						
Mother quality of attachment	-.35**					
Father emotional distress	.27**	-.22**				
Father quality of attachment	-.08	.08	-.24**			
Child cognitive	-.15*	.03	.00	.01		
Child socio-emotional	.24**	-.15*	.04	-.08	-.24**	
Child motor skills	-.04	.08†	.05	.04	.18**	-.19**
Full term						
Mother quality of attachment	-.41**					
Father emotional distress	.29**	-.16**				
Father quality of attachment	-.08**	-.14**	-.26**			
Child cognitive	-.06**	.02	-.04*	.02		
Child socio-emotional	.26**	-.17**	.13**	-.04**	-.18**	
Child motor skills	-.06**	.05**	-.05**	.00	.24**	-.16**

† $p < .10$, *$p < .05$ **$p < .001$

Table 3. *Multiple regression model predicting child socioemotional, cognitive, and motor skills functioning using maternal emotional distress and maternal quality of attachment*

	Socioemotional			Cognitive			Motor Skills		
	B	*SE*	R^2	*B*	*SE*	R^2	*B*	*SE*	R^2
Step 1									
Child Sex[a]	.15***	0.02	0.14	-.28***	0.02	0.06	-.32***	0.02	0.04
SES	-.19***	0.01		.22***	0.01		.05***	0.01	
Health Wave 1	.01	0.01		.01	0.01		-.04***	0.01	
Health Wave 2	.13***	0.01		-.04***	0.01		-.06***	0.01	
Very Preterm	.02	0.01		-.04***	0.01		-.03**	0.01	
Late Preterm	.01	0.01		-.04***	0.01		-.01	0.01	
Maternal Emotional Distress	.20***	0.01		-.04**	0.01		-.03	0.01	
Maternal QoA	-.09***	0.01		.01	0.01		.02	0.01	
Step 2									
Child Sex[a]	.15***	0.02	0.14	-.28***	0.02	0.06	-.32***	0.02	0.04
SES	-.19***	0.01		.22***	0.01		.05***	0.01	
Health Wave 1	.01	0.01		.01	0.01		-.04***	0.01	
Health Wave 2	.13***	0.01		-.04***	0.01		-.06***	0.01	

Very Preterm	.06	0.01	.01	0.15	-.01	0.17
Late Preterm	.05	0.01	-.04	0.18	.01	0.17
Maternal Emotional Distress	.20***	0.01	-.03**	0.01	-.02	0.01
Maternal Emotional Distress*Very Preterm	.02	0.01	-.02	0.01	.01	0.01
Maternal Emotional Distress*Late Preterm	-.01	0.01	-.02	0.01	.01	0.01
Maternal QoA	-.09***	0.01	.01	0.01	.01	0.01
Maternal QoA*Very Preterm	-.04	0.15	-.04	0.15	-.03	0.17
Maternal QoA*Late Preterm	-.04	0.18	-.01	0.18	-.01	0.17

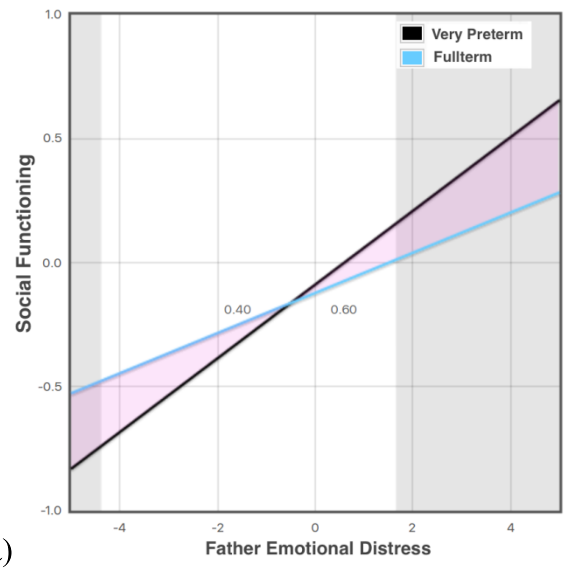
**$p < .01$ ***$p < .001$ *Note*. [a]Ref = female

Table 4. *Multiple regression model predicting child socioemotional, cognitive, and motor skills functioning using paternal emotional distress and paternal quality of attachment*

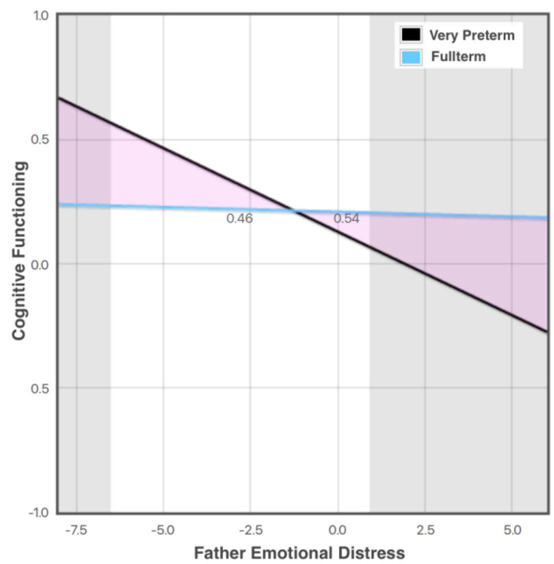
	Socioemotional			Cognitive			Motor Skills		
	B	*SE*	R^2	*B*	*SE*	R^2	*B*	*SE*	R^2
Step 1									
Child Sex[a]	.16***	0.02	0.08	-.28***	0.02	0.06	-.31***	0.02	0.04
SES	-.18***	0.01		.20***	0.01		.05***	0.01	
Health Wave 1	.01	0.01		.01	0.01		-.04***	0.01	
Health Wave 2	.15***	0.01		-.03*	0.01		-.05***	0.01	
Very Preterm	.02	0.01		-.04***	0.01		-.04***	0.01	
Late Preterm	.01	0.01		-.03**	0.01		-.01	0.01	
Paternal Emotional Distress	.12***	0.01		-.04***	0.01		-.04**	0.01	
Paternal QoA	-.01	0.01		.01			-.02	0.01	
Step 2									
Child Sex[a]	.16***	0.02	0.08	-.28***	0.02	0.06	-.31***	0.02	0.04
SES	-.18***	0.01		.20***	0.01		.05***	0.01	
Health Wave 1	.01	0.01		.01	0.01		-.04***	0.01	

Health Wave 2	.15***	0.01	-.03*	0.01	-.05***	0.01
Very Preterm	-.20	0.13	.10	0.12	-.01	0.18
Late Preterm	.22	0.17	-.12	0.18	-.18	0.17
Paternal Emotional Distress	.11***	0.01	-.04**	0.01	-.04**	0.01
Paternal Emotional Distress*Very Preterm	.03***	0.01	-.03***	0.01	-.01	0.01
Paternal Emotional Distress*Late Preterm	-.02	0.01	.01	0.01	.01	0.01
Paternal QoA	-.02	0.01	.01	0.01	-.02	0.01
Paternal QoA*Very Preterm	.22	0.13	-.14	0.12	-.03	0.17
Paternal QoA*Late Preterm	-.21	0.17	.08	0.18	.17	0.17

* $p < .05$ ** $p < .01$ *** $p < .001$ *Note*. [a]Ref = female



a)



b)

Figure 1: Children's socioemotional outcomes (a; left) and cognitive outcomes (b; right), as affected by the interaction between fathers' emotional distress and being born very preterm and those born full-term.

Note. Vertically shaded regions denote the significant portions of the interaction with respect to the mean. Shaded regions inside the interaction lines denote the proportion of interaction, the values for which are shown on either side of the crossover point.