Are preterm children with low birth weight differentially susceptible to the best and worst behavioural, ADHD symptom and academic outcomes at 7 years of age depending on family functioning?

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DECLARATION

This report contains no material which has been accepted for the award of any other degree or diploma in any University, and, to the best of my knowledge, this report contains no materials previously published except where due reference is made.

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Preterm Children with Low Birth Weight: An exploration of risk, resilience and family functioning as a moderating factor

ABSTRACT

Preterm birth is associated with numerous risks, including deficits in behavioural and academic functioning. However, there is wide variability in outcomes, and conclusions regarding factors that moderate developmental outcomes have not yet been drawn. This review examines the literature regarding outcomes of children born preterm and the differential susceptibility hypothesis as a potential framework for understanding differences in outcomes. Findings of this review indicate that further studies investigating differential susceptibility in preterm children are warranted. Future studies may consider using family functioning as a moderating factor as well as examining ADHD symptom severity to capture a wider range of functioning.

1. Literature Review

1.1. Introduction

Research suggests that in the developed world, approximately 8.6% of infants are born preterm (i.e. prior to 37 weeks' gestation) (Blencowe et al., 2012), with survival rates having significantly improved over time due to advances in neonatal intensive care (Doyle & VICS, 2004; Saigal & Doyle, 2008). However, although survival rates have improved, children born preterm continue to face a multitude of risks and impairments compared to their term-born counterparts, with one of the main risks associated with preterm birth, being the co-occurrence of low birth weight (LBW). Furthermore, while either preterm birth or

LBW carry a number of risks on their own, the two often co-occur, resulting in an especially high level of risk.

Preterm and LBW children are at greater medical and developmental risk across a number of areas. Regarding medical risk, they often experience brain injuries (e.g. Allan, Vohr, Makuch, et al., 1997; Inder, Warfield, Wang, Huppi, & Volpe, 2005) as well as chronic conditions such as asthma, cerebral palsy, visual disability and poorer cognitive and motor abilities (Hack, Taylor, Drotar, et al., 2005).

In regards to developmental risks, three of the main areas that are often adversely affected by preterm birth, include behaviour, academic functioning and an increased risk of ADHD symptoms (e.g. Bhutta, Cleves, Casey, Cradock, & Anand, 2002; Bora, Pritchard, Moor, Austin, & Woodward, 2011; Cooke, 2004). Similarly, LBW is also often associated with developmental adversities (e.g. WHO, 2014), meaning that when the preterm child is also born with LBW, their level of risk is heightened (e.g. Riechi, Moura-Ribeiro, & Ciasca, 2011). However, significant variation across outcomes within the preterm population has been found, with an increasing body of research investigating factors that may affect this trajectory. Accordingly, there has also been a move towards more resilience-based frameworks, investigating ways in which preterm children can thrive in the face of their inherent adversity. Thus, the differential susceptibility hypothesis has been applied across several studies, investigating whether preterm or LBW children may be differential susceptible to the best and worst outcomes depending on their environment. Within these studies, the quality of parenting has often been used as the moderating environmental factor. Accordingly, this review will aim to explore some of the main risks associated with preterm birth, as well as how the environment has increasingly been suggested as a potential moderating factor for these risks. Within this context, the differential susceptibility hypothesis will be described, followed by a review of research that has investigated this framework within the preterm and low birth weight population. Finally, family functioning will be suggested as a potential moderating factor worthy of investigation within the preterm population.

1.2. Biological and Medical Risk Associated with Preterm Birth

Many vital organs (e.g. brain, lungs, liver) are still developing during the final weeks of pregnancy, earlier delivery is associated with greater risk of death or serious disability (NIH, 2017). Regarding brain development specifically, as active brain development occurs during the second and third trimesters, premature infants have an increased risk of brain injury during this period of brain maturation. They have a greater risk of developing conditions such as hypoxia, ischemia, and sepsis, which may increase the risk of brain injuries and increase their biological risk, thus adversely affecting neurodevelopmental impairment (Allan, Vohr, Makuch, et al., 1997; Inder, Warfield, Wang, Huppi, & Volpe, 2005; Inder, Wells, Mogridge, Spencer, & Volpe, 2003; Luu, Ment, Schneider, et al., 2009; Ment, Allan, Makuch, et al., 2005; Ment, Oh, Ehrenkranz, et al., 1994; Vohr & Ment, 1996). Furthermore, impairment may persist to school age, including decreased brain volume, microstructure abnormalities, and alterations in neural connectivity, which may lead to increased learning challenges (Constable, Ment, Vohr, et al., 2008; Gozzo, Vohr, Lacadie, et al., 2009; Kessler, Ment, Vohr, et al., 2004; Kessler, Reiss, Vohr, et al., 2008; Ment, Peterson, Vohr, et al., 2006). In addition to brain abnormalities, younger gestational age has been associated with higher rates of chronic conditions such as asthma, cerebral palsy, visual disability and poorer cognitive and motor abilities (Hack, Taylor, Drotar, et al., 2005). A study by Moster, Lie, and Markestad (2008) examined the long-term medical and social consequences of preterm birth, examining whether outcomes differed depending on the level of prematurity. The authors found that the risk of severe medical disabilities (e.g. cerebral palsy, mental health disorders) 'increased sharply' with younger gestational age, and that even between categories of prematurity (e.g. very preterm vs. extremely preterm), the relative risk of adverse outcomes was higher for the younger gestational age group (Moster, Lie, & Markestad, 2008).

Evidently, children born preterm face a number of medical challenges, whereby severity of neonatal complications, along with gestational age and lower birth weight have been described as determinants of later development (Aarnoudse-Moens et al., 2009; Bhutta et al., 2002; Taylor et al., 2000). This has been reflected across a large number of studies, whereby preterm children have been found to face significant developmental challenges by school age (Doyle & VICS, 2004), including poorer mental health and emotional functioning (Crump, Winkleby, Sundquist, & Sundquist, 2010; Nosarti et al., 2012), cognitive impairments, behavioural problems and poorer academic achievement (Aarnoudse-Moens, et al., 2009; Bhutta, et al., 2002; Feldman, 2009; Johnson, Wolke, Hennessy, & Marlow, 2011; Saigal, den Ouden, & Wolke, 2003; Saigal, Hoult, Streiner, Stoskopf, & Rosenbaum, 2000; Taylor, Klein, & Hack, 2000).

1.3. Behaviour in Preterm Children

Inattention, internalising (i.e. anxiety, depression) and externalising (i.e. oppositional behaviour, conduct problems) symptoms are all behavioural consequences associated with preterm birth, whereby preterm children are at an increased risk of developing behavioural difficulties in comparison to their term-born counterparts (Bagner, Sheinkopf, Vohr, & Lester, 2010; Bhutta et al., 2002; Delobel-Ayoub et al., 2006; Foulder-Hughes & Cooke, 2003; Potilk, de Winter, Bos, Kerstjens, & Reijneveld, 2012; Vanderveen, Bassler, Robertson, & Kiroalani, 2009). Indeed, the prevalence rate of behavioural difficulties in children born preterm has been reported as 20%, and as double the risk faced by term-born infants (Arpi & Ferrari, 2013; Gray, Indurkhya, & McCormick, 2004). These difficulties have been reported to increase during school age (Reijneveld et al., 2006) and to continue through to adolescence and adulthood (Hack et al., 2004). While some studies have found no association between environmental factors and behavioural problems in preterm children (e.g. Conrad, Richman, Lindgren, & Nopoulos, 2010; Loe, Lee, Luna, & Feldman, 2011), others have found environmental factors such as low socio-economic status (SES) and family adversity to be associated with more behavioural problems (Delobel-Ayoub et al., 2009; Nadeau, Boivin, Tessier, Lefebvre, & Robaey, 2001). Similarly, a more optimal home environment has also been found to be associated with less internalising and externalising behaviours in preterm children (McCormick, Workman-Daniels, & Brooks-Gunn, 1996; Treyvaud et al., 2012).

However, parenting interventions at 18 months of age for children experiencing behavioural problems have been found to have positive results (Bagner et al., 2010; Bunting, 2004; Postumus, Raaijmakers, Maassen, van Engeland, & Matthys, 2011), indicating that despite the biological vulnerability experienced by preterm children in regards to their increased risk for developing behavioural problems, environmental factors can influence this trajectory.

1.4. ADHD in Preterm Children

One of the most common adverse outcomes in children born preterm, is the presence of Attention-Deficit/Hyperactivity Disorder (ADHD) or ADHD-like symptoms, with ADHD and attention difficulties reportedly the most common adverse behavioural outcome in very preterm children specifically (Bora, Pritchard, Moor, Austin, & Woodward, 2011; Botting, Powls, Cooke, & Marlow, 1997; Hack et al., 2009; Johnson et al., 2010; Treyvaud et al., 2013). Compared to term-born children, children born preterm are reportedly four times more likely to be diagnosed with ADHD (Johnson et al., 2010) and these difficulties are more commonly of the inattentive subtype rather than the hyperactive subtype (Brogan et al., 2014; Hack et al., 2009; Jaekel, Wolke, & Batemann, 2013; Johnson et al., 2010; Johnson & Wolke, 2013; Shum, Neulinger, O'Callaghan, & Mohay, 2008), which is also an important predictor of academic functioning (Jaekel et al., 2013) and has been found to continue through to adolescence (Burnett et al., 2013 and adulthood (Breeman, Jaekel, Baumann, Bartmann, & Wolke, 2016). Importantly, while many preterm children meet the diagnostic criteria for ADHD, many do not, but still experience high levels of attention difficulties which adversely effects their daily and academic functioning (Indredavik et al., 2004; Jaekel et al., 2013; Johnson & Wolke, 2013).

While a strong connection has been found between preterm birth and ADHD (Heinonen et al., 2011; Mick, Biederman, Prince, Rischer, & Faraone, 2002; Potgieter, Vervisch, & Lagae, 2003), there is evidence to suggest that environmental factors may also contribute to this association. For example, Murray et al. (2016) investigated the relationship between preterm birth, fetal growth impairment and ADHD, while adjusting for a number of environmental factors. The authors found that while birth factors were associated with attention difficulties, environmental influences (e.g. childhood and familial factors) had a greater impact on whether the child met the diagnostic criteria for ADHD. Accordingly, the authors argued that environmental factors may increase the risk of developing attention problems at a clinical level (Murray et al., 2016). These findings are consistent with multiple studies, which have found childhood environmental factors (e.g. low income, familial discord, parenting style, early traumatic factors) to contribute to the risk of developing ADHD (Briggs-Gowan et al., 2010; Nigg, Nikolas, & Burt, 2010; Wermter et al., 2010).

The heightened risk of ADHD that preterm children face has considerable importance, as ADHD has been found to lead to multiple secondary adverse outcomes later in life, including lower academic functioning, conduct problems, delinquency, family conflict and impaired relationships (DuPaul & Langbergm 2014; Johnston & Mash, 2001; Molina et al., 2007; Mannuzza, Klein, Abikoff, & Moulton, 2004; Hoza et al., 2005), although wide variability in symptom severity and functional impairment have been observed (Barkley, 2014; Wahlstedt et al., 2009). With regards to this variability, while adverse outcomes associated with ADHD have been thoroughly investigated, far less attention has been given to protective factors and resilience in the context of ADHD. Accordingly, it has been argued that there is a need to better understand these protective and resilience factors, in order to advance effective ADHD management strategies to support more positive outcomes (Dvorsky & Langberg, 2016). Accordingly, Dvorsky and Langberg (2016) have argued that future research should investigate resilience in ADHD within specific theoretical frameworks that are relevant to the specific risk of the sample under investigation.

While research in the area of protective factors in ADHD is in its infancy, of the available research, the strongest evidence has been found at the family level (Dvorsky & Langberg, 2016). Studies have found a more optimal parenting style to have a protective effect on the quality of functioning in children diagnosed with ADHD (Healey, Flory, Miller, & Halperin, 2011; Kawabata, Tseng, & Gau, 2012), with longitudinal studies also finding more optimal parenting to promote better functioning in children with ADHD (Chronis et al., 2007; Hinshaw, Zupan, Simmel, Nigg, & Melnick, 1998). Cross-sectional studies examining the effect of family-level variables on youth with ADHD have also found family cohesion and support to promote positive outcomes (Schei, Nøvik, Thompson, Indredavik, & Jozefiak, 2015; Theule, Wiener, Rogers, & Marton, 2011). Importantly, while positive family-level factors have been associated with better functioning in children with ADHD, in families of preterm children, these very factors (e.g. conflicted parent-child relationships, higher parental stress and psychopathology, impaired family functioning) have been found to often be suboptimal or impaired (Johnston & Marsh, 2001). Thus it is possible that these family-level factors, which are often disrupted in families of preterm children, may present a valuable area for change, whereby through appropriate intervention, the elevated risk faced by preterm children may be lowered. This has resulted in an argument for more research investigating contextual variables within the family-level and how these factors may influence different outcomes in children with ADHD (Deault, 2010). It has been argued that such research is critical in order to capture the relationships between various psychosocial factors and children's cognitive, behavioural and psychosocial functioning (Hinshaw, 2002). Deault (2010) also argued that empirical research has not successfully recognised this theoretical conceptualisation of ADHD, whereby research has focused on associations between ADHD symptomology and family factors, rather than examining the "broad spectrum of difficulties" (Deault, 2010, p. 170) that are commonly experienced by children with ADHD (e.g. academic functioning, social functioning, behaviour). Thus, it has been recommended that future research include a multidimensional conceptualisation of ADHD, examining different areas of functioning rather than ADHD symptoms alone (Deault, 2010).

1.5. Academic Functioning in Preterm Children

Another adverse outcome commonly associated with preterm birth is academic underachievement (Aarnoudse-Moens, Oosterlaan, Duivenvoorden, van Goudoever, & Weisglas-Kuperus, 2011; Pritchard et al., 2009), whereby they are significantly more likely to experience academic functioning deficits at school age than term-born children (O'Callaghan et al., 1996; Saigal, Rosenbaum, Szatmari, & Campbell, 1991; Salt & Redshaw, 2006, Wocadlo & Rieger, 2006). While math and reading problems are most common (Johnson & Breslau, 1999; Litt, Taylor, Klein, & Hack, 2005; Pritchard et al., 2009;

Saigal et al., 2000), spelling, language and handwriting difficulties have also been observed (O'Callaghan et al., 1996; Hille et al., 1994; Ornstein, Oglsson, Edonds, & Asztalos, 1991).

Many of these deficits remain consistent or even worsen over longer-term development (Cooke, 2004; Hack et al., 2002; Resnick et al., 1998), with no evidence of academic catch up found between 6-12 years of age in the British context (Botting, Cooke, & Marlow, 1997), or at 14 years of age in the Australian context (Rickards, Kelly, Doyle, & Callanan, 2001). Additionally, more than 50% of very preterm children are reported to utilise special education services at school by middle childhood (Alyward, 2002), lessening at 9-14 years of age, but still remaining between 20-30% (Hack et al., 2002; Resnick et al., 1998; Walther, den Ouden, & Verloove-Vanhorick, 2000). It has also been observed that these deficits in academic functioning appear to have a flow-on affect to later-life outcomes, including lower levels of educational achievement, less engagement in paid work or training compared to their term-born peers (Cooke, 2004; Hack et al., 2002; Saigal et al., 2006).

While there appears to be a strong association between preterm birth and academic underachievement, environmental factors have also been found to influence this relationship. In a study conducted by Gross, Mettelman, Dye and Stagle (2001), medical complications related to preterm birth had a negligible impact on academic functioning, whereas several environmental factors (i.e. parental education, child rearing by two parents, stable family composition and geographic residence over 10 years) were associated with better academic outcomes in preterm children. Interestingly, the authors also found that these same environmental factors were not observed to be as strongly influential in term-born children (Gross et al., 2001). The authors argued that these results indicated a need to study the family environment as an important factor affecting the academic functioning of preterm children (Gross et al., 2001).

1.6. Environmental Influences and the Preterm Child

Despite the increased level of risk associated with preterm birth, there is significant variability in short-term and long-term outcomes within the preterm population, whereby not all preterm infants necessarily develop significant problems (Poehlmann-Tynan et al., 2015; Treyvaud et al, 2012). Accordingly, due to the significant variation in outcomes observed within the preterm population, it has been suggested that rather than focusing on biological vulnerability alone, multifaceted relationships and interactions between both biological and environmental factors need to be considered (Msall & Park, 2008).

While it has been well established that distal environmental factors (e.g. SES) can adversely affect child development, there have been suggestions that this may occur directly or indirectly through more proximal factors (e.g. home environment) (Australian research Alliance for Children, 2009; Bronfenbrenner, 1986). This perspective has been reinforced through multiple population studies, which have found the home environment to have a greater influence on child outcomes than distal environmental factors and that these effects tended to remain strong and stable over time (e.g. Bradley, Corwyn, Burchinal, McAdoo, & Coll, 2001; Sylva, Melhuish, Sammons, Siraj-Blatchford, & Taggart, 2004; Weisglas-Kuperus, Baerts, Smrkovsky, & Sauer, 1993). Accordingly, the family environment has been found to have a strong influence on child development (Hilferty, Redmond, & Katz, 2009).

Importantly, within the preterm context, the very event of preterm birth in the household increases the risk of a number of negative effects on the family and home environment at the proximal level, which may then impact the quality of the home environment. Research has indicated that compared to parents of term-born infants, parents of preterm children experience greater levels of stress, distress, anxiety, depression and family burden, as well as poorer family functioning, particularly during the first several years of the child's life (e.g. Cronin, Shapiro, Casiro, & Cheang, 1995; Ong, Chandran & Boo, 2001; Shandor, Holditch-Davis, Schwartz, & Scher, 2007; Singer et al., 1999; Tu et al., 2007; Treyvaud, 2014; Treyvaud et al., 2010; Treyvaud et al., 2011; Vigod, Villegas, Dennis, & Ross, 2010), although some of these variables appear to improve with time (Saigal, Pinelli, Streiner, Boyle, & Stoskopf, 2010; Singer et al., 2010; Treyvaud, 2014). Studies have indicated that these increased levels of parental and familial strain may occur as a result of a number of stresses associated with preterm birth, such as the stress of the actual birth and subsequent infant hospitalisation (Treyvaud, 2014), medical complications experienced by the infant (Singer, et al., 1999; Gray, Edwards, O'Callaghan, Cuskelly, & Gibbons, 2013), and the stressful nature of the Neonatal Intensive Care Unit (NICU) environment (Miles, Funk, & Carlson, 1993). Others have reported that characteristics of the child (e.g. level of neurodevelopmental disability, medical illness, degree of prematurity, lower birth weight) may also influence parental and familial functioning (Lee, Penner, & Cox, 1991; Saigal et al., 2010; Schappin, Wijnrocks, Uniken, & Jongmans, 2013; Singer et al., 2010; Taylor, Klein, Minich, & Hack, 2001). However, others have not found an association between child characteristics and the home environment (Schappin, et al., 2013; Brummelte, Grunau, Synnes, Whitford, & Petrie-Thomas, 2011; Treyvaud, Doyle, Lee, Roberts, Cheong, Inder, & Anderson, 2011). Nevertheless, given the increased risk that preterm children inherently face as a function of being born preterm, these additional environmental factors at the familial level are likely to further increase their risk of adverse developmental outcomes.

Importantly, the aforementioned factors that may be negatively affected by preterm birth (i.e. parental and familial functioning) are important predictors of functioning in the preterm child, meaning that the very factors that are needed to support the development of the preterm child, are at risk of being adversely affected due to the stresses involved with preterm birth. It has been suggested that for children who are at increased risk, such as very preterm children, the quality of family functioning as well as parent functioning, can impact the child's level of risk or resilience (Treyvaud, 2014). This has been supported by research, indicating these familial factors to have both adverse (Gray et al., 2004; Huhtala et al., 2012) and protective (McCormick et al., 1996; Siegel, 1982; Singer et al., 2010; Treyvaud et al., 2012) effects on the developing preterm child depending on the quality. Additionally, it has been suggested that a child's developmental risk is related to the parents' and environments' ability to moderate the effects of risk factors on the child (Sameroff & Seifer, 1983), which Treyvaud (2014) argued is directly relevant to the preterm child, due to their heightened risk of a number of adverse developmental outcomes. Accordingly, these findings lend evidence to suggest that in providing preterm children a more optimal home environment, this may provide a protective effect, which may buffer against some of the risks inherently associated with preterm birth.

Indeed, with the growing acknowledgement that research needs to look beyond biology and consider environmental factors in child development, there have been a number of studies looking at the impact of parenting style on the development of both preterm and term-born children, with multiple studies finding parenting interventions to be effective in predicting more beneficial developmental outcomes in term-born (e.g. Barnes, Hoffman, Welte, Farrell, & Dintcheff, 2006; Dishion, Bullock, & Kiesner, 2008; Griffin, Botvin, Scheier, Diaz, & Miller, 2000; Otto & Atkinson, 1997; Smetana, Crean, & Daddis, 2002) and preterm children (e.g. Landry, Smith, Swank, Assel, & Vellet, 2001; Lowe, Erikson, MacLean, Schrader, & Fuller, 2013; Magill-Evans & Harrison, 1999; Poehlmann & Fiese, 2001; Yogman, Kindlon, & Earls, 1995). However, there has been comment to suggest that while parenting is one important environmental influence, this construct does not capture the bi-directionality of parent-child relationships, as children also have an impact upon their parents, and consequently, their parenting (Byles, Byrne, Boyle, & Offord, 1988). This appears to be particularly relevant to the family with a preterm child, whereby the preterm birth may negatively affect parental and familial outcomes (e.g. parental stress, depression, family burden), which may in turn adversely affect the development of the preterm child. Indeed, families of preterm children have been found to experience poorer overall family functioning than families of term-born children, and that this remained consistent seven years after the child's birth (Treyvaud, Lee, Doyle, & Anderson, 2014). Accordingly, family functioning has been suggested as a variable of interest, as it is better able to account for the multifaceted nature of parent-child relationships within the household (Byles et al., 1988).

However, in spite of emerging evidence indicating the importance of family environment in the development of preterm children, with the exception of the work of Treyvaud and colleagues (Treyvaud et al., 2011), family functioning has not been explored as a risk and resilience factor.

1.7. The Differential Susceptibility Hypothesis

Two competing theoretical frameworks have been proposed to explain how the environment can impact at-risk populations. The first is the diathesis-stress hypothesis, which has traditionally been the dominant theoretical framework for conceptualising the relationship between risk factors and adaptation (Monroe & Simons, 1991; Sameroff, 1983; Zuckerman, 1999). Within this hypothesis, it is suggested that poor environmental experiences (e.g. poor family functioning) further increase the risk of adverse outcomes for already vulnerable populations (e.g. preterm or LBW children), whereas they are less likely to affect non-vulnerable populations. It is further suggested that in response to optimal environmental experiences, at-risk individuals may catch-up to their non-vulnerable counterparts at best, but are not likely to experience better than average functioning. Accordingly, the diathesis-stress hypothesis does not consider the environment to have a potentially protective effect on at-risk populations.

More recently, another theoretical model has been proposed, the differential susceptibility hypothesis (Belsky, 1997a, 1997b, 2005; Boyce & Ellis, 2005), whereby specific susceptibility markers (e.g. temperamental characteristics, genetic polymorphisms and physiological stress reactivity) may render individuals differentially susceptible to the best and worst outcomes. Within this framework, while poor environmental conditions (e.g. poor family functioning) are still considered to impact negatively on the development of vulnerable individuals (e.g. preterm children), a new dimension is also considered. Specifically in regard to vulnerable individuals, it is suggested that the same factors that increase their risk (e.g. prematurity), may also act as plasticity factors, acting as a protective buffer against their biological risk.

Thus, if exposed to optimal environmental conditions (e.g. optimal family functioning), they are more likely to experience better outcomes, to the point where they may experience better functioning than their non-vulnerable counterparts, because they are more receptive to their environment in a 'for better and for worse' manner (Belsky, Bakermans-Kranenburg, & van Ijzendoorn, 2007).

Indeed, a number of studies have provided evidence for the differential susceptibility model, indicating that some children are in fact more susceptible to both the best and worst outcomes due to biological (Obradovic, Bush, Stamperdahl, Adler, & Boyce, 2010), genetic (Kochanska, Kim, Barry, & Philibert, 2011) and behavioural (Belsky et al., 2007) characteristics. This research has extended through to preterm and LBW populations, with some evidence suggesting that in comparison to full-term infants; preterm and LBW infants are more strongly affected by their early caregiving environment (Landry, Smith, & Swank, 2006; Landry et al., 2001; Poehlmann et al., 2011). Accordingly, preterm birth and LBW have more recently been proposed as plasticity factors (e.g. Gueron-Sela, Atzaba-Poria, Meiri, & Marks, 2015; Shah, Robbins, Coehlo, & Poehlmann, 2013).

There has been an increasing body of literature examining the diathesis-stress and differential susceptibility hypotheses in preterm and low birth weight populations, resulting in mixed findings. Gueron-Sela et al's (2015, 2016) studies found support for both hypotheses. In their 2016 study, they examined the effect of premature birth, temperamental reactivity and parenting on early cognitive development and found support for the diathesis-stress hypothesis when examining the effect of co-parenting structure on cognitive outcomes, but found support for the differential susceptibility hypothesis when examining the effect of maternal structuring on cognitive functioning in infants with highly reactive temperaments (Gueron-Sela et al., 2016). Similarly mixed findings were reported in their 2015 study, where the authors examined the effect of the caregiving environment on infant cognitive and social functioning (Gueron-Sela et al., 2015). Again, while cognitive functioning was found to be consistent with the diathesis-stress hypothesis, social functioning was consistent with the differential susceptibility hypothesis (Gueron-Sela et al., 2015). Other studies have looked at cognitive functioning and parenting (Shah et al., 2013), as well as behaviour and parenting (Poehlmann et al., 2011) in preterm children, and have found support solely for the differential susceptibility hypothesis. Similarly, a mixture of findings has been found in studies examining LBW as a susceptibility factor. Wu and Chiang (2016) found no support for differential susceptibility for motor development in preschool children. Similarly, no support for differential susceptibility was found in Jaekel, Pluess, Belsky, and Wolke's (2015) study which examined LBW as a susceptibility factor for academic achievement, or in Camerota, Willoughby, Cox and Greenberg's (2015) study, which examined executive functioning. The results of both studies were more indicative of diathesis stress rather than differential susceptibility. However, Poehlmann et al (2011) found some support for differential susceptibility and diathesis stress in relation to toddler self-regulation.

Accordingly, while the number of studies examining preterm birth and birthweight susceptibility factors has increased, findings have been mixed and definitive conclusions remain to be drawn.

1.8. Low Birth Weight as a Susceptibility Factor

While LBW is an additional risk often faced by preterm infants and is often associated with adverse outcomes, it has also been suggested that its consequences may be mitigated by supportive and sensitive parenting (McCormick et al., 2006; Orton, Spittle, Doyle, Anderson, & Boyd, 2009). Accordingly, LBW has been proposed as a potential susceptibility factor, as it is related to prenatal environmental quality and can therefore shape part of an individual's reactivity to postnatal experiences for greater adaptability (Pluess & Belsky (2011). As suggested by Wu and Chiang (2015), the idea of LBW as a susceptibility is grounded within two frameworks, including biological-sensitivity-to-context theory (BSCT; Boyce & Ellis, 2005), and fetal programming on development plasticity (Barker, 1998; Pluess & Belsky, 2011). Within BSCT, it is argued that environmental susceptibility is a function of the stress response system, whereby individuals are likely to develop sensitive stress reactivity in response to harsh and stressful conditions (e.g. preterm birth or LBW) in order to deal with threats and increase chance of survival (Boyce & Ellis, 2005). According to BSCT, sensitive stress reactivity can be measured through a number of physiological tests, and these results may be reflective of a child's early experiences (e.g. prenatal period, infancy), whereby the stress response system is formed in a way that it can respond to anticipated future environmental conditions adaptively (Boyce & Ellis, 2005; Ellis, Boyce, Belsky, Bakermans-Kranenburg, & van IJzendoorn, 2011). This idea is similarly reflected in foetal programming theory, which suggests that the fetus may increase stress reactivity in response to undernutrition, prenatal adversities and stress (Bateson et al., 2004; Jones et al., 2006). Research has supported these theories, reflecting that infants with LBW often exhibit difficult temperaments and elevated cortisol stress reactivity (Belsky & Pluess, 2009; Pluess & Belsky, 2011).

1.9. Conclusions and Directions for Future Work

This review aimed to explore some of the main adverse outcomes associated with preterm birth and to review the literature that has examined the differential susceptibility hypothesis within this population. Evidently, definitive conclusions are yet to be drawn, meaning that preterm birth and LBW are yet to be ruled in or ruled out as susceptibility factors. Accordingly, further research is needed to examine whether this is a plausible framework for investigating resilience in this population. Future research should consider including family functioning as a moderating factor in order to capture the bi-directionality of parent-child relationships, as well as the consideration of ADHD symptom severity and its multidimensionality in order to capture a wider range of functioning.

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Research Report Title Page

Title

Are preterm children with low birth weight differentially susceptible to the best and worst behavioural, ADHD symptom and academic outcomes at 7 years of age depending on family functioning?

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Declaration of Interest

The authors whose names are listed above certify that they have NO affiliations with or involvement in any organization or entity with any financial or non-financial interest in the subject matter or materials discussed in this manuscript.

Highlights

- Family functioning predicts behavioural difficulties in preterm children
- Preterm child differential susceptibility to family functioning not found
- Support for low birth weight as a susceptibility factor not found
- Adverse family functioning associated with worse outcomes for preterm child
- Optimal family functioning associated with better outcomes for preterm child

Are preterm children with low birth weight differentially susceptible to the best and worst behavioural, ADHD symptom and academic outcomes at 7 years of age depending on family functioning?

ABSTRACT

The differential susceptibility hypothesis (DSH) was examined in relation to preterm children with low birth weight (LBW), exploring whether LBW status may act as a differential susceptibility factor, moderating the effect of family functioning on preterm children's behaviour, academic functioning and ADHD symptoms at seven years of age. The sample utilised data from 657 infants born <33 weeks' gestation from a randomised control trial examining the effect of docosahexaenoic acid on child outcomes. Results did not support the DSH, and were more in line with diathesis stress. However, family functioning was found to be an area worthy of further investigation in the preterm population.

Keywords: Preterm infant, Low birth weight, Behavior, ADHD, Academic functioning, Family functioning,

1. Introduction

Research suggests that in the developed world, approximately 8.6% of infants are born preterm (i.e. prior to 37 weeks' gestation) (Blencowe et al., 2012), with the survival rate of preterm infants having significantly improved over time due to advances in neonatal intensive care (Doyle & VICS, 2004; Saigal & Doyle, 2008). However, although survival rates have improved, children born preterm continue to face a multitude of risks and impairments compared to their term-born counterparts, with the co-occurance of low birth weight (LBW) being one of the main risks associated with preterm birth. Although LBW is not exclusively connected to preterm birth, it is often an associated complication and is associated with many of the same adverse outcomes in and of itself (WHO, 2014). Accordingly, when the two occur together, the preterm child faces an especially high level of risk (Riechi, Moura-Ribeiro, & Ciasca, 2011). Importantly, there is significant variation within the preterm/LBW population, with greater prematurity and lower birth weight adversely contributing to infant survival rate (Tyson, Parikh, Langer, Green, & Higgins, 2008).

1.1. Behaviour, ADHD Symptoms and Academic Functioning in Preterm Children

Three of the main areas of functioning that are adversely affected in preterm children, include behaviour, academic functioning and an increased risk of ADHD symptoms. Regarding behaviour, the prevalence rate of behavioural difficulties in preterm children has been reported as 20%, and as double the risk faced by term-born infants (Arpi & Ferrari, 2013; Gray, Indurkhya, & McCormick, 2004). These difficulties include internalising (i.e. anxiety, depression) and externalising (i.e. oppositional behaviour, conduct problems) symptoms (e.g. Bagner, Sheinkopf, Vohr, & Lester, 2010; Bhutta et al., 2002; Delobel-Ayoub et al., 2006; Foulder-Hughes & Cooke, 2003; Potilk, de Winter, Bos, Kerstjens, & Reijneveld, 2012; Vanderveen, Bassler, Robertson, & Kiroalani, 2009) and reportedly increase during school age (Reijneveld et al., 2006) and continue through to adolescence and adulthood (Hack et al., 2004).

Attention-Deficit/Hyperactivity Disorder (ADHD) or ADHD-like symptoms are one of the most common adverse outcomes in preterm children (Bora, Pritchard, Moor, Austin, & Woodward, 2011; Botting, Powls, Cooke, & Marlow, 1997; Hack et al., 2009; Johnson et al., 2010; Treyvaud et al., 2013), whereby preterm children are reportedly four times more likely to be diagnosed with ADHD (Johnson et al., 2010). Importantly, while many preterm children meet the diagnostic criteria for ADHD, many do not, but still experience high levels of attention difficulties which adversely effects their daily and academic functioning (Indredavik et al., 2004; Jaekel et al., 2013; Johnson & Wolke, 2013).

Additionally, deficits in academic functioning are also commonly associated with preterm birth (e.g. Aarnoudse-Moens, Oosterlaan, Duivenvoorden, van Goudoever, & Weisglas-Kuperus, 2011; Pritchard et al., 2009), whereby they are significantly more likely to experience academic functioning deficits at school age than term-born children (O'Callaghan et al., 1996; Saigal, Rosenbaum, Szatmari, & Campbell, 1991; Salt & Redshaw, 2006, Wocadlo & Rieger, 2006). While math and reading problems are most common (Johnson & Breslau, 1999; Litt, Taylor, Klein, & Hack, 2005; Pritchard et al., 2009; Saigal et al., 2000), spelling, language and handwriting difficulties have also been observed (O'Callaghan et al., 1996; Hille et al., 1994; Ornstein, Oglsson, Edonds, & Asztalos, 1991). Many of these deficits remain consistent or even worsen over longer-term development (Cooke, 2004; Hack et al., 2002; Resnick et al., 1998), with no evidence of academic catch up found between 6-12 years of age (Botting, Cooke, & Marlow, 1997; Rickards, Kelly, Doyle, & Callanan, 2001).

Importantly, while preterm birth is often inherently associated with deficits across these areas, the environment also appear to have an effect. For example, regarding behaviour in preterm children, a more optimal home environment has also been found to be associated with less internalising and externalising behaviours in preterm children (McCormick, Workman-Daniels, & Brooks-Gunn, 1996; Treyvaud et al., 2012) and parenting interventions at 18 months of age for children experiencing behavioural problems have been found to have positive results (Bagner et al., 2010; Bunting, 2004; Postumus, Raaijmakers, Maassen, van Engeland, & Matthys, 2011). Similarly for ADHD, there is evidence to suggest that environmental factors may also affect this relationship. Murray et al. (2016) investigated the relationship between preterm birth, fetal growth impairment and ADHD, while adjusting for a number of environmental factors. The authors found that while birth factors were associated with attention difficulties, environmental influences (e.g. childhood and familial factors) had a greater impact on whether the child met the diagnostic criteria for ADHD. Accordingly, the authors argued that environmental factors may increase the risk of developing attention problems at a clinical level (Murray et al., 2016). Similar environmental effects have been reported in regards to academic functioning. In a study conducted by Gross, Mettelman, Dye and Stagle (2001), medical complications related to preterm birth had a negligible impact on academic functioning, whereas several environmental factors (i.e. parental education, child rearing by two parents, stable family composition) were associated with better academic outcomes in preterm children. Interestingly, the authors also found that these same environmental factors were not observed to be as strongly influential in term-born children (Gross et al., 2001). The authors argued that these results indicated a need to further study the relationship between the family environment and academic functioning in preterm children (Gross et al., 2001).

Accordingly, despite the biological vulnerability experienced by preterm children in regards to their increased developmental risk, environmental factors may influence this trajectory.

1.2. Environmental Influences and the Preterm Child

While it has been well established that distal environmental factors (e.g. SES) can adversely affect child development, there have been suggestions that this may occur directly or indirectly through more proximal factors (e.g. home environment) (Australian research Alliance for Children, 2009; Bronfenbrenner, 1986). This perspective has been reinforced through multiple population studies, which have found the home environment to have a greater influence on child outcomes than distal environmental factors and that these effects tended to remain strong and stable over time (e.g. Bradley, Corwyn, Burchinal, McAdoo, & Coll, 2001; Sylva, Melhuish, Sammons, Siraj-Blatchford, & Taggart, 2004; Weisglas-Kuperus, Baerts, Smrkovsky, & Sauer, 1993). Accordingly, the family environment has been found to have a strong influence on child development (Hilferty, Redmond, & Katz, 2009).

Importantly, within the preterm context, the very event of preterm birth in a household increases the risk of a number of negative effects on the family and home environment at the proximal level, such as increased stress, distress, mental health problems and poorer family functioning (e.g. Cronin, Shapiro, Casiro, & Cheang, 1995; Ong, Chandran & Boo, 2001; Shandor, Holditch-Davis, Schwartz, & Scher, 2007; Singer et al., 1999; Tu et al., 2007; Treyvaud, 2014; Treyvaud et al., 2010; Treyvaud et al., 2011; Vigod, Villegas, Dennis, & Ross, 2010). These increased levels of parental and familial strain may occur for a number of reasons, including the stress of the birth and subsequent infant hospitalisation (Treyvaud, 2014), infant medical complications (Singer, et al., 1999; Gray, Edwards, O'Callaghan, Cuskelly, & Gibbons, 2013), and the stressful nature of the Neonatal Intensive Care Unit (NICU) environment (Miles, Funk, & Carlson, 1993). Conversely, some have reported that characteristics of the child (e.g. level of neurodevelopmental disability, medical illness, degree of prematurity, lower birth weight) may also influence parental and familial functioning (Lee, Penner, & Cox, 1991; Saigal et al., 2010; Schappin, Wijnrocks, Uniken, & Jongmans, 2013; Singer et al., 2010; Taylor, Klein, Minich, & Hack, 2001).

These familial level environmental factors are likely to further increase the preterm child's risk of adverse developmental outcomes, as parental and familial functioning are important predictors of functioning in the preterm child. Accordingly, the very factors that are needed to support child development, are at risk of being adversely affected due to the stresses involved with preterm birth.

Indeed, studies that have looked at the efficacy of interventions at the familial level have found parenting interventions to be effective in predicting more beneficial developmental outcomes in preterm children (e.g. Landry, Smith, Swank, Assel, & Vellet, 2001; Lowe, Erikson, MacLean, Schrader, & Fuller, 2013; Magill-Evans & Harrison, 1999; Poehlmann & Fiese, 2001; Yogman, Kindlon, & Earls, 1995). However, while parenting is one important environmental influence, this construct does not capture the bi-directionality of parent-child relationships, as children also have an impact upon their parents, and consequently, their parenting (Byles, Byrne, Boyle, & Offord, 1988). This appears to be particularly relevant to the family with a preterm child, whereby the birth may negatively affect parental and familial outcomes (e.g. parental stress, depression, family burden), which may in turn adversely affect the development of the preterm child. Accordingly, family functioning has been suggested as a variable of interest, as it is better able to account for the multifaceted nature of parent-child relationships within the household (Byles et al., 1988).

1.3. The Differential Susceptibility Hypothesis

Two competing theoretical frameworks have been proposed to explain how the environment can impact at-risk populations (e.g. preterm children). The first is the diathesis-stress hypothesis, which has traditionally been the dominant theoretical framework for conceptualising the relationship between risk factors and adaptation (Monroe & Simons, 1991; Sameroff, 1983; Zuckerman, 1999). Within this hypothesis, it is suggested that poor environmental experiences (e.g. poor family functioning) further increase the risk of adverse outcomes for already vulnerable populations (e.g. preterm/LBW children), whereas they are less likely to affect non-vulnerable populations. It is further suggested that in response to optimal environmental experiences, at-risk individuals may catch-up to their non-vulnerable counterparts at best, but are not likely to experience better than average functioning.

Accordingly, the diathesis-stress hypothesis does not consider the environment to have a potentially protective effect on at-risk populations.

More recently, another theoretical model has been proposed, the differential susceptibility hypothesis (Belsky, 1997a, 1997b, 2005; Boyce & Ellis, 2005), whereby specific susceptibility markers (e.g. temperamental characteristics, genetic polymorphisms and physiological stress reactivity) may render individuals differentially susceptible to the best and worst outcomes. Within this framework, while poor environmental conditions (e.g. poor family functioning) are still considered to impact negatively on the development of vulnerable individuals (e.g. preterm children), a new dimension is also considered. Specifically in regard to vulnerable individuals, it is suggested that the same factors that increase their risk (e.g. prematurity), may also act as plasticity factors, acting as a protective buffer against their biological risk.

Thus, if exposed to optimal environmental conditions (e.g. optimal family functioning), they are more likely to experience better outcomes, to the point where they may experience better functioning than their non-vulnerable counterparts, because they are more receptive to their environment in a ‘for better and for worse’ manner (Belsky, Bakermans-Kranenburg, & van Ijzendoorn, 2007).

Indeed, a number of studies have provided evidence for the differential susceptibility model, indicating that some children are in fact more susceptible to both the best and worst outcomes due to biological (Obradovic, Bush, Stamperdahl, Adler, & Boyce, 2010), genetic (Kochanska, Kim, Barry, & Philibert, 2011) and behavioural (Belsky et al., 2007) characteristics. This research has extended through to preterm/LBW populations, with some evidence suggesting that in comparison to full-term infants; preterm/LBW infants are more strongly affected by their early caregiving environment (Landry, Smith, & Swank, 2006; Landry et al., 2001; Poehlmann et al., 2011). Accordingly, preterm birth and LBW have more recently been proposed as plasticity factors (e.g. Gueron-Sela, Atzaba-Poria, Meiri, & Marks, 2015; Shah, Robbins, Coehlo, & Poehlmann, 2013).

The increasing body of literature examining the diathesis-stress and differential susceptibility hypotheses in preterm/LBW populations has resulted in mixed findings. Gueron-Sela et al's (2015, 2016) studies found support for both hypotheses. In their 2016 study, they examined the effect of premature birth, temperamental reactivity and parenting on early cognitive development and found support for the diathesis-stress hypothesis when examining the effect of co-parenting structure on cognitive outcomes, but found support for the differential susceptibility hypothesis when examining the effect of maternal structuring on cognitive functioning in infants with highly reactive temperaments (Gueron-Sela et al., 2016). Similarly mixed findings were reported in their 2015 study, where the authors examined the effect of the caregiving environment on infant cognitive and social functioning (Gueron-Sela et al., 2015). Again, while cognitive functioning was found to be consistent with the diathesis-stress hypothesis, social functioning was consistent with the differential susceptibility hypothesis (Gueron-Sela et al., 2015). Other studies have looked at cognitive functioning and parenting (Shah et al., 2013), as well as behaviour and parenting (Poehlmann et al., 2011) in preterm children, and have also found mixed results. Similarly, a mixture of findings has been found in studies examining LBW as a susceptibility factor. Wu and Chiang (2016) found no support for differential susceptibility for motor development in preschool children. Similarly, no support for differential susceptibility was found in Jaekel, Pluess, Belsky, and Wolke's (2015) study which examined LBW as a susceptibility factor for academic achievement, or in Camerota, Willoughby, Cox and Greenberg's (2015) study, which examined executive functioning. The results of these studies were more indicative of diathesis stress rather than differential susceptibility.

Accordingly, while the number of studies examining preterm birth and birthweight susceptibility factors has increased, findings have been mixed and definitive conclusions remain to be drawn.

1.4. The Present Study

The present study will aim to build upon the existing research and address the current gaps within the literature by focusing on several outcomes that are commonly impaired in preterm children, including ADHD symptoms, academic functioning and behaviour. Within this study, a number of considerations will also be given to these variables in order to capture the observations and criticisms proposed by other authors in this area. Firstly, symptom severity in ADHD will be examined rather than the presence or absence of ADHD diagnosis, in order to capture children both with a diagnosis, and also those who do not meet diagnostic criteria for ADHD, but are likely to experience functional deficits (Indredavik et al., 2004; Jaekel et al., 2013; Johnson & Wolke, 2013). Furthermore, rather than considering only ADHD, this study will examine academic functioning and behaviour also, in order to capture the multidimensional nature of ADHD, and the 'broad spectrum of difficulties' commonly associated with ADHD (Deault, 2010, p. 170).

Moreover, rather than focusing on biological vulnerability alone, increasing consideration has been given to environmental factors and their influence on developmental outcomes in preterm children (Delobel-Ayoub et al., 2009; Gross et al., 2001; Msall & Park, 2008; Murray et al., 2016). Accordingly, the present study will focus on family functioning as a variable of interest, in order to examine the impact of a proximal environmental variable that is able to capture the bi-directionality of parent-child relationships that has not been captured in studies examining the effect of parenting (Byles et al., 1988).

Furthermore, there has been a call for more research examining outcomes from a resilience perspective rather than a deficit-based perspective (Dvorksy & Langberg, 2016), with differential susceptibility emerging as a popular framework, particularly in the preterm and LBW population. However, while the body of research in this area has grown, findings remain mixed. Accordingly, the present study will examine whether LBW is a potential susceptibility factor within the preterm population, rendering them differentially susceptible to the best and worst behavioural, academic and ADHD symptom outcomes depending on family functioning. The findings of this study will be useful in informing prevention and intervention approaches for working with preterm children and their families.

We hypothesised that preterm/LBW infants would show less optimal academic functioning, as well as more behavioural problems and ADHD symptoms at 7 years of age when they experienced a combination of lower birthweight and less optimal family functioning, controlling for gender, cultural background and parents' highest level of education. We also hypothesised that preterm infants with LBW would show more optimal academic functioning, as well as less behavioural problems and ADHD symptoms at 7 years of age when they experienced a combination of higher birthweight and more optimal family functioning.

2. Materials and Methods

2.1. Original Study Participants and Procedure

This study utilised data from a docosahexaenoic acid (a type of omega-3 fatty acid) trial in a sample of 657 infants born <33 weeks' gestation (Makrides et al., 2009). Data was collected between 2001 and 2005 from five perinatal centres across Australia (South Australia, Victoria, Queensland and Western Australia). The original trial excluded infants who had major congenital or chromosomal abnormalities or were from a multiple birth where not all live-born infants were eligible. Infants were also excluded if they were in other fatty acid trials or if fish oil was contraindicated. Medical data was collected at birth and during infant hospital admission, and neurodevelopmental data was collected at seven years corrected age. A negligible effect of docosahexaenoic acid was found for some secondary outcomes, indicating no consistent significant differences between groups, hence the sample was treated as one cohort for the following analysis (Collins et al., 2015; Makrides et al., 2009).

The study was approved by all Human Research Ethics committees across the five perinatal centres and informed parental consent was obtained for all participants.

2.2. Present Study Participants and Procedure

Data from the original trial (Makrides et al., 2009) and the 7-year follow up study (Collins et al., 2015) were used in this study. Participants were excluded from the current study if they were missing key 7-year outcome data, and for participants from multiple births, one participant was randomly selected. This resulted in a sample size of 473 participants. The overall sample included 220 females (46.5%) and 253 males (53.5%), of which 435 (92%) were Caucasian, 16 (3.4%) were Aboriginal, 16 (3.4%) were from an Asian background and 6 (1.3%) were from another background. Furthermore, 95 (20.1%) children were from multiple pregnancies. Gestational ages ranged from 23 to 33 weeks across the sample, with a mean age of 29.15 weeks at birth (*SD*=2.36). Infant birthweight ranged from 320g to 2482g across the sample, with a mean birthweight of 1298g (*SD*=420). Infants spent between 2 to 112 days in NICU, with a mean number of 21 days (*SD*=24.67). Furthermore, a mean of 64.18 days (*SD*=30.73) were spent in hospital care by the sample, ranging from 18-289 days. Regarding the highest level of mother’s education, approximately half of the mother’s and father's had completed a post-secondary qualification. More detailed information can be found in Table 1. Mothers' age at birth ranged from 17 to 44 with a mean of 30.10 (*SD*=5.55). Sample characteristics based on birthweight status are presented in Table 1.

Table 1

Sample characteristics (*n*=473).

Variables	ELBW (*n*=128) range (mean, SD)	VLBW (*n*=183) range (mean, SD)	LBW (*n*=162) range (mean, SD)
Maternal age (years)	18 - 42 (29.80, 5.68)	17 - 44 (30.53, 5.54)	17 - 42 (29.84, 5.46)
Gestational age (weeks)	23 - 31 (26.55, 1.97)	25 - 33 (29.17, 1.57)	29 - 33 (31.20, .92)
Birthweight (g)	320 - 999 (778.40, 139.06)	1000 - 1490 (1248.14, 148.62)	1500 - 2482 (1766.13, 196.24)
Days in NICU	2 - 112 (47.95, 26.56)	0 - 99 (16.74, 17.19)	0 - 40 (4.82, 5.62)
Days in Hospital Care	45 - 289 (97.76, 31.65)	26 - 122 (61.83, 17.89)	18 - 99 (40.31, 11.83)
	N (%)	*N* (%)	*N* (%)
Mother Highest Education			
Secondary	63 (49.2%)	82 (44.8%)	88 (39.4%)
Certificate/Diploma	32 (25%)	58 (31.7%)	40 (24.7%)
Degree	24 (18.8%)	35 (19.1%)	25 (15.4%)
Higher Degree	8 (6.3%)	8 (4.4%)	9 (5.6%)
Unknown	1 (.8%)	N/A	N/A
Father Highest Education			
Secondary	69 (53.9%)	91 (49.7%)	87 (53.7%)
Certificate/Diploma	25 (19.5%)	53 (29.0%)	41 (25.3%)
Degree	18 (14.1%)	24 (13.1%)	21 (13.0%)
Higher Degree	10 (7.8%)	10 (5.5%)	8 (4.9%)
Unknown	6 (4.7%)	5 (2.7%)	5 (3.1%)
Gender			
Female	71 (55.5%)	75 (41.0%)	74 (45.7%)
Male	57 (44.5%)	108 (59.0%)	88 (54.3%)
Cultural background			

Caucasian	118 (92.2%)	172 (94.0%)	145 (89.5%)
Aboriginal	3 (2.3%)	4 (2.2%)	9 (5.6%)
Asian	6 (4.7%)	3 (1.6%)	7 (4.3%)
Other	1 (.8%)	4 (2.2%)	1 (.6%)
Multiple Pregnancy			
Yes	34 (26.6%)	39 (21.3%)	22 (13.6%)
No	94 (73.4%)	144 (78.7%)	140 (86.4%)

NICU, Neonatal Intensive Care Unit

Birthweight Status, ELBW (<1000g), VLBW (<1500g), LBW (<2500g).

2.3. Measures

Baseline participant characteristics were collected from medical records and interviews with parents. Key characteristics included infant sex and race, maternal and paternal education, as well as gestational age, birth weight and birth weight z-scores. At seven years, additional data was collected across a number of domains, including family functioning, child academic functioning, behavioural functioning and ADHD symptoms. The following measures were used to capture these outcomes at seven years of age:

2.3.1. Family Assessment Device (FAD). The FAD (Epstein, Baldwin, & Bishop, 1983) is a measure of structural, organisational and transactional characteristics of families and is based on the McMaster Model of Family Functioning. The parent-completed FAD includes 60 statements about a family (e.g. "We are reluctant to show our affection for one another"), requiring the respondent to rate their agreement with the statement using a 4-point Likert scale ranging from "strongly agree" to "strongly disagree." Scores for each scale range from 1 (healthy functioning) to 4 (unhealthy functioning), whereby higher scores indicate more problematic family functioning and where a score of two or more is indicative of problematic family functioning. The FAD is comprised of six scales that capture the six dimensions of the McMaster Model of Family Functioning, including: Problem Solving ($\propto = 0.74$), Communication (∝ = 0.60), Roles (∝ = 0.66), Affective Responsiveness (∝ = 0.61), Affective Involvement (∝ = 0.69) and Behavioural Control (∝ = 0.66). There is also a seventh scale that measures General Family Functioning (∝ = 0.76).

2.3.2. Strengths and Difficulties Questionnaire (SDQ) - Parent Report Form. The SDQ (Goodman, 1997) is a brief behavioural screening questionnaire for children aged 3-16 years of age. It is comprised of 25 items that make up 5 scales, including: Emotional Symptoms (∝ = 0.70), Conduct Problems (∝ = 0.70), Hyperactivity/Inattention (0.85), Peer Problems (∝ = 0.64) and Prosocial Behaviour (∝ = 0.75) as well as a Total Behavioural Difficulties scale (∝ = 0.86), which is the sum of the Emotional Symptoms, Conduct Problems, Hyperactivity/ Inattention and Peer Problems scales. Items include both positive and negative attributes of the child (e.g. “Often loses temper;” “Generally liked by others”) which the parent is required to rate on a 3-point Likert scale ranging from “not true” to “certainly true.” Higher scores on the SDQ indicate more problematic behavioural functioning, with the exception of the Prosocial scale, where higher scores are indicative of more optimal functioning.

2.3.3. Conners 3rd Edition ADHD Index (Conners 3). The Conners 3 Index parent-report form (Conners, 2008) is a measure of inattention and hyperactivity problems. The measure includes ten behavioural description items that are rated on a 4-point Likert scale, ranging from “not at all” to “very much true,” with higher scores indicating a greater number and/or frequency of concerns. Scoring involves converting raw scores to sex- and age-normed standardised *T* scores.

2.3.4. Wide Range Achievement Test 4th Edition (WRAT-4). The WRAT-4 (Wilkinson & Robertson, 2006) is a measure of basic academic abilities across the domains of reading, spelling and arithmetic, and three subtests were administered; Word Reading, Spelling and Math Computation. The Word Reading subtest consists of 15 letter recognition items as well as 55 word reading items. The letter recognition items are only administered if the child does not meet the basal scoring requirements for the word reading items. The Spelling subtest consists of two sections, including a 13 letter writing section (for children 7 years old and younger) and a 42 word spelling section. The Math Computation subtest also consists of two sections, including a 15 item oral math component and a 40-item math computation section. Scoring involves converting raw scores to age-normed standard scores (*M*=100, *SD*=15). Standard scores range from <45 to >155, whereby higher scores indicate higher achievement.

2.3.5. Birthweight status

Infants were stratified by birthweight based on the World Health Organisation's (WHO) definition for categorising low birth weight (WHO, 2004). The categories included extremely low birth weight (ELBW, <1000g) (*n*=128, 27.1%), very low birth weight (VLBW, <1500g) (*n*=183, 38.7%), and low birth weight (LBW, <2500g) (*n*=162, 34.2%).

2.4. Analytic approach for testing differential susceptibility

Statistical analyses were conducted using SPSS (Version 21.0, New York, 2012) . Firstly, a one-way multivariate analysis of variance (MANOVA) was performed to examine any differences between birthweight groups in their health outcomes as well as their scores across the key study outcomes (i.e. WRAT-4, SDQ, Conner's-3, FAD). Post hoc tests (i.e. univariate *F* and Tukey HSD) were also performed when *F* was significant.

In order to test for differential susceptibility, the steps outlined by Belsky et al. (2007) were followed. Accordingly, statistical tests for genuine (cross-over) interactions were conducted by running separate regression analyses for each outcome (i.e. Math Computation, Spelling, Word Reading, ADHD symptoms, Total Behavioural Difficulties). In each regression analysis, control variables were entered into the first step (infant gender, race, mother's education and father's education). The FAD General Functioning subscale score, as well as infant birthweight category (ELBW, VLBW, LBW) were entered into the second step, and the birthweight x family functioning interaction was entered in the third step. As outlined by Belsky et al. (2007), the second and third steps for testing for differential susceptibility involve testing the independence of the susceptibility factor and predictor (i.e. birthweight and family functioning) and also testing the association between the susceptibility factor and outcomes. In order to accurately test for differential susceptibility, the susceptibility factor cannot be correlated with the predictor or the outcomes (Belsky et al., 2007). Thus, bivariate correlations between birthweight, FAD scores and SDQ, WRAT-4 and Conners-3 scores were examined (Table 2). Although infant birthweight and FAD General Functioning scores were not correlated, infant birthweight was significantly correlated with the WRAT Word Reading, Spelling and Math Computation scores, as well as the SDQ Total Behavioural Difficulties score. In order to control for these correlations in the analysis, a procedure recommended by Ellis et al. (2011) for dealing with correlations between the susceptibility factor and outcomes was followed. This involved partialing out the variance in the outcome explained by the susceptibility factor, by running separate regression analyses with birthweight regressed onto the outcome and then saving the residuals. The statistical tests for genuine interactions as described above were then re-run, controlling for the residuals in the model. Post hoc analyses were also conducted for significant interaction effects and regression plots were constructed for all outcomes regardless of significance. Plots that depicted significant interaction effects were compared with the prototypical plots for significant interactions presented by Belsky et al. (2007) to determine whether they reflected differential susceptibility.

2.5. Additional analyses

The regression analyses reported in the main text included the Total Behavioural Difficulties scale from the SDQ and the General Functioning scale from the FAD. However, to ensure completeness of analysis, additional regression analyses were conducted utilizing all six FAD scales (Problem Solving, Communication, Roles, Affective Responsiveness, Affective Involvement, Behaviour Control, General Functioning) as well as the additional five scales from the SDQ (Emotional Symptoms, Conduct Problems, Hyperactivity, Peer Problems, Prosocial Behaviour). These additional results are reported as supplementary tables.

Table 2. *Bivariate correlations and descriptive statistics for key variables*

Variable	1	2	3	4	5	6	7	8
1. Infant birthweight	-							
2. Birthweight z-score	.62**	-						
3. FAD General Functioning scale	.02	-.01	-					
4. WRAT-4 Word Reading	.11*	.07	-.01	-				
5. WRAT-4 Spelling	.15**	.09*	-.02	.81**	-			
6. WRAT-4 Math Computation	.18**	.08	-.08	.63**	.81**	-		
7. Conners-3 ADHD symptoms	-.08	.00	.18**	-.16**	-.20**	-.24**	-	
8. SDQ total difficulties	-.10*	-.04	.29**	-.40**	-.20**	-.26**	.70**	-

Note: FAD, Family Assessment Device; WRAT, Wide Range Achievement Device, Fourth Edition; SDQ, Strengths and Difficulties Questionnaire.
*p<.05. **p<.01.

3. Results

3.1. Neonatal health and key study outcomes of preterm infants by birthweight status (i.e. ELBW, VLBW, LBW)

Infant health outcomes prior to hospital discharge, as well as key study outcomes at 7-year follow-up were compared between birthweight groups (ELBW, VLBW, LBW) using one-way multivariate analysis of variance (MANOVA). Infant health outcomes included APGAR scores (1- and 5-minute), number of days requiring oxygen, number of CPAP support days, length of NICU stay and length of hospital stay. Key study outcomes included math's, spelling and word reading outcomes as measured by the WRAT-4, ADHD symptoms as measured by the Conners-3 and Total Behavioural Difficulties as measured by the Strengths and Difficulties questionnaire.

Birthweight groups were significantly different in terms of overall outcomes ($F(18, 922) = 91.28$, $p<.001$), with results presented in Table 3. Univariate F and Tukey HSD post hoc tests found that compared with VLBW and LBW infants, ELBW infants experienced greater 1-minute and 5-minute APGAR scores ($p<.001$). All birthweight groups significantly differed from one another in terms of number of days requiring oxygen and CPAP support days, as well as length of stay in NICU and in hospital care ($p<.001$), with a greater number of days across these outcomes associated with lower birth weight. Regarding academic and behavioural outcomes at seven years of age, no significant differences between birthweight groups were found for Word Reading and ADHD symptoms. Significant differences between groups were found for Math Computation ($p=.001$), Spelling ($p=.01$) and Total Behavioural Difficulties ($p=.05$), with post hoc tests indicating that the ELBW group significantly differed from the LBW group for Spelling and Total Behavioural Difficulties, and differed significantly from both the VLBW and LBW groups for Math Computation. The partial Eta squared statistics for academic and behavioural outcomes ranged from .01 to .03, indicating that birth weight status explained only a small portion of variance (1-3%).

3.2. Test of differential susceptibility

Results from the regression analyses are presented according to outcome, with results from Step 2 (as no significant results found in Step 1) of the regression analysis presented for academic outcomes in Table 4, and from all steps of the regression analysis for ADHD Symptoms and Behavioural Difficulties presented in Table 5 and Table 6 respectively.

Birthweight status was not a significant predictor of any of the outcomes (see Tables 4-6). Furthermore, while no interaction effects were found between birthweight status and family functioning on academic and ADHD symptom outcomes, a significant interaction effect was found for Total Behavioural Difficulties (Table 6, step 3). Post hoc tests indicated that variations in family functioning significantly related to more behavioural difficulties in ELBW infants (β= 0.36, p>.001), VLBW infants (β= 0.24, p=.001), and LBW infants (β= 0.38, p>.001). In all birthweight groups, infants exhibited more behavioural difficulties when families experienced more problematic family functioning, and less behavioural difficulties when families experienced less problematic family functioning (see Figure 1).
While no significant interaction effects were found for academic and ADHD symptom outcomes, as reflected in Figures 2-5, there was a general trend whereby lower birth weight was generally associated with worse outcomes, and more problematic family functioning was generally associated with worse developmental outcomes across all infant groups.

Outcome scores on the SDQ and WRAT subtests were close to the *Average* range across the sample. However, for ADHD outcome scores, participants across all three birthweight groups experienced a *High Average* number of symptoms when they experienced a low score of family functioning, but these scores moved into the *Elevated* range for LBW and VLBW infants, and the *Very Elevated* range for ELBW infants when they experienced a high score of family functioning (see Figure 2).

Table 3

Overall group differences: health and academic and behavioural outcomes according to birthweight

	ELBW *N*=128	VLBW *N*=182	LBW *N*=162	*F*(df)	*p*	Partial n^2
Neonatal Health Outcomes, mean (SD)						
Birthweight (g)	778.40 (139.06)	1248.90 (148.67)	1766.13 (196.24)	1306.25 (2)	<.001	.85
Birthweight z-score	-1.22 (1.17)	-.51 (.85)	.22 (.80)	83.42 (2)	<.001	.27
Gestational age (weeks)	26.55 (1.97)	29.18 (1.57)	31.16 (.92)	337.77 (2)	<.001	.59
APGAR score: 1 min	5.81 (2.14)	6.54 (2.06)	6.85 (1.81)	9.99 (2)	<.001	.04
APGAR score: 5 min	7.99 (1.30)	8.34 (1.18)	8.54 (.95)	8.27 (2)	<.001	.03
Number of days requiring oxygen	57.63 (37.32)	17.62 (25.09)	4.30 (9.31)	165.45	<.001	.41
Number of days in NICU	47.95 (26.56)	16.75 (17.24)	4.82 (5.63)	219.05 (2)	<.001	.48
Number of days hospitalized	97.76 (31.65)	61.84 (17.94)	40.31 (11.83)	267.88 (2)	<.001	.53
Family Functioning (FAD)						
General Functioning Scale	1.53 (0.41)	1.61 (0.44)	1.52 (0.35)	2.50 (2)	.08	.01
Academic and Behavioural Outcomes						
Math Computation (WRAT-4) standard score	87.16 (14.66)	91.94 (14.11)	93.01 (12.50)	6.88 (2)	.001	.03
Spelling (WRAT-4) standard score	95.82 (17.66)	98.37 (15.15)	101.66 (14.70)	4.90 (2)	.01	.02
Word Reading (WRAT-4) standard score	100.15 (18.33)	104.27 (15.50)	104.06 (13.98)	2.90 (2)	.06	.01
Conner's-3 ADHD symptom *t*-score	67.10 (19.04)	65.77 (18.94)	63.60 (17.83)	1.29 (2)	.28	.01
Total behavioural difficulties (SDQ)	11.49 (6.56)	10.28 (6.27)	9.70 (5.88)	2.92 (2)	.05	.01

NICU, Neonatal Intensive Care Unit; FAD, Family Assessment Device; WRAT-4, Wide Range Achievement Test, Fourth Edition; SDQ, Strengths and Difficulties Questionnaire.

Birthweight Status, ELBW (<1000g), VLBW (<1500g), LBW (<2500g).

Table 4

Birthweight status and family functioning predicting academic outcomes as measured by the WRAT-4 in preterm infants.

Step 2 regression results	Predictor	Standardised coefficients Beta	*t*	Sig.	95% confidence interval for *B*		R^2
					Lower bound	Upper bound	
Math Computation (WRAT-4)	Gender	-.09	-1.92	.06	-.36	.00	.08**
	Cultural background	.02	.38	.70	-.15	.23	
	Mother's highest level of education	.03	.70	.48	.00	.00	
	Father's highest level of education	-.04	-.72	.47	.00	.00	
	FAD (general functioning scale)	-.01	-.13	.90	-.49	.43	
	Birthweight status	.01	.16	.87	-.11	.13	
Spelling (WRAT-4)	Gender	-.15	-3.25	.00	-.48	-.12	.09**
	Cultural background	.03	.54	.59	-.14	.24	
	Mother's highest level of education	.01	.22	.82	.00	.00	
	Father's highest level of education	-.10	-1.90	.06	.00	.00	
	FAD (general functioning scale)	.03	.27	.78	-.39	.51	
	Birthweight status	.00	.04	.97	-.11	.12	
Word Reading (WRAT-4)	Gender	-.12	-2.51	.01	-.41	-.05	.09**
	Cultural background	.01	.28	.78	-.16	.21	
	Mother's highest level of education	.01	.10	.92	.00	.00	
	Father's highest level of education	-.06	-1.27	.21	.00	.00	
	FAD (general functioning scale)	.05	.53	.60	-.33	.57	
	Birthweight status	.01	.12	.91	-.11	.12	

*p<.05. **p<.01. WRAT-4, Wide Range Achievement Test, Fourth Edition; FAD, Family Assessment Device.

Birthweight Status, ELBW (<1000g), VLBW (<1500g), LBW (<2500g).

Table 5

Birthweight status and family functioning predicting ADHD symptoms as measured by the Conner's-3 in preterm infants.

Regression Results	Predictor	Standardised coefficients Beta	*t*	Sig.	95% confidence interval for *B*		R^2
					Lower bound	Upper bound	
Step 1	Gender	.12	2.63	.01	1.15	7.96	.02*
	Cultural background	-.05	-1.00	.32	-5.32	1.73	
	Mother's highest level of education	.04	.87	.38	-.00	.01	
	Father's highest level of education	.04	.72	.47	-.00	.00	
Step 2	Gender	.11	2.39	.02	.73	7.41	.09**
	Cultural background	-.05	-1.06	.29	-5.34	1.60	
	Mother's highest level of education	.05	.93	.35	-.00	.01	
	Father's highest level of education	.03	.60	.55	-.00	.00	
	FAD (general functioning scale)	.18	1.91	.06	-.25	16.64	
	Birthweight status	-.07	-1.46	.15	-3.73	.55	
Step 3	Gender	.11	2.49	.01	.89	7.57	.11
	Cultural background	-.05	-1.0	.31	-5.29	1.69	
	Mother's highest level of education	.05	.97	.34	-.00	.01	
	Father's highest level of education	.03	.57	.57	-.00	.00	
	FAD (general functioning scale)	.28	1.83	.07	-.98	26.99	
	Birthweight status	-.07	-1.60	.11	-3.93	.40	
	Birthweight status x general functioning	-.12	-.80	.43	-15.27	6.45	

*p<.05. **p<.01.

FAD, Family Assessment Device.

Birthweight Status, ELBW (<1000g), VLBW (<1500g), LBW (<2500g).

Table 6

Birthweight status and family functioning predicting total behavioural difficulties as measured by the SDQ in preterm infants.

Regression Results	Predictor	Standardised coefficients Beta	*t*	Sig.	95% confidence interval for *B*		R^2
					Lower bound	Upper bound	
Step 1	Gender	.14	3.03	.00	.10	.46	.02*
	Cultural background	-.04	-.86	.39	-.27	.11	
	Mother's highest level of education	-.02	-.34	.74	.00	.00	
	Father's highest level of education	.04	.78	.44	.00	.00	
Step 2	Gender	.11	2.61	.01	.06	.40	.16**
	Cultural background	-.05	-1.05	.29	-.28	.08	
	Mother's highest level of education	-.01	-.16	.87	.00	.00	
	Father's highest level of education	.03	.63	.53	.00	.00	
	FAD (general functioning scale)	.28	3.10	.00	.25	1.12	
	Birthweight status	.01	.18	.86	-.10	.12	
Step 3	Gender	.12	2.77	.01	.07	.41	.18
	Cultural background	-.04	-.92	.36	-.26	.10	
	Mother's highest level of education	-.01	-.20	.84	.00	.00	
	Father's highest level of education	.02	.42	.68	.00	.00	
	FAD (general functioning scale)	.52	3.52	.00	.59	2.01	
	Birthweight status	-.01	-.23	.82	-.13	.10	
	Birthweight status x general functioning	-.30	-2.08	.04	-1.15	-.03	

*$p<.05$. **$p<.01$.

FAD, Family Assessment Device.

Birthweight Status, ELBW (<1000g), VLBW (<1500g), LBW (<2500g).

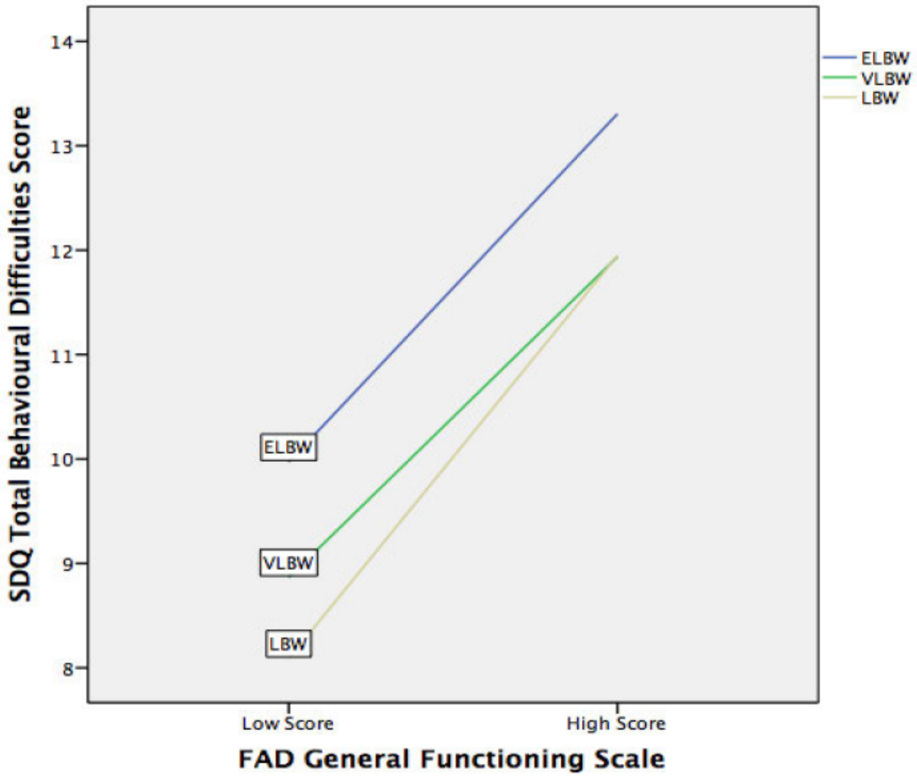

Figure 1. The relationship between the Family Assessment Device General Functioning Scale and Total Behavioural Difficulties as measured by the Strengths and Difficulties Questionnaire, based on birthweight status. ELBW (Extremely Low Birth Weight, <1000g), VLBW (Very Low Birth Weight, <1500g), LBW (Low Birth Weight, <2500g). Higher Total Behavioural Difficulties represent more problematic behavioural functioning and higher FAD General Functioning scores represent more problematic family functioning.

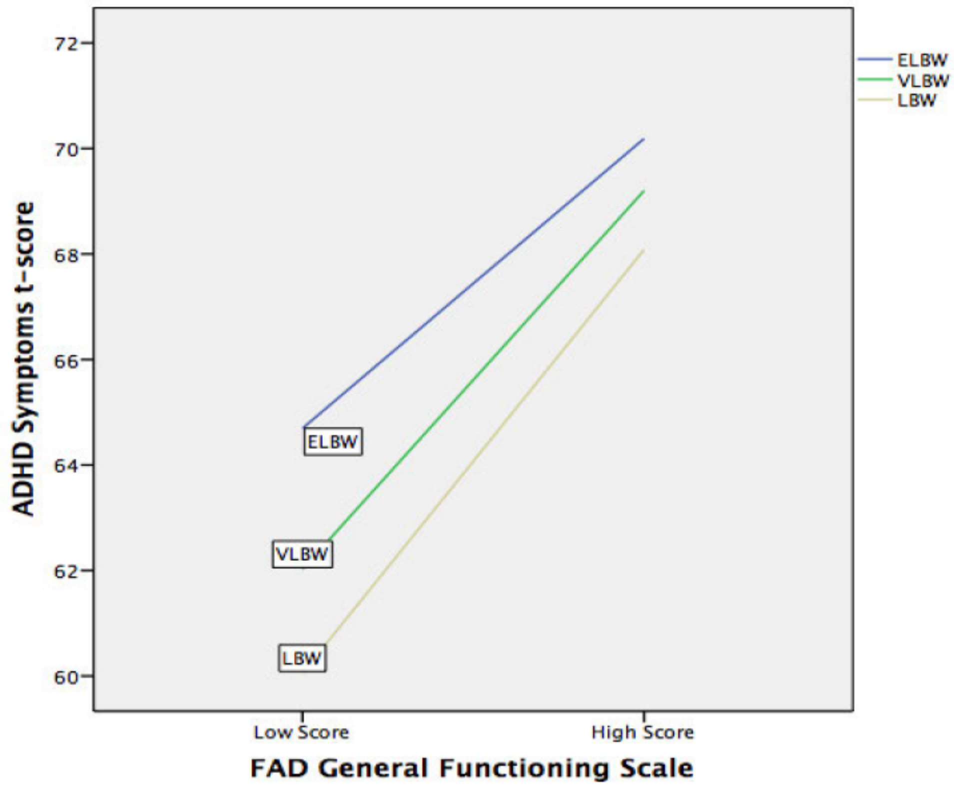

Figure 2. The relationship between the Family Assessment Device General Functioning Scale and ADHD symptoms as measured by the Conner's-3, based on birthweight status. ELBW (Extremely Low Birth Weight, <1000g), VLBW (Very Low Birth Weight, <1500g), LBW (Low Birth Weight, <2500g). Higher ADHD scores represent more ADHD symptoms and higher FAD General Functioning scores represent more problematic family functioning.

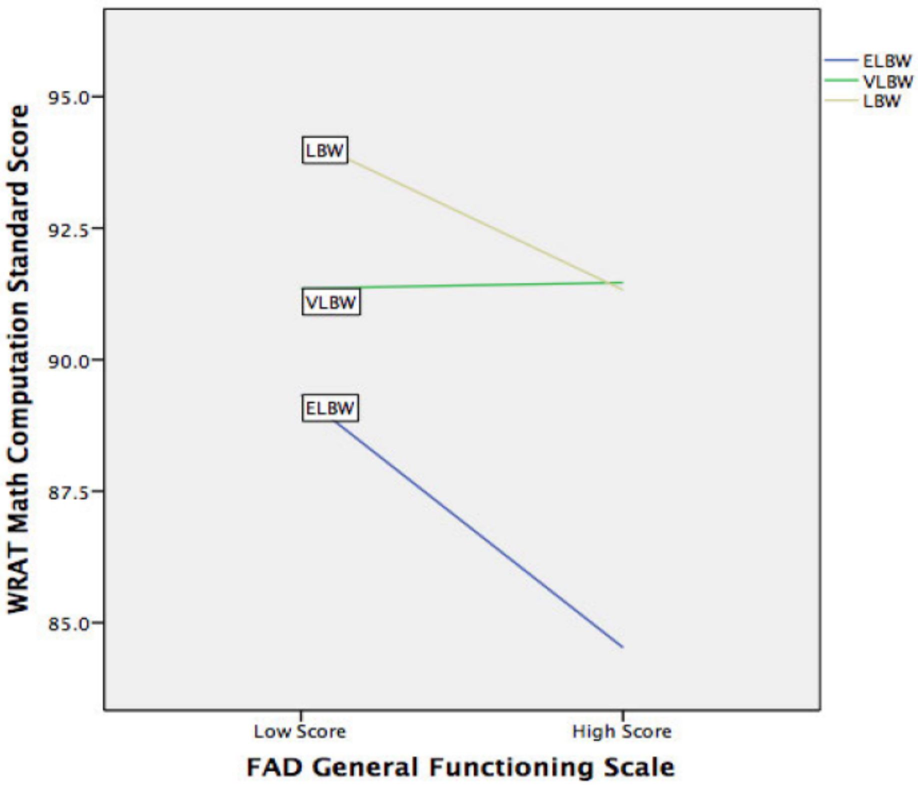

Figure 3. The relationship between the Family Assessment Device General Functioning Scale and Math Computation standard scores as measured by the Wide Range Achievement Test (fourth edition), based on birthweight status. ELBW (Extremely Low Birth Weight, <1000g), VLBW (Very Low Birth Weight, <1500g), LBW (Low Birth Weight, <2500g). Higher Math Computation scores represent better performance and higher FAD General Functioning scores represent more problematic family functioning.

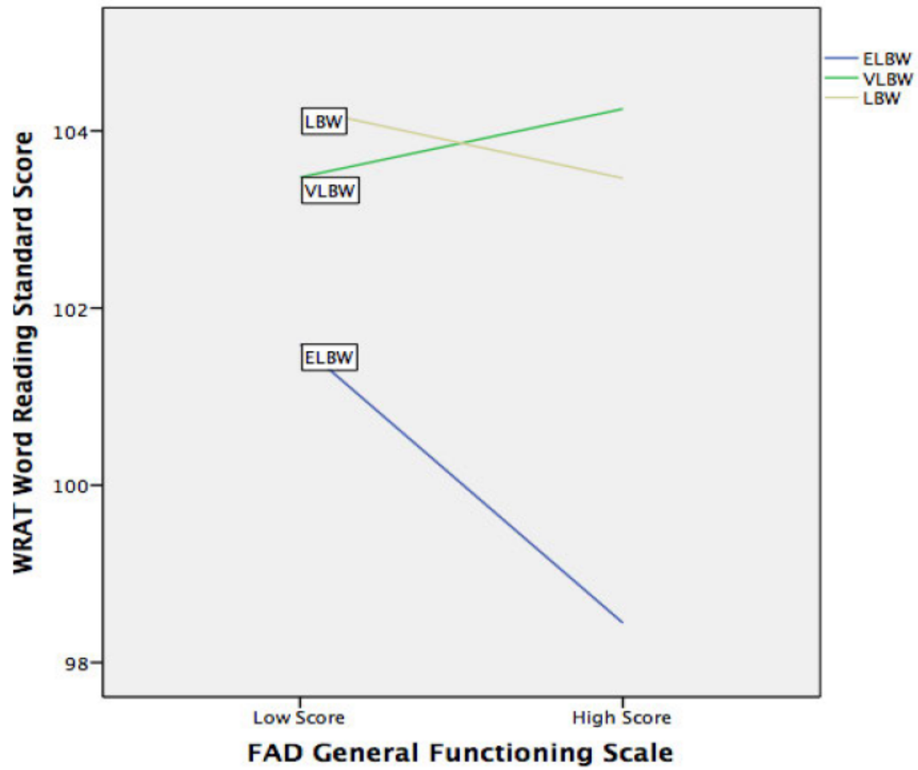

Figure 4. The relationship between the Family Assessment Device General Functioning Scale and Word Reading standard scores as measured by the Wide Range Achievement Test (fourth edition), based on birthweight status. ELBW (Extremely Low Birth Weight, <1000g), VLBW (Very Low Birth Weight, <1500g), LBW (Low Birth Weight, <2500g). Higher Word Reading scores represent better performance and higher FAD General Functioning scores represent more problematic family functioning.

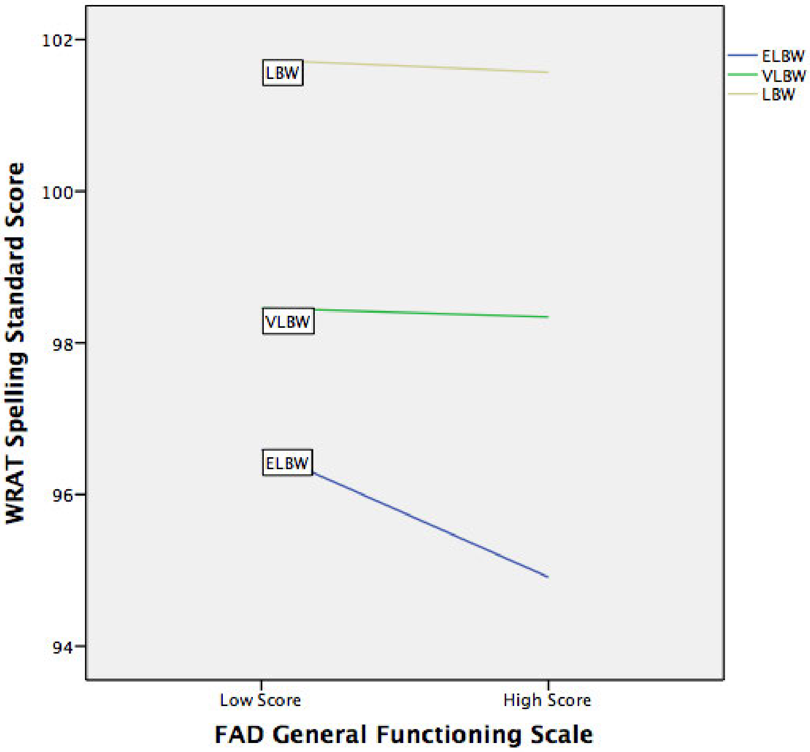

Figure 5. The relationship between the Family Assessment Device General Functioning Scale and Spelling standard scores as measured by the Wide Range Achievement Test (fourth edition), based on birthweight status. ELBW (Extremely Low Birth Weight, <1000g), VLBW (Very Low Birth Weight, <1500g), LBW (Low Birth Weight, <2500g). Higher Spelling scores represent better performance and higher FAD General Functioning scores represent more problematic family functioning.

3.3. Additional Analyses

Additional regression analyses were conducted with all six FAD scales (Problem Solving, Communication, Roles, Affective Responsiveness, Affective Involvement, Behaviour Control, General Functioning), and their interactions with birthweight status were entered into the regression models. Within the additional regression analyses, the five outcomes (Math Computation, Spelling, Word Reading, ADHD symptoms, Total Behavioural Difficulties), as well as the additional five scales from the SDQ (Emotional Symptoms, Conduct Problems, Hyperactivity, Peer Problems, Prosocial Behaviour) were analysed.

The same regression analyses were performed, replacing birthweight categories with birthweight z-scores (as a continuous variable) as a susceptibility factor to examine whether the results differed. Bivariate correlations were conducted (see Table S-1), and when the susceptibility factor was correlated with any of the outcomes or any of the FAD variables, the steps outlined by Ellis et al (2011) were again followed to partial out the variance in the outcome. The results reflected similar trends and did not differ in any meaningful way. Regression analyses examining birthweight status as a susceptibility factor are presented in Tables S-2 – S8 and regression analyses examining birthweight z-scores as a susceptibility factor are presented in Tables S-9 – S-13.

Results from the additional regression analyses found a number of significant interaction effects which are indicated in the supplementary tables. All patterns of results were more consistent with the diathesis stress hypothesis than the differential susceptibility hypothesis and in line with the main pattern of findings discussed above. The only exception was the interaction effect of birthweight z-scores and the FAD general functioning scale which reflected a contrastive effect.

4. Discussion

This study explored how the quality of family functioning, as well as low birth weight can affect the preterm child in terms of behaviour, academic and ADHD symptom outcomes at seven years of age. We investigated whether preterm children with different levels of low birth weight (ELBW, VLBW, LBW) were differentially susceptible to family functioning. Our results found family functioning to be both an independent predictor of behavioural difficulties in preterm children, and to also have an interaction effect with birthweight status, whereby preterm children with lower birthweight experienced more problematic behavioural difficulties.

The results of the present study did not support the differential susceptibility hypothesis, but rather, indicated patterns more consistent with diathesis stress. Accordingly, all preterm infants were affected by family functioning in a similar pattern (i.e. more problematic family functioning was associated with worse outcomes and more optimal family functioning was associated with better outcomes), and preterm infants from the ELBW group appeared to have the most impaired functioning, indicating greater risk for preterm children with lower birthweight. This was further reinforced through the analysis of medical data during infant hospitalisation after birth, which indicated that preterm infants with lower birthweight experienced significantly higher health risks (i.e. APGAR score, length of hospital stay, oxygen support). This is in line with previous research that has found lower gestational age and lower birth weight to be associated with significantly greater risk and more adverse outcomes (e.g. Ment, Allan, Makuch, & Voht, 2005; Moster, Terie, & Markestad, 2008).

Several other studies have investigated the differential susceptibility hypothesis among preterm children and children with low birth weight. However, this study was the first to investigate low birth weight in a sample of preterm children as an additional risk factor. However, in line with the findings of Gueron-Sela et al (2016), the results of the present study also indicated that child susceptibility factors may not necessarily act in a cumulative linear manner. Accordingly, the combination of preterm birth and low birth weight did not reflect differential susceptibility. This is in contrast to the findings of Poehlmann et al (2011), who found the combination of preterm birth and proneness to distress to have a differential susceptibility effect on child cognitive development.

Another potential reason that differential susceptibility was not reflected in this study, was that family functioning and child outcomes were measured at 7-years of age. While this was a reasonable approach, as previous studies have found an association between earlier life family functioning and later life family functioning (e.g. Johnson, 2010), this may not have been the case in this particular sample. In most studies, the environmental outcome (e.g. parenting, home environment) has been captured at an earlier time-point than the child outcome measure (e.g. Gueron-Sela et al., 2015; Gueron-Sela et al., 2016; Poehlman et al., 2011), which may provide a period of time for environmental effects to occur, and therefore for the child's functioning to change. In our study, it is possible that family functioning scores reported at 7-years of age were not reflective of the quality of family functioning during infancy. Consequently, the child academic, behavioural and ADHD symptom outcomes may have been influenced by the quality of family functioning experienced by the child during their infancy, which, had it been measured, may have reflected a different relationship than what was reflected in our findings.

The findings of the present study are best compared to those of Shah et al (2013), as the authors included three preterm groups (very preterm, moderate preterm, late preterm) and did not include a term-group. However, the present study included a significantly larger sample size. In terms of behavioural outcomes, both the findings of our study and those of Shah et al (2013) did not find support for the differential susceptibility hypothesis.

It is noteworthy that outcome scores for both academic functioning and behavioural functioning were close to or in the *Average* range across the sample, regardless of birthweight status. Whereas for ADHD symptoms, scores were in the *High Average* range in the context of less problematic family functioning, but moved to the *Elevated* range for LBW and VLBW infants, and the *Very Elevated* range for ELBW infants in the context of more problematic family functioning. Thus, in line with the suggestions of Murray et al. (2016), it is possible that in regard to ADHD symptoms, the quality of family functioning may impact the child in such a way that has clinical significance, regardless of birthweight. It is also possible that the effect of family functioning may be less noticeable when preterm children are already functioning around the *Average* range, as was evidenced for behavioural and academic functioning in this sample.

Further to this, over eighty percent of the sample did not meet the cut off score for what is considered problematic family functioning, which is in contrast to studies that have indicated families of preterm children to experience high levels of problematic family functioning (Treyvaud et al., 2014). Accordingly, although there was a minimal attrition rate (92% of participants from the original trial participated in 7-year follow up), it is possible that families with lower family functioning were amongst those who did not participate in the 7-year follow up. Thus, it may be that the present sample experienced better family functioning than would normally be expected in the preterm population, and that this indeed had a protective effect on their developmental outcomes. Future studies should include a sample of preterm children with varying levels of family functioning that more evenly range from more optimal to problematic functioning in order to determine how outcomes vary in the context of more problematic family functioning.

This study had a number of strengths. Firstly, most studies conducted in this area, as well as all those that have specifically investigated differential susceptibility, have focused on preterm outcomes during infancy. However, in line with recommendations for future research suggested by Gueron-Sela et al (2015), the present study contributed to the literature by examining outcomes at seven years of age. A large sample was also included, with an evenly spread distribution of participants across the three birthweight categories, allowing for meaningful comparisons to be made. Furthermore, Gueron-Sela et al (2015) and Shah et al (2013) recommended that research investigating differential susceptibility should include comparisons of differing levels of prematurity and birth weight, as well as preterm infants with differing levels of medical risk. The present study achieved this by including the additional risk of low birth weight in a preterm sample, which was associated with differing levels of medical risk based on birthweight status. Additionally, several limitations from previous studies were addressed, including the inclusion of ADHD symptoms rather than the presence or absence of an ADHD diagnosis, as well as the inclusion of academic functioning and behavioural functioning in order to capture the multidimensional nature of ADHD (Deault, 2010, p. 170). Furthermore, the variable of family functioning was selected as a key variable of interest as it has been relatively unexplored in the preterm population, despite its relevance in this population (Treyvaud et al., 2011). Through examining family functioning, the present study was better able to account for the bi-directionality of parent-child relationships that is not captured in parenting measures. This is particularly important in the preterm population, as multiple studies have indicated that the very event of having a preterm child born into a family can have a profound effect on the family (e.g. Cronin et al., 1995; Treyvaud, 2014).

Limitations were also present in this study. Firstly, a normal comparison groups was not included, as all participants were preterm and had a birthweight <2,500g. Accordingly, while this study would have been able to detect any differences in susceptibility within a large preterm cohort with differing levels of LBW, if a term-born or normal birthweight control group was included, differences in susceptibility could have been detected between the two groups. It may be that although preterm and LBW children differ from one another in terms of outcomes, depending on their level of risk, prematurity and birthweight, these differences may not equate to differences in susceptibility. It may be that as a group, preterm children have a common predisposition to respond similarly to the environment, whereby it may be more appropriate to treat preterm and/or low birth weight children as one group in terms of environmental susceptibility, and compare them to a normal control group, rather than to split the preterm group in terms of risk.

Additionally, the present study did not include a measure of infant temperamental reactivity or proneness to distress, which have been found to be specific differential susceptibility factors in the preterm population (e.g. Gueron-Sela et al., 2016; Poehlmann et al., 2011). Furthermore, while the FAD and SDQ are commonly used measures of family functioning and child behavioural functioning, they are not the 'gold standard' approach of assessment. These measures were completed by the mother of the child, which may have resulted in reporting bias. While this format of collecting data has been widely used across a number of studies, future studies may consider using a multi-informant approach to assessment, as well as an observational assessment in order to triangulate data.

The present study did not find support for the differential susceptibility hypothesis. However, there was a general trend whereby poorer family functioning was associated with worse outcomes, reinforcing the idea that prevention and intervention strategies at the family-level are worthy of further investigation in order to support the preterm/LBW child. Using the FAD as a screening tool for identifying at-risk families may be an area worthy of investigation. Furthermore, as the present sample experienced better than expected family functioning, future studies may examine child outcomes in a sample that includes families with more problematic family functioning, in order to gain a better understanding of how this may impact child functioning. The inclusion of infant temperamental reactivity or proneness to distress may also be considered in future studies in order to determine whether these factors better explain differential susceptibility in the preterm/low birth weight population.

As the body of research investigating differential susceptibility in the preterm and LBW population grows, it appears that more questions than answers arise. While some studies have found some support for the differential susceptibility hypothesis, overall, the findings can at best be described as mixed. There is no clear general consensus regarding what factors inevitably cause differential susceptibility in preterm and LBW children.

Whether differential susceptibility is a viable theory for understanding resilience in preterm/LBW children remains to be determined. However, what is clear is that preterm/LBW children are inherently at greater risk for a number of neurodevelopmental difficulties, and that the quality of their proximal environment appears to have an effect. The findings of the present study indicate family functioning to be one such area worthy of further attention and investigation.

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Supplementary Tables (S-1 – S-13)

Table S-1. *Bivariate correlations and descriptive statistics for key variables*

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Infant birthweight	-																	
2. Birthweight z-score	.62**	-																
3. FAD problem solving	.00	.02	-															
4. FAD communication	-.05	-.04	.68**	-														
5. FAD roles	-.02	.04	.52**	.53**	-													
6. FAD affective responsiveness	.01	.00	.56**	.65**	.46**	-												
7. FAD affective involvement	.10*	.05	.47**	.54**	.56**	.55**	-											
8. FAD behaviour control	.04	.03	.50**	.51**	.55**	.53**	.53**	-										
9. FAD general functioning	.02	-.01	.74**	.73**	.61**	.73**	.63**	.62**	-									
10. WRAT word reading	.11*	.07	.07	-.02	-.15**	.00	-.05	-.12**	-.01	-								
11. WRAT spelling	.15**	.09*	.08	-.11*	-.15**	-.02	-.06	-.07	-.02	.81**	-							
12. WRAT math	.18**	.08	.02	-.11*	-.19**	-.06	-.08	-.11*	-.08	.63**	.81**	-						
13. Conners-3 ADHD symptoms	-.08	.00	.11*	.14**	.22**	.14**	.13**	.06	.18**	-.16**	-.20**	-.24**	-					
14. SDQ emotional symptoms	-.03	.04	.10*	.07	.20**	.14**	.09*	.08	.16**	.00	-.03	-.11*	.35**	-				
15. SDQ conduct problems	-.02	-.02	.16**	.19**	.29**	.19**	.23**	.11*	.28**	-.13**	-.17**	-.18**	.52**	.34**	-			
16. SDQ hyperactivity	-.11*	-.04	.17**	.18**	.25**	.16**	.16**	.10*	.22**	-.22**	-.27**	-.31**	.76**	.34**	.54**	-		
17. SDQ peer problems	-.12**	-.09	.16**	.18**	.25**	.19**	.15**	.12*	.22**	-.01	-.10*	-.12**	.36**	.39**	.38**	.39**	-	
18. SDQ prosocial	-.12*	-.01	-.28**	-.25**	-.31**	-.31**	-.24**	-.21**	-.35**	.04	.11*	.14**	-.31**	-.17**	-.45**	-.38**	-.36**	-
19. SDQ total difficulties	-.10*	-.04	.20**	.21**	.33**	.23**	.20**	.13**	.29**	-.40**	-.20**	-.26**	.70**	.69**	.75**	.82**	.69**	-.45**

Note: FAD, Family Assessment Device; WRAT, Wide Range Achievement Device, Fourth Edition; SDQ, Strengths and Difficulties Questionnaire.

**p*<.05. ***p*<.01.

Table S-2

Birthweight status and family functioning predicting ADHD symptoms as measured by the Conner's-3 and behavioural problems as measured by the SDQ in preterm infants.

Step 2 regression results	Predictor	Standardised coefficients Beta	*t*	Sig.	95% confidence interval for *B*		R^2
					Lower bound	Upper bound	
ADHD Symptoms (Conner's-3)	Gender	.11	2.39	.02*	.73	7.41	.09**
	Cultural background	-.05	-1.06	.29	-5.34	1.60	
	Mother's highest level of education	.05	.93	.35	-.00	.01	
	Father's highest level of education	.03	.60	.55	-.00	.00	
	FAD (problem solving scale)	-.08	-1.08	.28	-10.35	3.00	
	FAD (communication scale)	.01	.09	.93	-6.68	7.35	
	FAD (roles scale)	.20	3.20	.00**	4.08	17.08	
	FAD (affective responsiveness scale)	.03	.35	.72	-4.74	6.81	
	FAD (affective involvement scale)	-.01	-.08	.94	-5.93	5.50	
	FAD (behaviour control scale)	-.13	-2.05	.04*	-13.66	-.28	
	FAD (general functioning scale)	.18	1.91	.06	-.25	16.64	
	Birthweight status	-.07	-1.46	.15	-3.73	.55	
Conduct Problems (SDQ)	Gender	.09	1.94	.05*	-.00	.63	.14**
	Cultural background	-.04	-.95	.34	-.49	.17	
	Mother's highest level of education	-.01	-.21	.84	-.00	.00	
	Father's highest level of education	.03	.57	.57	.00	.00	
	FAD (problem solving scale scale)	-.12	-1.65	.10	-1.17	.10	
	FAD (communication scale)	-.03	-.36	.72	-.79	.55	
	FAD (roles scale)	.22	3.60	.00**	.51	1.75	
	FAD (affective responsiveness scale)	-.02	-.35	.73	-.65	.45	
	FAD (affective involvement scale)	.06	.91	.37	-.29	.80	

	FAD (behaviour control scale)	-.16	-2.65	.01*	-1.49	-.22
	FAD (general functioning scale)	.34	3.71	.00**	.71	2.31
	Birthweight status	-.00	-.10	.92	-.22	.19
Hyperactivity (SDQ)	Gender	.22	4.89	.00	.26	.61
	Cultural background	-.07	-1.47	.14	-.32	.05
	Mother's highest level of education	.06	1.21	.23	.00	.00
	Father's highest level of education	.01	.27	.79	.00	.00
	FAD (problem solving scale)	-.02	-.28	.78	-.40	.30
	FAD (communication scale)	.02	.34	.73	-.30	.43
	FAD (roles scale)	.18	2.99	.00	.18	.86
	FAD (affective responsiveness scale)	-.00	-.06	.95	-.31	.29
	FAD (affective involvement scale)	.02	.32	.75	-.25	.35
	FAD (behaviour control scale)	-.08	-1.28	.20	-.58	.12
	FAD (general functioning scale)	.14	1.54	.13	-.10	.79
	Birthweight status	.01	.15	.88	-.10	.12

*p<.05. **p<.01.

FAD, Family Assessment Device; SDQ, Strengths and Difficulties Questionnaire.

Birthweight Status, ELBW (<1000g), VLBW (<1500g), LBW (<2500g).

Note: Regression results which included a significant interaction effect in Step 3 of the analysis are presented in individual tables (see Tables S-3 – S-8).

Table S-3

Birthweight status and family functioning predicting Math Computation performance as measured by the WRAT-4 in preterm infants.

Regression Results	Predictor	Standardised coefficients Beta	*t*	Sig.	95% confidence interval for *B*		R^2
					Lower bound	Upper bound	
Step 1	Gender	-.09	-1.89	.06	-.36	.01	.01
	Cultural background	.01	.13	.90	-.18	.20	
	Mother's highest level of education	.05	1.07	.29	.00	.00	
	Father's highest level of education	-.06	-1.16	.25	.00	.00	
Step 2	Gender	-.09	-1.92	.06	-.36	.00	.08**
	Cultural background	.02	.38	.70	-.15	.23	
	Mother's highest level of education	.03	.70	.48	.00	.00	
	Father's highest level of education	-.04	-.72	.47	.00	.00	
	FAD (problem solving scale)	.24	3.33	.00**	.25	.97	
	FAD (communication scale)	-.14	-1.93	.06	-.76	.01	
	FAD (roles scale)	-.22	-3.48	.00**	-.98	-.27	
	FAD (affective responsiveness scale)	.04	.62	.54	-.21	.41	
	FAD (affective involvement scale)	.02	.34	.74	-.26	.37	
	FAD (behaviour control scale)	-.06	-1.03	.30	-.55	.17	
	FAD (general functioning scale)	-.01	-.13	.90	-.49	.43	

	Birthweight status	.01	.16	.87	-.11	.13	
Step 3	Gender	-.09	-1.98	.05*	-.37	-.00	.09
	Cultural background	.02	.44	.66	-.15	.23	
	Mother's highest level of education	.03	.58	.56	.00	.00	
	Father's highest level of education	-.03	-.56	.57	.00	.00	
	FAD (problem solving scale)	.30	2.41	.02*	.14	1.39	
	FAD (communication scale)	-.13	-1.09	.28	-.98	.28	
	FAD (roles scale)	-.40	-3.87	.00**	-1.72	-.56	
	FAD (affective responsiveness scale)	.03	.22	.82	-.47	.59	
	FAD (affective involvement scale)	.14	1.28	.20	-.18	.87	
	FAD (behaviour control scale)	-.07	-.62	.54	-.84	.44	
	FAD (general functioning scale)	-.04	-.24	.81	-.85	.67	
	Birthweight status	.01	.19	.85	-.11	.13	
	Birthweight status x problem solving scale	-.08	-.66	.51	-.63	.31	
	Birthweight status x communication scale	-.04	-.32	.75	-.56	.40	
	Birthweight status x roles scale	.25	2.30	.02*	.08	1.00	
	Birthweight status x affective responsiveness scale	.05	.38	.70	-.33	.49	
	Birthweight status x affective involvement scale	-.15	-1.45	.15	-.69	.10	
	Birthweight status x behaviour control scale	.00	.04	.97	-.48	.50	

Birthweight status x general functioning scale	.02	.14	.89	-.55	.63

*p<.05. **p<.01.

FAD, Family Assessment Device; WRAT-4, Wide Range Achievement Test, Fourth Edition.

Birthweight Status, ELBW (<1000g), VLBW (<1500g), LBW (<2500g).

Table S-4

Birthweight status and family functioning predicting Spelling performance as measured by the WRAT-4 in preterm infants.

Regression Results	Predictor	Standardised coefficients Beta	*t*	Sig.	95% confidence interval for *B*		R^2
					Lower bound	Upper bound	
Step 1	Gender	-.15	-3.13	.00**	-.47	-.11	.04*
	Cultural background	.01	.23	.78	-.16	.21	
	Mother's highest level of education	.03	.62	.53	.00	.00	
	Father's highest level of education	-.12	-2.36	.02*	.00	.00	
Step 2	Gender	-.15	-3.25	.00**	-.48	-.12	.09**
	Cultural background	.03	.54	.59	-.14	.24	
	Mother's highest level of education	.01	.22	.82	.00	.00	
	Father's highest level of education	-.10	-1.90	.06	.00	.00	
	FAD (problem solving scale)	.26	3.59	.00**	.30	1.01	
	FAD (communication scale)	-.14	-1.86	.06	-.74	.02	
	FAD (roles scale)	-.17	-2.64	.01*	-.83	-.12	
	FAD (affective responsiveness scale)	.05	.73	.46	-.19	.42	
	FAD (affective involvement scale)	-.02	-.26	.80	-.35	.27	
	FAD (behaviour control scale)	-.09	-1.41	.16	-.62	.10	
	FAD (general functioning scale)	.03	.27	.78	-.39	.51	

	Birthweight status	.00	.04	.97	-.11	.12	
Step 3	Gender	-.15	-3.24	.00**	-.48	-.12	.11
	Cultural background	.03	.64	.52	-.13	.25	
	Mother's highest level of education	.00	.08	.94	.00	.00	
	Father's highest level of education	-.09	-1.84	.07	.00	.00	
	FAD (problem solving scale)	.35	2.77	.01*	.25	1.49	
	FAD (communication scale)	-.17	-1.41	.16	-1.07	.18	
	FAD (roles scale)	-.32	-3.14	.00**	-1.49	-.34	
	FAD (affective responsiveness scale)	.01	.05	.96	-.51	.54	
	FAD (affective involvement scale)	.07	.61	.54	-.36	.69	
	FAD (behaviour control scale)	-.14	-1.31	.19	-1.07	.21	
	FAD (general functioning scale)	.12	.77	.44	-.46	1.05	
	Birthweight status	-.01	-.12	.90	-.13	.11	
	Birthweight status x problem solving scale	-.11	-.90	.37	-.68	.25	
	Birthweight status x communication scale	.02	.16	.88	-.44	.52	
	Birthweight status x roles scale	.22	2.04	.04*	.02	.93	
	Birthweight status x affective responsiveness scale	.08	.63	.53	-.28	.54	
	Birthweight status x affective involvement scale	-.12	-1.15	.25	-.62	.16	

Birthweight status x behaviour control scale	.07	.62	.53	-.34	.65
Birthweight status x general functioning scale	-.12	-.81	.42	-.83	.34

**p*<.05. ***p*<.01.

FAD, Family Assessment Device; WRAT-4, Wide Range Achievement Test.

Birthweight Status, ELBW (<1000g), VLBW (<1500g), LBW (<2500g).

Table S-5

Birthweight status and family functioning predicting Word Reading performance as measured by the WRAT-4 in preterm infants.

Regression Results	Predictor	Standardised coefficients Beta	*t*	Sig.	95% confidence interval for *B*		R^2
					Lower bound	Upper bound	
Step 1	Gender	-.11	-2.25	.03*	-.39	-.03	.02
	Cultural background	.01	.15	.88	-.17	.20	
	Mother's highest level of education	.02	.44	.66	.00	.00	
	Father's highest level of education	-.08	-1.64	.10	.00	.00	
Step 2	Gender	-.12	-2.51	.01*	-.41	-.05	.87**
	Cultural background	.01	.28	.78	-.16	.21	
	Mother's highest level of education	.01	.10	.92	.00	.00	
	Father's highest level of education	-.06	-1.27	.21	.00	.00	
	FAD (problem solving scale)	.22	3.02	.00**	.19	.91	
	FAD (communication scale)	-.07	-.93	.35	-.56	.20	
	FAD (roles scale)	-.19	-2.94	.00**	-.87	-.17	
	FAD (affective responsiveness scale)	.08	1.11	.27	-.13	.48	
	FAD (affective involvement scale)	.02	.24	.81	-.27	.35	
	FAD (behaviour control scale)	-.19	-3.00	.00**	-.91	-.19	
	FAD (general functioning scale)	.05	.53	.60	-.33	.57	

	Birthweight status	.01	.12	.91	-.20	.12	
Step 3	Gender	-.12	-2.55	.01*	-.41	-.05	.10
	Cultural background	.02	.32	.75	-.16	.22	
	Mother's highest level of education	-.00	-.04	.97	.00	.00	
	Father's highest level of education	-.05	-1.04	.30	.00	.00	
	FAD (problem solving scale)	.27	2.19	.03*	.07	1.30	
	FAD (communication scale)	-.14	-1.19	.24	-1.00	.25	
	FAD (roles scale)	-.40	-3.90	.00**	-1.70	-.56	
	FAD (affective responsiveness scale)	.14	1.15	.25	-.22	.83	
	FAD (affective involvement scale)	.15	1.38	.17	-.15	.89	
	FAD (behaviour control scale)	-.19	-1.72	.09	-1.19	.08	
	FAD (general functioning scale)	.03	.17	.87	-.69	.82	
	Birthweight status	.01	.11	.92	-.11	.12	
	Birthweight status x problem solving scale	-.07	-.63	.53	-.62	.32	
	Birthweight status x communication scale	.07	.52	.60	-.35	.60	
	Birthweight status x roles scale	.28	2.60	.01*	.15	1.06	
	Birthweight status x affective responsiveness scale	-.05	.39	.70	-.49	.33	
	Birthweight status x affective involvement scale	-.17	-1.58	.11	-.70	.08	

Birthweight status x behaviour control scale	.01	.05	.96	-.48	.50
Birthweight status x general functioning scale	.02	.14	.89	-.54	.63

*p<.05. **p<.01.

FAD, Family Assessment Device; WRAT-4, Wide Range Achievement Test, Fourth Edition.

Birthweight Status, ELBW (<1000g), VLBW (<1500g), LBW (<2500g).

Table S-6

Birthweight status and family functioning predicting Emotional Symptoms as measured by the SDQ in preterm infants.

Regression Results	Predictor	Standardised coefficients Beta	*t*	Sig.	95% confidence interval for *B*		R^2
					Lower bound	Upper bound	
Step 1	Gender	-.06	-1.25	.21	-.63	.14	.01
	Cultural background	-.03	-.54	.59	-.51	.29	
	Mother's highest level of education	-.08	-1.58	.11	-.00	.00	
	Father's highest level of education	.08	1.57	.12	.00	.00	
Step 2	Gender	-.07	-1.56	.12	-.68	.08	.07**
	Cultural background	-.02	-.45	.65	-.49	.31	
	Mother's highest level of education	-.07	-1.50	.14	-.00	.00	
	Father's highest level of education	.07	1.36	.17	.00	.00	
	FAD (problem solving scale)	-.04	-.53	.60	-.96	.56	
	FAD (communication scale)	-.11	-1.50	.13	-1.41	.19	
	FAD (roles scale)	.22	3.42	.00	.55	2.03	
	FAD (affective responsiveness scale)	.07	.97	.33	-.33	.98	
	FAD (affective involvement scale)	-.07	-1.04	.30	-1.0	.31	
	FAD (behaviour control scale)	-.09	-1.51	.13	-1.34	.18	
	FAD (general functioning scale)	.20	2.15	.03	.09	2.00	

	Birthweight status	-.02	-.43	.67	-.30	.19	
Step 3	Gender	-.07	-1.41	.16	-.65	.11	.09
	Cultural background	-.01	-.15	.88	-.43	.37	
	Mother's highest level of education	-.08	-1.54	.12	-.00	.00	
	Father's highest level of education	.06	1.25	.21	.00	.00	
	FAD (problem solving scale)	-.05	-.40	.69	-1.55	1.03	
	FAD (communication scale)	-.17	-1.44	.15	-2.23	.34	
	FAD (roles scale)	.23	2.22	.03	.16	2.55	
	FAD (affective responsiveness scale)	-.03	-.28	.78	-1.27	.95	
	FAD (affective involvement scale)	.05	.43	.67	-.85	1.32	
	FAD (behaviour control scale)	-.28	-2.57	.01	-3.06	-.41	
	FAD (general functioning scale)	.42	2.68	.01	.58	3.76	
	Birthweight status	-.04	.79	.43	-.35	.15	
	Birthweight status x problem solving scale	.01	.09	.93	-.94	1.03	
	Birthweight status x communication scale	.08	.64	.52	-.67	1.32	
	Birthweight status x roles scale	-.00	-.02	.99	-.97	.96	
	Birthweight status x affective responsiveness scale	.13	1.05	.30	-.40	1.33	
	Birthweight status x affective involvement scale	-.15	-1.47	.14	-1.43	.21	

Birthweight status x behaviour control scale	.24	2.14	.03	.09	2.14
Birthweight status x general functioning scale	-.28	-1.85	.07	-2.40	.08

*p<.05. **p<.01.

FAD, Family Assessment Device; SDQ, Strengths and Difficulties Questionnaire.

Birthweight Status, ELBW (<1000g), VLBW (<1500g), LBW (<2500g).

Table S-7

Birthweight status and family functioning predicting Peer Problems as measured by the SDQ in preterm infants.

Regression Results	Predictor	Standardised coefficients Beta	*t*	Sig.	95% confidence interval for *B*		R^2
					Lower bound	Upper bound	
Step 1	Gender	.09	1.82	.07	-.01	.35	.01
	Cultural background	.00	.05	.96	-.19	.20	
	Mother's highest level of education	-.03	-.56	.58	.00	.00	
	Father's highest level of education	-.01	-.26	.80	.00	.00	
Step 2	Gender	.07	1.43	.15	-.05	.31	.09**
	Cultural background	-.00	-.08	.93	-.19	.18	
	Mother's highest level of education	-.02	-.38	.71	.00	.00	
	Father's highest level of education	-.03	-.51	.61	.00	.00	
	FAD (problem solving scale)	-.06	-.89	.38	-.52	.20	
	FAD (communication scale)	-.01	-.18	.85	-.41	.34	
	FAD (roles scale)	.24	3.81	.00**	.33	1.02	
	FAD (affective responsiveness scale)	.07	.94	.35	-.16	.46	
	FAD (affective involvement scale)	-.05	-.72	.47	-.42	.19	
	FAD (behaviour control scale)	-.10	-1.65	.10	-.66	.06	
	FAD (general functioning scale)	.18	1.97	.05*	.00	.90	

	Birthweight status	.00	.03	.98	-.11	.12	
Step 3	Gender	.07	1.61	.11	-.03	.33	.12
	Cultural background	-.01	-.11	.91	-.20	.18	
	Mother's highest level of education	-.03	-.52	.61	.00	.00	
	Father's highest level of education	-.03	-.69	.49	.00	.00	
	FAD (problem solving scale)	.11	.88	.38	-.33	.88	
	FAD (communication scale)	-.19	-1.67	.10	-1.11	.09	
	FAD (roles scale)	.32	3.13	.00**	.33	1.46	
	FAD (affective responsiveness scale)	.09	.72	.47	-.33	.71	
	FAD (affective involvement scale)	-.12	-1.12	.26	-.80	.22	
	FAD (behaviour control scale)	-.27	-2.56	.01*	-1.43	-.19	
	FAD (general functioning scale)	.33	2.13	.03*	.06	1.56	
	Birthweight status	-.02	-.34	.73	-.14	.10	
	Birthweight status x problem solving scale	-.19	-1.67	.10	-.85	.07	
	Birthweight status x communication scale	.25	2.12	.04*	.04	.97	
	Birthweight status x roles scale	-.11	-1.05	.29	-.69	.21	
	Birthweight status x affective responsiveness scale	-.04	-.38	.71	-.48	.33	
	Birthweight status x affective involvement scale	.07	.70	.49	-.25	.52	

Birthweight status x behaviour control scale	.22	1.97	.05*	.00	.96
Birthweight status x general functioning scale	-.18	-1.22	.22	-.94	.22

**p*<.05. ***p*<.01.

FAD, Family Assessment Device; SDQ, Strengths and Difficulties Questionnaire.

Birthweight Status, ELBW (<1000g), VLBW (<1500g), LBW (<2500g).

Table S-8

Birthweight status and family functioning predicting Prosocial Behaviour as measured by the SDQ in preterm infants.

Regression Results	Predictor	Standardised coefficients Beta	*t*	Sig.	95% confidence interval for *B*		R^2
					Lower bound	Upper bound	
Step 1	Gender	-.15	-3.12	.00**	-.47	-.11	.03*
	Cultural background	.05	1.16	.25	-.08	.30	
	Mother's highest level of education	.02	.40	.69	.00	.00	
	Father's highest level of education	.05	.94	.35	.00	.00	
Step 2	Gender	-.12	-2.81	.01*	-.41	-.07	.18**
	Cultural background	.07	1.58	.12	-.04	.32	
	Mother's highest level of education	.02	.36	.72	.00	.00	
	Father's highest level of education	.05	1.04	.30	.00	.00	
	FAD (problem solving scale)	-.06	-.83	.41	-.48	.20	
	FAD (communication scale)	.11	1.57	.12	-.07	.64	
	FAD (roles scale)	-.18	-2.99	.00**	-.83	-.17	
	FAD (affective responsiveness scale)	-.14	-2.11	.04*	-.61	-.02	
	FAD (affective involvement scale)	-.00	-.05	.96	-.30	.28	
	FAD (behaviour control scale)	.05	.88	.38	-.19	.49	
	FAD (general functioning scale)	-.21	-2.42	.02*	-.95	-.10	

	Birthweight status	.00	.01	.00**	-.11	.11	
Step 3	Gender	-.13	-2.95	.00**	-.42	-.09	.20
	Cultural background	.06	1.47	.14	-.05	.31	
	Mother's highest level of education	.02	.47	.64	.00	.00	
	Father's highest level of education	.06	1.18	.24	.00	.00	
	FAD (problem solving scale)	-.18	-1.50	.13	-1.03	.14	
	FAD (communication scale)	.32	2.88	.00**	.27	1.42	
	FAD (roles scale)	-.19	-1.94	.05*	-1.06	.01	
	FAD (affective responsiveness scale)	-.08	-.68	.50	-.67	.32	
	FAD (affective involvement scale)	-.05	-.47	.64	-.60	.37	
	FAD (behaviour control scale)	.04	.42	.67	-.47	.72	
	FAD (general functioning scale)	-.34	-2.30	.02*	-1.54	-.12	
	Birthweight status	.02	.39	.70	-.09	.13	
	Birthweight status x problem solving scale	.15	1.34	.18	-.14	.74	
	Birthweight status x communication scale	-.28	-2.48	.01*	-1.01	-.12	
	Birthweight status x roles scale	.02	.22	.83	-.38	.48	
	Birthweight status x affective responsiveness scale	-.07	-.60	.55	-.50	.27	
	Birthweight status x affective involvement scale	.07	.67	.50	-.24	.49	

Birthweight status x behaviour control scale	.00	.00	.97	-.45	.47
Birthweight status x general functioning scale	.16	1.11	.27	-24	.87

**p*<.05. ***p*<.01.

FAD, Family Assessment Device; SDQ, Strengths and Difficulties Questionnaire.

Birthweight Status, ELBW (<1000g), VLBW (<1500g), LBW (<2500g).

Table S-9

Birthweight z-scores and family functioning predicting academic and behavioural outcomes as measured by the WRAT-4 and SDQ in preterm infants.

Step 2 regression results	Predictor	Standardised coefficients Beta	*t*	Sig.	95% confidence interval for *B*		R^2
					Lower bound	Upper bound	
Math Computation (WRAT-4)	Gender	-.08	-1.65	.10	-4.67	.40	.09**
	Cultural background	.02	.52	.61	-1.95	3.33	
	Mother's education	.02	.36	.72	-.00	.01	
	Father's education	-.03	-.58	.56	-.00	.00	
	FAD (problem solving scale)	.24	3.26	.00**	3.34	13.50	
	FAD (communication scale)	-.15	-2.07	.04*	-11.01	-.30	
	FAD (roles scale)	-.24	-3.73	.00**	-14.38	-4.45	
	FAD (affective responsiveness scale)	.03	.48	.63	-3.29	5.44	
	FAD (affective involvement scale)	.04	.59	.56	-3.05	5.67	
	FAD (behaviour control scale)	-.06	-.97	.33	-7.58	2.58	
	FAD (general functioning scale)	.00	.01	.99	-6.37	6.43	
	Birthweight z-score	.09	2.05	.04*	.05	2.38	
Spelling (WRAT-4)	Gender	-.14	-3.00	.00**	-7.16	-1.49	.10**

	Cultural background	.03	.65	.52	-1.97	3.89	
	Mother's education	-.00	-.08	.93	-.01	.01	
	Father's education	-.09	-1.79	.08	-.00	.00	
	FAD (problem solving scale)	.25	3.50	.00**	4.42	15.72	
	FAD (communication scale)	-.15	-1.98	.05*	-11.99	-.04	
	FAD (roles scale)	-.18	-2.88	.00**	-13.66	-2.59	
	FAD (affective responsiveness scale)	.04	.59	.55	-3.41	6.34	
	FAD (affective involvement scale)	-.00	-.05	.96	-4.97	4.74	
	FAD (behaviour control scale)	-.09	-1.38	.17	-9.73	1.72	
	FAD (general functioning scale)	.04	.44	.66	-5.56	8.72	
	Birthweight z-score	.11	2.32	.02*	.24	2.83	
Word Reading (WRAT-4)	Gender	-.11	-2.37	.02*	-6.31	-.59	.09**
	Cultural background	.02	.34	.73	-2.46	3.49	
	Mother's education	-.01	-.09	.93	-.01	.01	
	Father's education	-.06	-1.23	.22	-.00	.00	
	FAD (problem solving scale)	.21	2.93	.00**	2.81	14.25	
	FAD (communication scale)	-.07	-.96	.34	-8.99	3.09	
	FAD (roles scale)	-.20	-3.13	.00**	-14.50	-3.31	

	FAD (affective responsiveness scale)	.07	1.03	.31	-2.35	7.49	
	FAD (affective involvement scale)	.02	.33	.74	-4.08	5.73	
	FAD (behaviour control scale)	-.19	-3.00	.00**	-14.53	-3.04	
	FAD (general functioning scale)	.06	.67	.50	-4.76	9.70	
	Birthweight z-score	.10	2.08	.04*	.07	2.70	
Peer Problems (SDQ)	Gender	.06	1.23	.22	-.12	.52	.10**
	Cultural background	-.01	-.18	.86	-.36	.30	
	Mother education	-.01	-.11	.91	-.00	.00	
	Father education	-.03	-.50	.55	.00	.00	
	FAD (problem solving scale)	-.06	-.82	.42	-.91	.37	
	FAD (communication scale)	-.01	-.07	.95	-.69	.65	
	FAD (roles scale)	.25	4.01	.00**	.65	1.89	
	FAD (affective responsiveness scale)	.07	1.03	.30	-.26	.84	
	FAD (affective involvement scale)	-.06	-.91	.37	-.80	.29	
	FAD (behaviour control scale)	-.10	-1.64	.10	-1.17	.11	
	FAD (general functioning scale)	.17	1.82	.07	-.06	1.56	

	Birthweight z-score	-.09	-2.03	.04*	-.30	-.01	
Prosocial Behaviour (SDQ)	Gender	-.11	-2.57	.01*	-.74	-.10	.18**
	Cultural background	.07	1.71	.09	-.04	.63	
	Mother education	.01	.12	.91	-.00	.00	
	Father education	.06	1.19	.23	.00	.00	
	FAD (problem solving scale)	-.05	-.75	.46	-.89	.40	
	FAD (communication scale)	.09	1.28	.20	-.23	1.12	
	FAD (roles scale)	-.18	-3.10	.00**	-1.62	-.36	
	FAD (affective responsiveness scale)	-.14	-2.15	.03*	-1.16	-.05	
	FAD (affective involvement scale)	.02	.26	.80	-.48	.62	
	FAD (behaviour control scale)	.06	.95	.34	-.33	.95	
	FAD (general functioning scale)	-.21	-2.38	.02*	-1.80	-.17	
	Birthweight z-score	-.00	-.05	.97	-.15	.14	

*p<.05. **p<.01.

FAD, Family Assessment Device; SDQ, Strengths and Difficulties Questionnaire; WRAT-4, Wide Range Achievement Test, Fourth Edition.

Birthweight Status, ELBW (<1000g), VLBW (<1500g), LBW (<2500g).

Note: Regression results which included a significant interaction effect in Step 3 of the analysis are presented in individual tables (see Tables S-10 – S-13).

Table S-10

Birthweight z-scores and family functioning predicting ADHD Symptoms as measured by the Conner's-3 in preterm infants.

Regression Results	Predictor	Standardised coefficients Beta	*t*	Sig.	95% confidence interval for *B*		R^2
					Lower bound	Upper bound	
Step 1	Gender	.12	2.63	.01*	1.15	8.00	.02*
	Cultural background	-.05	-1.00	.32	-5.32	1.73	
	Mother's education	.04	.87	.38	-.00	.01	
	Father's education	.04	.72	.47	-.00	.00	
Step 2	Gender	.10	2.28	.02*	.53	7.20	.09**
	Cultural background	-.05	-1.12	.26	-5.46	1.49	
	Mother's education	.05	1.06	.29	-.00	.01	
	Father's education	.03	.52	.60	-.00	.00	
	FAD (problem solving scale)	-.08	-1.11	.27	-10.48	2.93	
	FAD (communication scale)	.02	.24	.81	-6.16	7.87	
	FAD (roles scale)	.20	3.36	.00**	4.29	17.31	
	FAD (affective responsiveness scale)	.03	.38	.70	-4.66	6.91	
	FAD (affective involvement scale)	-.02	-.24	.81	-6.41	5.01	
	FAD (behaviour control scale)	-.13	-2.08	.04*	-13.80	-.39	
	FAD (general functioning scale)	.18	1.90	.06	-.29	16.66	

	Birthweight z-score	.00	.07	.97	-1.47	1.57	
Step 3	Gender	.11	2.30	.02*	.57	7.25	.11
	Cultural background	-.06	-1.20	.23	-5.62	1.36	
	Mother's education	.05	1.08	.28	-.00	.01	
	Father's education	.02	.45	.66	-.00	.00	
	FAD (problem solving scale)	-.05	-.56	.58	-9.64	5.41	
	FAD (communication scale)	.05	.59	.55	-5.32	9.92	
	FAD (roles scale)	.18	2.64	.01*	2.41	16.35	
	FAD (affective responsiveness scale)	.04	.56	.58	-4.53	8.12	
	FAD (affective involvement scale)	-.00	-.03	.98	-6.27	6.08	
	FAD (behaviour control scale)	-.08	-1.13	.26	-11.63	3.13	
	FAD (general functioning scale)	.09	.88	.38	-5.07	13.35	
	Birthweight z-score	-.40	-1.41	.16	-16.25	2.69	
	Birthweight z-score x problem solving scale	.38	1.15	.25	-2.55	9.76	
	Birthweight z-score x communication scale	.39	1.15	.25	-2.48	9.47	
	Birthweight z-score x roles scale	-.36	-1.05	.30	-8.52	2.60	
	Birthweight z-score x affective responsiveness scale	.26	.93	.35	-2.82	7.89	
	Birthweight z-score x affective involvement scale	.05	.16	.88	-5.10	5.98	
	Birthweight z-score x behaviour control scale	.58	1.94	.05	-1.0	12.88	
	Birthweight z-score x general functioning scale	-.90	-2.33	.02*	-17.28	-1.47	

*$p<.05$. **$p<.01$.

FAD, Family Assessment Device.

Birthweight Status, ELBW (<1000g), VLBW (<1500g), LBW (<2500g).

Table S-11

Birthweight z-scores and family functioning predicting Conduct Problems as measured by the SDQ in preterm infants.

Regression Results	Predictor	Standardised coefficients Beta	*t*	Sig.	95% confidence interval for *B* Lower bound	95% confidence interval for *B* Upper bound	R^2
Step 1	Gender	.11	2.41	.02*	.08	.74	.02
	Cultural background	-.04	-.76	.45	-.48	.21	
	Mother's education	-.02	-.33	.74	-.00	.00	
	Father's education	.03	.63	.53	.00	.00	
Step 2	Gender	.09	1.94	.05*	-.00	.63	.14**
	Cultural background	-.04	-.95	.34	-.49	.17	
	Mother's education	-.01	-.19	.85	-.00	.00	
	Father's education	.03	.58	.56	.00	.00	
	FAD (problem solving scale)	-.11	-1.62	.11	-1.16	.11	
	FAD (communication scale)	-.03	-.39	.70	-.80	.54	
	FAD (roles scale)	.22	3.62	.00**	.52	1.76	
	FAD (affective responsiveness scale)	-.02	-.34	.74	-.64	.45	
	FAD (affective involvement scale)	.06	.93	.35	-.29	.80	
	FAD (behaviour control scale)	-.16	-2.64	.01*	-1.49	-.22	
	FAD (general functioning scale)	.33	3.67	.00**	.70	2.30	

	Birthweight z-score	-.02	-.51	.61	-.18	.11	
Step 3	Gender	.09	1.97	.05*	.00	.64	.15
	Cultural background	-.05	-1.15	.25*	-.53	.14	
	Mother's education	-.01	-.17	.87	-.00	.00	
	Father's education	.02	.45	.65	.00	.00	
	FAD (problem solving scale)	-.08	-.98	.33	-1.08	.36	
	FAD (communication scale)	.01	.07	.94	-.70	.75	
	FAD (roles scale)	.19	2.96	.00**	.34	1.67	
	FAD (affective responsiveness scale)	-.03	-.40	.69	-.72	.48	
	FAD (affective involvement scale)	.06	.93	.35	-.31	.87	
	FAD (behaviour control scale)	-.12	-1.86	.06	-1.36	.04	
	FAD (general functioning scale)	.26	2.59	.01*	.28	2.03	
	Birthweight z-score	-.18	-.65	.51	-1.19	.60	
	Birthweight z-score x problem solving scale	.43	1.35	.18	-.18	.99	
	Birthweight z-score x communication scale	.50	1.52	.13	-.13	1.01	
	Birthweight z-score x roles scale	-.19	-.57	.57	-.68	.38	
	Birthweight z-score x affective responsiveness scale	-.05	-.18	.86	-.55	.46	
	Birthweight z-score x affective involvement scale	-.02	-.08	.94	-.55	.50	
	Birthweight z-score x behaviour control scale	.27	.94	.35	-.32	.91	
	Birthweight z-score x general functioning scale	-.79	-2.15	.03*	-1.57	-.07	

*$p<.05$. **$p<.01$.

FAD, Family Assessment Device; SDQ, Strengths and Difficulties Questionnaire.

Birthweight Status, ELBW (<1000g), VLBW (<1500g), LBW (<2500g).

Table S-12

Birthweight z-scores and family functioning predicting Emotional Symptoms as measured by the SDQ in preterm infants.

Regression Results	Predictor	Standardised coefficients Beta	*t*	Sig.	95% confidence interval for *B*		R^2
					Lower bound	Upper bound	
Step 1	Gender	-.06	-1.25	.21	-.63	.14	.01
	Cultural background	-.03	-.54	.59	-.51	.29	
	Mother's education	-.08	-1.58	.11	-.00	.00	
	Father's education	.08	1.57	.12	.00	.00	
Step 2	Gender	-.07	-1.60	.11	-.67	.07	.07**
	Cultural background	-.02	-.48	.63	-.49	.30	
	Mother's education	-.07	-1.48	.14	-.00	.00	
	Father's education	.07	1.32	.19	.00	.00	
	FAD (problem solving scale)	-.04	-.59	.56	-.98	.54	
	FAD (communication scale)	-.10	-1.41	.16	-1.36	.23	
	FAD (roles scale)	.22	3.42	.00**	.55	2.03	
	FAD (affective responsiveness scale)	.07	.96	.34	-.34	.98	
	FAD (affective involvement scale)	-.07	-1.14	.26	-1.02	.27	
	FAD (behaviour control scale)	-.10	-1.54	.12	-1.35	.16	
	FAD (general functioning scale)	.21	2.19	.03*	.11	2.03	

	Birthweight z-score						
Step 3	Gender	-.07	-1.54	.13	-.67	.08	.10
	Cultural background	-.03	-.62	.54	-.52	.27	
	Mother's education	-.07	-1.43	.15	-.00	.00	
	Father's education	.05	1.04	.30	.00	.00	
	FAD (problem solving scale)	.04	.45	.65	-.66	1.05	
	FAD (communication scale)	-.14	-1.71	.09	-1.61	.11	
	FAD (roles scale)	.21	3.12	.00**	.47	2.04	
	FAD (affective responsiveness scale)	.05	.60	.55	-.40	.93	
	FAD (affective involvement scale)	-.08	-1.22	.23	-1.13	.27	
	FAD (behaviour control scale)	-.02	-.22	.83	-.92	.74	
	FAD (general functioning scale)	.12	1.15	.25	-.43	1.66	
	Birthweight z-score	-.16	-.56	.58	-1.37	.76	
	Birthweight z-score x problem solving scale	.70	2.13	.03*	.06	1.45	
	Birthweight z-score x communication scale	-.23	-.68	.50	-.91	.44	
	Birthweight z-score x roles scale	.04	.12	.90	-.59	.67	
	Birthweight z-score x affective responsiveness scale	-.16	-.57	.57	-.78	.43	
	Birthweight z-score x affective involvement scale	-.11	-.35	.73	-.73	.51	
	Birthweight z-score x behaviour control scale	.77	2.55	.01*	.22	1.68	
	Birthweight z-score x general functioning scale	-.83	-2.20	.03*	-1.88	-.10	

p<.05. ***p*<.01.

FAD, Family Assessment Device; SDQ, Strengths and Difficulties Questionnaire.

Birthweight Status, ELBW (<1000g), VLBW (<1500g), LBW (<2500g).

Table S-13

Birthweight z-scores and family functioning predicting Hyperactivity as measure by the SDQ in preterm infants.

Regression Results	Predictor	Standardised coefficients Beta	*t*	Sig.	95% confidence interval for *B*		R^2
					Lower bound	Upper bound	
Step 1	Gender	.23	4.95	.00**	.76	1.76	.06**
	Cultural background	-.06	-1.34	.18	-.87	.17	
	Mother's education	.06	1.31	.19	.00	.00	
	Father's education	.01	.16	.88	.00	.00	
Step 2	Gender	.21	4.68	.00**	.67	1.65	.13**
	Cultural background	-.07	-1.56	.12	-.91	.11	
	Mother's education	.07	1.43	.15	.00	.00	
	Father's education	.01	.16	.88	.00	.00	
	FAD (problem solving scale)	-.02	-.27	.79	-1.11	.84	
	FAD (communication scale)	.04	.52	.61	-.76	1.29	
	FAD (roles scale)	.19	3.13	.00**	.57	2.47	
	FAD (affective responsiveness scale)	.00	.00	1.00	-.84	.85	
	FAD (affective involvement scale)	.01	.09	.93	-.79	.87	
	FAD (behaviour control scale)	-.08	-1.31	.19	-1.62	.33	
	FAD (general functioning scale)	.13	1.46	.14	-.32	2.15	

	Birthweight z-score	-.04	-.91	.36	-.33	.12	
Step 3	Gender	.21	4.70	.00**	.68	1.65	.15
	Cultural background	-.08	-1.74	.08	-.96	.06	
	Mother's education	.07	1.44	.15	.00	.00	
	Father's education	.01	.12	.91	.00	.00	
	FAD (problem solving scale)	.02	.30	.77	-.93	1.27	
	FAD (communication scale)	.08	1.00	.32	-.55	1.67	
	FAD (roles scale)	.15	2.31	.02*	.18	2.21	
	FAD (affective responsiveness scale)	.00	.01	.99	-.92	.93	
	FAD (affective involvement scale)	.03	.43	.67	-.71	1.10	
	FAD (behaviour control scale)	-.04	-.57	.57	-1.38	.76	
	FAD (general functioning scale)	.05	.50	.62	-1.00	1.69	
	Birthweight z-score	-.37	-1.34	.18	-2.31	.44	
	Birthweight z-score x problem solving scale	.44	1.38	.17	-.27	1.53	
	Birthweight z-score x communication scale	.53	1.62	.11	-.15	1.59	
	Birthweight z-score x roles scale	-.42	-1.28	.20	-1.34	.29	
	Birthweight z-score x affective responsiveness scale	.06	.23	.82	-.69	.87	
	Birthweight z-score x affective involvement scale	.16	.54	.59	-.58	1.03	
	Birthweight z-score x behaviour control scale	.40	1.36	.18	-.29	1.59	

Birthweight z-score x general functioning scale	-.83	-2.26	.02*	-2.47	-.17

*p<.05. **p<.01.

FAD, Family Assessment Device; SDQ, Strengths and Difficulties Questionnaire.

Birthweight Status, ELBW (<1000g), VLBW (<1500g), LBW (<2500g).

Information for Authors

INFANT BEHAVIOR AND DEVELOPMENT

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AUTHOR INFORMATION PACK

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