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Father-child interactions at 3-months and 2 years: contributions to children's cognitive development at 2 years

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ABSTRACT

The quality of father-child interactions has become a focus of increasing research in the field of child development. We examined the potential contribution of father-child interactions at 3-months and 24-months to children's cognitive development at 24-months. Observational measures of father-child-interactions at 3-months and at 24-months were used to assess the quality of fathers' parenting (n=192). At 24 months, the Mental Developmental Index (MDI) of the Bayley's Scales of Infant Development measured cognitive functioning. The association between interactions and cognitive development was examined using multiple linear regression analyses, adjusting for paternal age, education and depression, infant age, and maternal sensitivity. Children whose fathers displayed more withdrawn and depressive behaviours in father-infant interactions at 3-months, scored lower on the MDI at 24 months. At 24-months, children whose fathers were more engaged and sensitive, and those whose fathers were less controlling in their interactions, scored higher on the MDI. These findings were independent of the effects of maternal sensitivity. Results indicate that father-child interactions, even from a very young age (i.e. 3-months) may influence children's cognitive development. They highlight the potential significance of interventions to promote positive parenting by fathers, and policies that encourage fathers to spend more time with their young children.

Key words: Father-child interactions, cognitive development, early parenting, child development, father-infant interactions.

INTRODUCTION

Favourable environmental experiences, especially those embedded within early caregiving relationships, have a positive impact on a child's cognitive development (Bernier, Carlson, & Whipple, 2010). However, while there is compelling support for this association in mothers, less is known about the association between father-infant interactions and children's cognitive development. There is evidence of positive benefits of fathers' presence in their children's homes, fathers sensitive parenting (Bornstein, Hahn, & Haynes, 2004; Sarkadi, Kristiansson, Oberklaid, & Bremberg, 2008) and their increased involvement in childcare on other child outcomes such as emotional and behavioural development (Lamb, 2010; Pleck & Masciadrelli, 2004). However, the evidence regarding the important domain of cognitive development is sparse – existing evidence mainly includes older children and disadvantaged samples, and to our knowledge no study has utilized observational measures of very early father-infant interactions.

A substantial body of evidence suggests that fathers are critical for child well-being. For example, while there are positive benefits of father involvement on a range of child outcomes throughout development (Panter-Brick et al., 2014); available research also indicates the numerous risks associated with father absence (for e.g. Amato (1994). Furthermore, although mothers continue to contribute the majority of their time to children, paternal involvement in care-giving has increased, especially in middle-socio-economic families (Paquette & Bigras, 2010; Yeung, Sandberg, Davis-Kean, & Hofferth, 2001). Consequently studies have not only focussed on the quantity of time fathers spend with their children, but also (although to a lesser extent) on the quality of their interactions. These observational studies suggest that even though parents display similarities in their interaction styles, father-child interactions have a distinct quality - more stimulating, vigorous and arousing, in comparison to mother-child interactions (Dixon et al., 1981; MacDonald &

Parke, 1986). Their interactive episodes promote their child's risk taking and exploration tendencies (Kromelow, Harding, & Touris, 1990), which in turn may facilitate the development of children's cognitive skills. Thus, early social experiences with fathers and mothers may differentially impact children's development (Cabrera, Shannon, & Tamis-LeMonda, 2007; Hunter, McCarthy, MacTurk, & Vietz, 1987). Therefore, it may be equally important to consider how fathers impact early child development, in addition to studying the influence of mothers.

For instance, a positive association has been reported between paternal involvement in care-taking tasks (as early as the first month of infancy) and Bayley Mental Development Index (MDI) scores one year later (Nugent, 1991), and in another study, increased father engagement with preterm children (measured via maternal interview) was associated with improved cognitive outcome on the Stanford-Binet Intelligence scale at 36 months (Yogman, Kindlon, & Earls, 1995). More recent evidence suggests that paternal positive affect and cognitive stimulation in play and care-giving (obtained via paternal self-report) with children aged 9 months, benefits their concurrent cognitive skills (Bronte-Tinkew, Carrano, Horowitz, & Kinukawa, 2008). Yet, other studies utilizing diverse samples and methodologies have failed to find an association (Cabrera, Shannon, West, & Brooks-Gunn, 2006; Hunter, et al., 1987; Magill-Evans & Harrison, 2001). For instance, there was no association between self-report measures of paternal involvement at 9 months and cognitive scores at the same time point in Latino infants (Cabrera, et al., 2006).

Research on father-child interactions in toddlerhood has provided more consistent results than that in infancy. For instance, supportive paternal behaviours at two years were associated with children's intellectual functioning scores at 2 and 3 years of age (Cabrera, Shannon, et al., 2007). Another study has shown an association between paternal supportiveness at 14 months and increased cognitive ability at 24 and 36 months in low-

income children facing developmental risks (Jeon, Peterson, & DeCoster, 2013). Overall, studies have demonstrated that supportive, sensitive and stimulating paternal behaviours during toddlerhood are positively associated with children's cognitive outcomes after controlling for various demographic and socio-economic factors (Cabrera, Fitzgerald, Bradley, & Roggman, 2007; Cabrera, Shannon, et al., 2007; Shannon, Tamis-LeMonda, London, & Cabrera, 2002; Tamis-LeMonda, Shannon, Cabrera, & Lamb, 2004).

So far, the vast majority of studies that have examined how father's might influence their children's cognitive development have largely focussed on disadvantage, including father-absent families (Marsiglio, Amato, Day, & Lamb, 2000), low-income families (Cook, Roggman, & Boyce, 2011; Jeon, et al., 2013; Ryan, Martin, & Brooks-Gunn, 2006), preterm babies (Magill-Evans & Harrison, 2001; Yogman, et al., 1995) and children with rare medical conditions (McGrath, Wypij, Rappaprt, Newburger, & Bellinger, 2004). Consequently, these results may not be applicable to lower-risk samples from middle and higher socio-economic functioning. Not only does the diversity of samples and methodologies used in previous research make it difficult to draw firm conclusions, but available studies are subject to a number of methodological limitations. For example, maternal reports of the parenting strategies of children's fathers are often used, and these may be prone to bias (Mikelson, 2008; Yogman, et al., 1995). Even when paternal reports of early involvement are used (Bronte-Tinkew, et al., 2008), these can lack the independence and detail provided by observational methods. Moreover, the majority of studies have measured fathers' parenting and child development concurrently (Bronte-Tinkew, et al., 2008; Yarrow et al., 1984). Critically, few prospective studies exist that examine the father's early contribution to later cognitive abilities (Nugent, 1991). Although prospective studies fall short of providing evidence of a causal effect from paternal parenting and later child developmental outcomes, they do provide stronger evidence than cross-sectional studies.

Therefore, the current study aims to examine the association between father-infant interactions (at 3 and 24 months) and children's cognitive skills at 24 months. In doing so we addresses several gaps in the existing literature: First, to examine the association between father-child interactions, (in the 3 month postnatal period as well as at 24 months), and child cognitive outcomes (measured at 24 months); thereby, including interactions at a younger age than most studies. The early focus of this study is critical, due to the infant's rapid development and high susceptibility to the quality of interactions with parents at this age. Second, this study utilizes observational measures of interactions, allowing for independent examination of a range of early parenting dimensions in different interaction settings. Moreover, at 24 months in addition to using a free-play session (i.e. without toys) we also use a joint book session. Although there is evidence from the maternal literature on the implications of a book-sharing context for cognitive development (for example, Blake, Macdonald, Bayrami, Agosta, and Milian (2006)) there is much less literature on fathers. The available studies in fathers have largely focused on low income families (Pancsofar & Vernon-Feagans, 2010) and have included the frequency of book-reading rather than specific paternal behaviours in this interaction context (Duursma, Pan, & Raikes, 2008). Thus, this study aims to understand the cognitive development of children from socio-economically diverse families, in different interactive settings, whereby the quality of father-child interactions are assessed. Third, an independent, blinded assessment of cognition is utilized. Fourth, and as indicated, the vast majority of evidence focuses on families from lower socio-economic contexts. Although understandable, due to the possibility that the family's circumstances impact on their ability to develop positive parent-child relationships (Shannon et al., 2002), there is relatively little evidence of the relationship between father-infant interactions and child cognitive outcomes in families from middle and higher socio-economic

backgrounds. Fifth, we examine the independent effect of father's on child cognitive development, controlling for paternal depression, age, education, maternal sensitivity and infant's age. Father's age is related to involvement with their child (Pleck, 1997), and the experience of adverse parenting is associated with parenthood at an early age (Pogarsky, Thornberry, & Lizotte, 2006). Father's educational qualifications are linked to both the study exposure - poorly educated father's often find it harder to establish positive and sensitive relationships with their children (Cabrera, Shannon, et al., 2007; Gavin et al., 2002; Tamis-LeMonda, et al., 2004) and outcome – well educated parents are particularly sensitive to their infant's development, and are more likely to expose their child to cognitive stimulating experiences (Cabrera, Shannon, et al., 2007; Tamis-LeMonda, et al., 2004). Empirical evidence also suggests that paternal depression is associated with parenting impairment in fathers (for a review see, Wilson and Durbin (2010)), and may also have implications for children's cognitive outcomes (Paulson, Keefe, & Leiferman, 2009). Maternal sensitivity is related in predicted ways to children's cognitive development (for example, (Beckwith & Rodning, 1996; Eshel, Daelmans, Cabral de Mello, & Martines, 2006; Field et al., 1985; Lemelin, Tarabulsky, & Provost, 2006)). Moreover, sensitivity comprises aspects of interaction, (i.e. warm and sensitive support, responsive and contingent parenting providing appropriate levels of stimulation) that have consistently been associated with improved cognitive ability. In addition to these factors we will also control for infant's age at the time of assessment. This is because it is likely that an older child more advanced in their social and cognitive development will influence the play session between father and child (Roopnarine, Krishnakumar, Metindogan, & Evans, 2006).

Finally, we examine whether the influence of father-child interactions on cognitive development is moderated by infant gender. Some findings suggest that fathers influence the development of sons more than daughters (Bronte-Tinkew, et al., 2008; Mott, Kowaleski-

Jones, & Menaghan, 1997). Fathers have been found to be more responsive to boy's affective states (Feldman, 2003), and less sensitive and engaged in play and care-taking activities with their infant daughters compared to sons (Manlove & Vernon-Feagans, 2002; Schoppe-Sullivan et al., 2006). As a result of these varying interaction styles, it is possible that fathers may differentially influence sons and daughters in terms of their subsequent cognitive development. However, caution should be exercised in this regard, as not all studies show these gender effects (Flouri & Buchanan, 2004; Pougner, Serbin, Stack, & Schwartzman, 2011).

We hypothesise that positive patterns of father-infant interactions at 3 months and 24 months will contribute to children's cognitive functioning at 24 months, over and above any effects of maternal sensitivity, infant age, and paternal age, education and psychopathology. Furthermore, we predict that there will be a stronger association between father-child interactions and cognitive functioning for sons than for daughters.

METHOD

Design and sample

Participants were recruited from the maternity wards of two hospitals in the United Kingdom (Ramchandani et al., 2011). Eligibility criteria included: parent's age 18 or over at the time of the child's birth, fluent English, infant's birth weight 2500 grams or more, gestation 37 weeks or more, and no congenital abnormalities. Mothers, fathers, and their infant took part in home assessments when the infant was 3 months and 24 months old. Child outcome data, at the 24 month time-point, was collected between 2008 and 2010. Parents gave informed consent. Ethical approval was granted by the Oxfordshire Research Ethics Committee.

Sample at 3 months and 24 months

At the 3 months assessment 192 fathers and their infants took part in the study. Fathers had a mean age of 35 years ($SD= 5.86$ years; range= 19-55 years), the majority were white (94.6%), and either married or living with a partner (99.5%). Infants had a mean age of 14.5 weeks ($SD= 3.0$, range= 10-41 weeks) at this point, and approximately half of the sample (52.6%) were female. Families were contacted again when their children were 24 months old (mean infant age = 25.15, $SD = 2.29$) - 156 (81%) agreed to participate. There was no difference between those who did and did not complete the 24 month visit, in terms of, paternal age, $t(189) = 1.135$, $p = .258$, education ($\chi^2(3) = 3.09$, $p = 0.377$), and employment status ($\chi^2(3) = 0.75$, $p = 0.862$).

Procedure

At 3 months, father-child interactions were video-recorded at home in a floor-mat setting. Fathers were asked to talk to and play with their infant, for 3 minutes, as they would normally, without the use of any toys. Similar assessments of parent-infant face-to-face interactions have been used in previous studies (Feldman, Greenbaum, & Yirmiya, 1999; Murray, Fiori-Cowley, Hooper, & Cooper, 1996; Sethna, Murray, Netsi, Psychogiou, & Ramchandani, 2015). Of the total sample ($N=192$), data was available for 179 participants. Missing data were due to child distress, refusal to be filmed or technical difficulties. At 24 months, father-child interactions were recorded in two (home based) interactive settings - 2 minutes of 'free-play' without the use of any toys, and a 5 minute 'book-session' with the use of a book. Data were available for 129 fathers in the free-play session and 132 fathers in the book-session. Children were tested at 24 months with the Bayley's Scale of Infant Development (BSID-11, Bayley, 1993). Data were available on 136 children. Complete data on 3-month father-infant interactions and 2-year cognitive development outcome were available for 128 participants. Likewise, at the 24 month time-point, complete data were

available on 117 participants in the free-play session and 119 participants in the book-session. These samples are used in the present analyses (see figure 1).

Measures

Father-infant interactions at 3 months

Interactions were coded using the Global Rating Scales (GRS, Murray, et al., 1996). 13 paternal behaviours were rated on a series of 5-point scales (1-5) - lower scores indicating inadequate interactions. Dimensions of paternal interaction derived as per standard use in previous studies include: (1) Sensitivity (paternal response to the infant's communication cues in a way that is appropriate to the infant's needs and experiences, including attitude and feelings towards the infant - Cronbach's $\alpha = 0.72$), (2) Intrusiveness (over-stimulating vocal and physical activity around the infant, cutting across infant communication - Cronbach's $\alpha = 0.44$), (3) Remoteness (withdrawal and disengagement - Cronbach's $\alpha = 0.90$) and (4) Depressive affect (affective state and level of enjoyment, including, anxious, vocal and physical activity - Cronbach's $\alpha = 0.57$). 20% of interactions were independently coded for inter-rater agreement. Inter-rater intra-class correlations (ICC, Shrout & Fleiss, 1979) ranged from .74 to .88. Discrepancies between raters were discussed, and final ratings were determined in collaboration with members of the Winnicott Research Unit who were involved in the development of the scale.

Father-child interactions at 24 months

Father-child interactions were coded by trained researchers who were not involved in coding the 3-month interactions. A coding scheme (Madden et al., 2015), adapted from the original domains of the GRS scales, but also including a broader range of behaviours displayed by both the child and father (e.g. physicality in their interactions) at this later phase of development, was used. This is because the GRS is only applicable for coding the

interactions of mothers and their children in early infancy. 22 items were coded for parent behaviours and subsequently subject to principle component factor analysis.

3 factors emerged from the free play session which explained 66% of the variance in the data.

(1) 'Sensitivity' had an eigenvalue of 2.96, and explained 32.9% of the variance. This factor was weighted onto by positive expressed emotion, emotional tone and reciprocity and synchronicity - Cronbach's alpha = 0.73.

(2) 'Control' had an eigenvalue of 1.82 and explained 20.2% of the variance. This factor weighted onto by intrusions and negative expressed emotion, conflictual behaviour and low sensitivity - Cronbach's alpha = 0.39

(3) 'Engagement' had an eigenvalue of 1.28 and explained 13.1% of the variance. This factor was explained by the father's ability to follow the child's attention and increased engagement and communication - Cronbach's alpha = 0.59

3 factors emerged from the book session explaining 52% of the variance in the data.

(1) 'Sensitivity' had an eigenvalue of 4.44 and explained 31.7% of the variance. This factor was explained by warmth, reciprocity and synchronicity, positivity in expressed emotion and emotional tone, as well as following the child's attention and elaborating on their speech - Cronbach's alpha = 0.77.

(2) 'Control' had an eigenvalue of 1.62 and explained 1.6% of the variance. This factor was weighted onto by conflictuous behaviour, instrumental touching, strong control, and negative emotion - Cronbach's alpha = 0.39

(3) 'Cognitive stimulation' had an eigenvalue of 1.21 and explained 8.6% of the variance. The factor was weighted onto by educational references and displays of positive affect - Cronbach's alpha = 0.44

There was moderate to good inter-rater agreement on each dimension, with the average weighted kappa ranging from 0.56 to 0.69.

Cognitive development

Children's cognitive functioning was assessed using the Bayley Scales of Infant Development-Second Edition (Bayley, 1993) which provided a standardised Mental Development Index (MDI) score. The indexed scale has a mean of 100 and a standard deviation of 15. The mean MDI score for our sample was 97.50 ($SD = 13.35$).

Study covariates

The Structured Clinical Interview for DSM-IV Axis 1 Disorders (SCID First, Spitzer, Gibbon, & Williams, 2002) was used to diagnose Major Depressive Disorder at 3 months and 24 months. Paternal age (years) and education (no qualifications, GCSE's, A Levels or equivalent, Diploma or equivalent, Degree, Postgraduate) were assessed at 3 months. Maternal sensitivity was assessed during observed mother-infant interactions by blinded raters at both 3-months using the GRS (Murray, et al., 1996), and at 24 months (Madden, et al., 2015). Infant age (months) was determined at both study points.

Statistical Analysis

Statistical analysis was performed using SPSS Version 21.0 (IBM Corp, Armonk, NY), with significance set at $p < 0.05$. First, we examined correlations between paternal interaction dimensions at 3 months and at 24 months. Second, independent simple linear regression analyses were conducted to test the univariate associations between each of the father-infant interaction dimensions at 3 months and MDI scores. Third, where an association was found, we applied the PROCESS macro tool (Hayes, 2013) to estimate and test the adjusted associations and also to examine whether the interaction between each paternal dimension

and gender (paternal interaction dimension x gender) predicted cognitive development. The following covariates were included in the individual models tested: paternal age, education and depression, infant age and maternal sensitivity. PROCESS applies bias corrected bootstrapping intervals to probe the interaction term and make inferences about indirect effects, rather than relying on the normality assumption. The number of bootstrap samples used to determine 95% bias-corrected bootstrap confidence intervals was 10000. PROCESS also produces the conditional effects of the independent variable at the two values of a binary moderator (Gender: male = 0, female = 1). The above steps were repeated to examine concurrent associations between father-child interactions and cognitive development at 24 months.

RESULTS

Associations between paternal interaction dimensions at 3 months and at 24 months (Table 1)

Fathers who were less remote in their interactions at 3 months (higher scores on the GRS) showed increased positive-responsiveness ($r = 0.198$, $p = 0.028$) and engagement ($r = 0.245$, $p = 0.006$) in the free-play context at 24 months, and were also more sensitive in the book session ($r = 0.203$, $p = 0.022$). There was evidence of a weak positive association (at trend level) between paternal remoteness in free play at 3 months and cognitive stimulation in the book session at 24 months ($r = 0.150$, $p = 0.093$) – i.e. fathers who were less remote at 3 months made more educational references with displays of positive affect in the book session at 24 months. Furthermore, fathers who displayed positive affect (higher scores on the GRS) during the 3-month interactions were also likely to be more engaged in the free-play session at 24 months ($r = 0.230$, $p = 0.011$), and more sensitive in the book session ($r = 0.165$, $p = 0.064$) – the latter at trend level only.

3-month father-child interactions and cognitive development

Paternal Sensitivity: There was evidence of a marginally significant association between paternal sensitivity and cognitive development ($\beta = 0.16, p = 0.086$) which was largely unchanged when adjusting for covariates – infants of sensitive fathers had higher MDI scores (see Table 2). Furthermore, there was no evidence of moderation by infant gender on the association between paternal sensitivity and cognitive development - since the interaction term did not reach significance (see Table 2).

Paternal intrusiveness: In contrast, paternal intrusiveness was not associated with child cognitive development ($\beta = 0.017, p = 0.850$) and hence no further analyses were conducted on this dimension.

Paternal remoteness: Paternal remoteness was significantly associated with 24 month MDI scores ($\beta = 0.20, p = 0.035$) – infants of engaged fathers had higher MDI scores at 24 months. While this association remained significant when adjustments were made for covariates, there was no evidence of moderation by infant gender on the association between paternal remoteness and child cognitive skills (see Table 2).

Paternal depressive affect: Similarly, paternal depressive affect was significantly associated with 24 month MDI scores ($\beta = 0.25, p = 0.008$) – infants of fathers whose affective state was positive (higher GRS scores) had higher MDI scores at 24 months. This association remained when adjusting for covariates (see Table 2). Furthermore, while there was a marginally significant association between gender and MDI scores ($B = 4.53, p = 0.056$) implying increased cognitive skills in female infants, the interaction term (infant gender x paternal depressive affect) was not significant (see Table 2). Thus there was no evidence of moderation by infant gender on the association between paternal depressive affect and child cognitive skills.

Concurrent associations between father-infant interactions and cognitive development at 24 months

Free-play session

Increased paternal ‘engagement’ (i.e. high levels of sensitive, attentive and involved play with fathers) and decreased ‘Control’ (i.e. less intrusive and conflictual behaviours) were associated with increased cognitive abilities (i.e. higher MDI scores) at 24 months ($\beta = 0.23$, $p = 0.024$ and $\beta = -0.20$, $p = 0.046$ respectively). Next, when adjusting for covariates the concurrent associations between paternal ‘engagement’ and ‘Control’ during free-play and children’s MDI scores at 24 months were not significant (see Table 3). ‘Sensitivity’ was not associated with MDI scores ($\beta = 0.06$, $p = 0.523$) and hence no further analyses were conducted on this dimension.

Furthermore, there was no evidence of moderation by infant gender on any of the associations examined in the free-play context (Table 3).

Book-session

Paternal ‘sensitivity’ ($\beta = 0.31$, $p = 0.001$), ‘control’ ($\beta = -0.31$, $p = 0.002$) and ‘cognitive stimulation’ ($\beta = .25$, $p = 0.011$) dimensions were associated with MDI scores; implying, that children obtained higher scores on cognitive functioning when their fathers displayed increased levels of warmth, reciprocity, and positivity, and low levels of control and conflictual behaviours. When adjusting for covariates these associations remained (Table 4). However, and similar to the free-play session, there was no evidence of moderation by infant gender on any of the associations examined in the book-session (Table 4).

DISCUSSION

The results of this study indicate that specific dimensions of father-child interactions at both time-points are associated with MDI scores even when adjusting for paternal depression, age and education, maternal sensitivity and infant age. These dimensions include paternal ‘remoteness’ and ‘depressive affect’ at 3 months; ‘engagement’ during free-play at 24 months; and ‘sensitivity’, ‘cognitive stimulation’, and ‘control’ during the book session at 24 months. There was no robust evidence found of differential effects on boys or girls. To our knowledge this is the first longitudinal investigation to study the how father-child interactions as early as 3 months influence children’s cognitive development. Thus, knowing that the association between interactions and cognitive outcome is evident at a very early age highlights the importance of putting preventative measures in place in early infancy to support fathers to better interact with their children.

3-month father-child interactions and cognitive development

Children whose fathers demonstrate increased ‘remoteness’ and ‘depressive affect’ in their interactions obtained lower scores on the MDI. These findings are consistent with previous evidence which has found that highly involved fathers promote a higher level of cognitive competence in their children (Bronte-Tinkew, et al., 2008), and can be explained in a number of ways. It is likely that remote fathers use fewer verbal and non-verbal strategies to communicate with their infants, thereby, reducing the infant’s social learning experience. Moreover, the first year of life is a period characterized by rapid advances in language and other symbolic competencies (Lamb, 1997). More withdrawn fathers may also provide a less stimulating social environment, which may thus impact the child’s cognitive skills. Alternatively the link between paternal remoteness and depressive affect with child MDI scores could be explained by paternal cognitive skills that are inherited by the child. Since a genetic component for cognitive functioning has been described (Jester et al., 2009;

Polderman et al., 2007), we cannot rule out that the association between paternal behaviours and child cognitive skills is a result of the genetic inheritance of cognitive skills from parent to child. In line with this explanation it is also possible that children may model cognitive styles and affective responses of the father, which in turn may influence paternal interactions and subsequent cognitive skills (Kane & Garber, 2004).

Father-child interactions and cognitive development at 24 months

During free-play increased paternal ‘engagement’ (i.e. involved and attentive paternal behaviours) was associated with higher MDI scores. This finding is also consistent with previous research, indicating that highly engaged fathers are more likely to promote positive cognitive outcomes in toddlerhood (Conner, Knight, & Cross, 1997; Easterbrooks & Goldberg, 1984; Lugo-Gill & Tamis-LeMonda, 2008; Tamis-LeMonda, et al., 2004). Fathers who are more engaged and attentive in their interactions promote an environment for sharing social information which supports core cognitive skills. Furthermore, in the free-play session, we did not find an association between paternal ‘sensitivity’ and MDI scores. It is possible that behaviours which constitute this dimension (reciprocity, synchronicity and positive emotion) are less likely to support cognitive skills at 24 months, given that diverse features of parenting differentially predict developmental outcomes (Roopnarine, et al., 2006; Ryan, et al., 2006).

During the book-session, sensitive, calm, and less controlling and anxious behaviour in fathers is associated with higher MDI scores in their children aged 24 months. In line with previous evidence (Cabrera, Fitzgerald, et al., 2007; Cabrera, Shannon, et al., 2007; Shannon, et al., 2002; Tamis-LeMonda, et al., 2004), fathers who support their children to explore and engage with objects and the world around them, allow the child to acquire new information and develop their cognitive skills. On the other hand, controlling and conflictual interactions, which are linked to poor verbal input (Baumwell, Tamis-LeMonda, & Bornstein, 1997; Radin

& Epstein, 1975), may limit the child's experience of shared attention and turn taking, thus restricting learning behaviours in support of cognitive improvement. Our findings from the book session link to evidence which suggests that the provision of rich language experiences and educational references support cognitive and learning skills (Coley, Lewin-Bizan, & Carrano, 2011). This requires further investigation with fathers and may support the need for targeted interventions which not only encourage father-child book reading, but provide information on ways to optimize the effects of book reading on children's cognitive development. One such model, dialogic book-sharing (an interactive form of shared reading), significantly benefits child development (Vally, Murray, Tomlinson, & Cooper, 2015; Whitehurst et al., 1994).

It is also important to keep in mind that data from the concurrent arm of the study were correlational and do not imply a direction of effect from parent to child. Hence, we cannot be certain whether lower MDI scores are a consequence of poorer parenting quality, or whether infants with poor cognitive skills influence their father's interactions. It is also likely that an atypical social trajectory in the child would affect parents' interactive patterns. For example, the infant's biological characteristics likely influence his/her interactive abilities and may also influence paternal behaviour. Therefore, in our research design bidirectional influences cannot be ruled out – i.e. children with higher cognitive skills might elicit a more positive response in their parent, and thus increase paternal sensitivity (Bernier, et al., 2010). More positive paternal interactions may in turn facilitate the child's curiosity and ability to master new skills. In contrast, a poorly regulated child or one who is less able to engage positively may fail to get the same response from his/her parent (Lunkenheimer, Kemp, & Albrecht, 2013). It is also possible that, since infant and father are closely genetically related, the associations observed could be mediated through shared genetic

variants, including an inherited cognitive ability and behavioural style (Tucker-Drob, Briley, & Harden, 2013).

Father-child interactions and cognitive development in girls and boys

There was no robust evidence of a gender interaction at either study time point. This is in line with previous evidence on gender differences in other areas of child development with some evidence to suggest that fathers treat sons and daughters similarly (Belsky, 1984; Lamb, Frodi, Hwang, & Frodi, 1982; Pougner, et al., 2011). However, previous work has also indicated that sons may be more influenced by father involvement (Bronte-Tinkew, et al., 2008).

Strengths and limitations

The findings reported should be interpreted in light of certain limitations. First, although attrition was minimal, fathers in the study were predominantly Caucasian, middle class, and had relatively high levels of education. Accordingly, the generalizability of the findings to other populations may be limited somewhat. Second, although the sample was relatively large, there were a smaller number of male and female infants, and this may have limited our ability to detect gender-related effects. Third, conclusions about the role of early father-infant interactions in children's cognitive development are constrained by the measures included in the study. Although the 2 year coding scheme (Madden, et al., 2015) was derived from an existing measure with proven reliability and validity, the measure has not received extensive psychometric evaluation. Furthermore, the reliance on a brief sequence of father-infant interactions at both study time-points may limit generalizability. However, the inclusion of two different interactive settings at 24 months has brought to light different styles of paternal interactions that are linked with children's cognitive functioning.

Despite these caveats, this is the first study to examine the longitudinal association between observed father-infant interactions as early as 3-months of age and later cognitive development in children. Observational measures of father-child interactions prevented bias and measurement imprecision which would have otherwise been present in self-report measures. Video observations were coded by trained researchers who were blinded to family characteristics; and those who coded the 2-year interactions were blind to the 3-month interactions, and vice versa. The MDI was also conducted by a trained researcher, allowing an accurate administration of this assessment.

In summary, the association between paternal interactions and cognitive outcome is evident at a very early age, therefore, putting preventative measures in place in early infancy to support fathers to better interact with their children is of immense importance. Moreover, fathers' parenting is likely to mirror the parenting that they themselves receive (Madden, et al., 2015), so interventions at an individual and policy level offer the potential to be of benefit across generations (Pougner, et al., 2011).

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Table 1. Interrelations between measures of father-child interactions at 3 months and 24 months

Interaction dimensions	1	2	3	4	5	6	7	8	9	10
3months										
1. Sensitivity	1									
2. Intrusiveness	.438**	1								
3. Remoteness	.153*	-	1							
		.233**								
4. Depressive affect	.279**	-.100	.572**	1						
24 months (free play)										
5. Sensitivity	-.023	-.047	.198*	.082	1					
6. Control	-.077	-.029	.070	-.065	-.150	1				
7. Engagement	-.041	.017	.245**	.230*	.270**	-.077	1			
24 months (book session)										
8. Sensitivity	.146	.001	.203*	.165 (0.064)	.239**	-.159	.173	1		
9. Control	-.055	-.088	.119	.083	.042	.137	-.053	-.148	1	
10. Cognitive stimulation	-.031	.038	.150 (0.093)	.024	.142	.039	.111	.285**	-.015	1

** Correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

Table 2. Independent models examining 3 month father-child interaction dimensions and cognitive development at 24 months (n=128)

3-month interaction dimensions	Coef (B)	p	(95% CI)	Model summary
Sensitivity (<i>M</i> = 3.71, <i>SD</i> = 0.04)				
Paternal sensitivity	3.87	0.074	-0.38, 8.12	<i>R</i> ² = 0.130, <i>F</i> = 2.02, <i>p</i> = 0.051
Infant gender	4.97	0.039	0.26, 9.69	
Infant gender x paternal sensitivity	2.94	0.498	-5.63, 11.51	
Age (Father)	-0.02	0.940	-0.41, 0.38	
Education (Father)	1.27	0.080	-0.15, 2.68	
Depression (Father)	-1.98	0.303	-5.76, 1.81	
Age (Infant)	-0.02	0.972	-1.08, 1.04	
Sensitivity (Mother)	3.81	0.050	-0.00, 7.63	
Remoteness (<i>M</i> = 3.59, <i>SD</i> = 0.06)				
Paternal remoteness	3.28	0.018	0.57, 5.98	<i>R</i> ² = 0.15, <i>F</i> = 2.32, <i>p</i> = 0.025
Infant gender	4.51	0.058	-0.15, 9.17	
Infant gender x paternal remoteness	0.13	0.963	-5.17, 5.42	
Age (Father)	0.01	0.960	-0.377, 0.40	
Education (Father)	1.37	0.056	-0.04, 2.77	
Depression (Father)	-2.09	0.271	-5.83, 1.65	
Age (Infant)	0.07	0.890	-0.98, 1.13	
Sensitivity (Mother)	3.89	0.043	0.13, 7.67	
Depressive Affect (<i>M</i> = 4.02, <i>SD</i> = 0.04)				
Paternal depressive affect	5.68	0.012	1.27, 10.08	<i>R</i> ² = 0.15, <i>F</i> = 2.43, <i>p</i> = 0.019
Infant gender	4.53	0.056	-0.12, 9.17	
Infant gender x paternal depressive affect	1.54	0.725	-7.11, 10.19	
Age (Father)	0.02	0.939	-0.37, 0.40	
Education (Father)	1.36	0.056	-0.04, 2.76	
Depression (Father)	-2.18	0.250	-5.91, 1.55	
Age (Infant)	0.05	0.924	-0.99, 1.10	
Sensitivity (Mother)	2.76	0.151	-1.02, 6.54	

GRS interaction dimensions scored on a scale from 1-5, low scores indicate poor interactions. Gender: 0= male, 1 = female; M = Mean, SD = Standard Deviation.

Table 3. Independent models examining concurrent associations between father-child interaction dimensions during free-play at 24 months and cognitive development

24-month dimensions (Free-play session)	<i>Coef (B)</i>	<i>p</i>	<i>(95% CI)</i>	<i>Model summary</i>
Control				
Paternal control	-2.76	0.132	-6.38, 0.85	$R^2 = 0.084, F = 1.01, p = 0.433$
Infant gender	1.53	0.596	-4.18, 7.24	
Infant gender x paternal control	-1.29	0.752	-9.34, 6.77	
Age (Father)	-0.03	0.906	-0.54, 0.48	
Education (Father)	1.42	0.115	-0.35, 3.18	
Depression (Father)	-1.71	0.450	-6.19, 2.77	
Age (Infant)	0.01	0.999	-1.16, 1.16	
Sensitivity (Mother)	1.49	0.304	-1.37, 4.35	
Engagement				
Paternal engagement	2.24	0.086	-0.10, 5.58	$R^2 = 0.10, F = 1.24, p = 0.287$
Infant gender	1.34	0.642	-4.39, 7.07	
Infant gender x paternal engagement	3.34	0.397	-4.46, 11.13	
Age (Father)	-0.03	0.913	-0.53, 0.48	
Education (Father)	1.41	0.112	-0.34, 3.17	
Depression (Father)	-1.59	0.48	-6.02, 2.84	
Age (Infant)	-0.07	0.904	-1.22, 1.08	
Sensitivity (Mother)	1.62	0.26	-1.25, 4.50	

Gender: 0= male, 1 = female; *M*= Mean, *SD*= Standard Deviation.

Table 4. Independent models examining concurrent associations between father-child interaction dimensions during the book session at 24 months and cognitive development

24-month dimensions (Book session)	Coef (B)	p	(95% CI)	Model summary
Sensitivity				
Paternal sensitivity	3.98	0.003	1.42, 6.53	$R^2 = 0.18, F = 2.48, p = 0.018$
Infant gender	1.55	0.583	-4.05, 7.15	
Infant gender x paternal sensitivity	-1.09	0.684	-6.40, 4.22	
Age (Father)	-0.12	0.62	-0.58, 0.35	
Education (Father)	1.17	0.157	-0.46, 2.80	
Depression (Father)	-2.04	0.288	-5.82, 1.75	
Age (Infant)	0.075	0.894	-1.04, 1.19	
Sensitivity (Mother)	3.41	0.036	0.23, 6.60	
Control				
Paternal control	-4.25	0.010	-7.47, -1.03	$R^2 = 0.17, F = 2.34, p = 0.025$
Infant gender	-0.26	0.926	-5.85, 5.32	
Infant gender x paternal control	-2.77	0.452	-10.06, 4.52	
Age (Father)	-0.07	0.751	-0.54, 0.39	
Education (Father)	1.41	0.091	-0.23, 3.05	
Depression (Father)	-1.97	0.306	-5.76, 1.83	
Age (Infant)	-0.04	0.947	-1.16, 1.09	
Sensitivity (Mother)	3.12	0.059	-0.13, 6.36	
Cognitive Stimulation				
Paternal cognitive stimulation	2.57	0.037	1.72, 6.87	$R^2 = 0.17, F = 2.31, p = 0.026$
Infant gender	0.28	0.92	-5.34, 5.89	
Infant gender x paternal cognitive stimulation	8.69	0.105	-1.86, 19.24	
Age (Father)	-0.01	0.957	-0.48, 0.45	
Education (Father)	1.45	0.081	-0.18, 3.08	
Depression (Father)	-1.84	0.338	-5.64, 1.95	
Age (Infant)	-0.01	0.980	-1.13, 1.10	
Sensitivity (Mother)	2.99	0.069	-0.24, 6.23	

Gender: 0= male, 1 = female; M= Mean, SD= Standard Deviation.

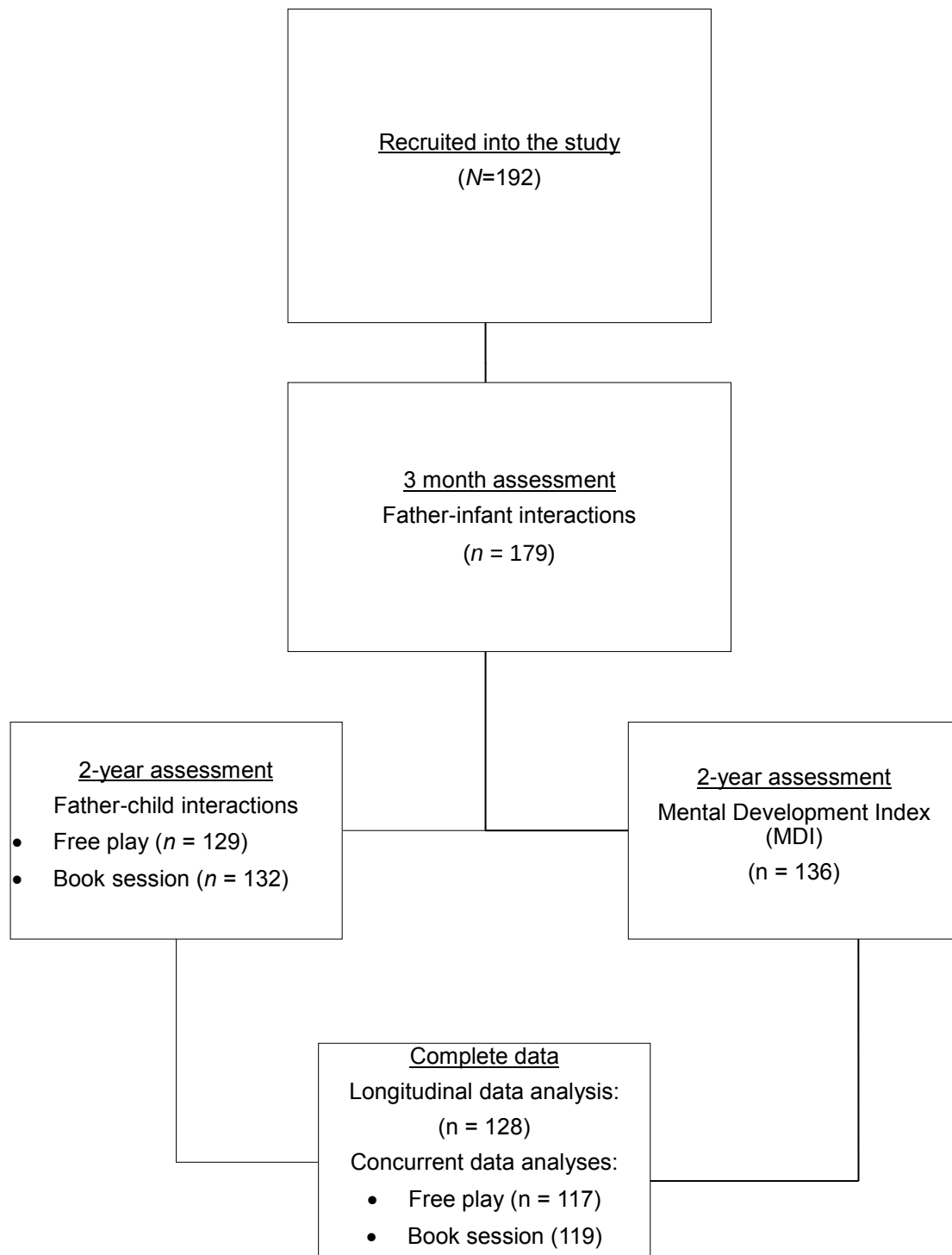


Figure 1. Participant flow through the study stages