THE QUALITY OF CAREGIVER-INFANT INTERACTIONS AND NEURODEVELOPMENTAL OUTCOMES OF INFANTS PRENATALLY EXPOSED TO PESTICIDES IN BANANA-GROWING AREAS IN COSTA RICA

AMEETA DUDANI

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Abstract

Background: The quality of early caregiver-child interactions is recognized as one of the strongest influences on children's cognitive and social development, and among the most significant modifiable environmental factors. Epigenetic studies show that maternal nurturing (i.e., licking and grooming by mothers towards baby rats) promotes positive development in young rats who have experienced prenatal environmental adversity. However, no study to date has examined the impact of caregiving interactions within the context of prenatal environmental exposures. The objective of this dissertation research was to explore the relationship between the quality of caregiver-infant interactions and infant neurodevelopmental outcomes in a high-risk sample of mother-infant dyads living within poverty-stricken and pesticide-exposed banana growing areas in rural Costa Rica. This international, community-based field study was part of a larger, ongoing longitudinal study examining the developmental outcomes of infants prenatally exposed to pesticides: the Infants' Environmental Health Study.

Methods: Home visits were conducted with 94 caregiver-infant dyads living in banana-growing villages in Matina county, Costa Rica. The quality of caregiver-infant interactions was measured using a standardized observational task: the Nursing Child Assessment Satellite Training Teaching scale. One-year infant neurodevelopmental outcomes (i.e., cognitive, language, motor and social-emotional) were assessed using the Bayley-III. Multiple regression analyses examined associations between overall quality of caregiver-infant interactions and Bayley-III outcomes, adjusting for pesticide exposure and confounders.

Results: Compared to U.S. Hispanic mothers, 35% of the sample had overall caregiving interaction scores at/below the 10^{th} percentile cutoff, indicating less than optimal interactions. Quality of caregiving interactions was significantly associated with infants' expressive language abilities ($r = 0.072$, $p<.05$). Aspects of caregiving such as stimulation and growth-fostering of infants were identified as key predictors of language outcomes.

Conclusions: The results of this study suggest a positive impact of early caregiving on infant neurodevelopment for infants experiencing the double burden of environmental exposure and poverty, and highlight aspects of caregiving that can be modified to help improve outcomes of these children. The results have important implications for environmental health research and for early intervention work with this population and with other populations having environmental and concomitant risks.

Dedication

This dissertation is dedicated to my wonderful friends and family, but most of all to my mom, who has supported and encouraged me throughout life and particularly during this journey. She has portrayed and instilled in me the values of hard work and humility and has been the best kind of friend one could ask for.

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INTRODUCTION

Pesticides are one of the most pressing environmental health problems in Costa Rica and other developing countries. The use of neurotoxic pesticides is imminent and chronic in poverty-stricken, tropical agricultural communities such as the banana-growing communities in Limón, Costa Rica, where the cumulative impact of pesticide exposure and poverty presents a significant burden for the health and development of inhabitants, particularly young children. Moreover, prenatal exposure to even low levels of pesticides is associated with significant health and developmental problems in children.

The quality of early caregiver-infant interactions is widely acknowledged to be one of the strongest influences on child development. Warm, nurturing and stimulating caregiving practices are known to buffer children against the effects of negative early life experiences, helping to foster resilience in children. In the area of children's environmental health, however, the relationship between the quality of caregiver-infant interactions and infant development has not been examined. There is growing recognition of the importance of social and parenting factors in shaping developmental outcomes of children with prenatal neurotoxin exposure. In addition, epigenetic research with animal populations have shown a buffering impact of maternal nurturing on gene expression and behavioural regulation of young rats who have experienced prenatal adversity. Hence, it is crucial to examine the relationship between a modifiable environmental factor, such as the quality of caregiver-infant interactions, and neurodevelopmental outcomes of infants who have been prenatally exposed to pesticides in banana-growing communities.

Studying the effects of an important modifiable environmental variable in early life, the caregiving environment, has significant implications for the development of early intervention strategies for these children, who face the double burden of prenatal environmental chemical exposure and a poor living environment. The identification of positive and negative aspects of caregiver-infant interactions can be used to tailor intervention strategies in order to alter risk trajectories of pesticide-exposed children, and help to promote resilience in these vulnerable children. The present exploratory study reflects a unique contribution to the field of children's environmental health and the results are valuable for rural, agricultural communities facing the cumulative risk of environmental exposures and poverty.

The burden of pesticides

The health impact of prenatal and early life pesticide exposure is a significant public health concern, particularly in rural, tropical agricultural communities, such as banana-growing areas in Costa Rica (Barraza, Jansen, van Wendel de Joode, & Wesseling, 2011; Eskenazi et al., 2008; Rosas & Eskenazi, 2008; van Wendel de Joode et al., 2012). Many pesticides are known neurotoxins, especially in high-dose environments, and exposure can exert neurotoxicological effects through multiple routes (Cooper, 2005; Munoz-Quezada et al., 2013; Saunders et al., 2012; Schantz & Widholm, 2001). Prenatal exposure is a significant concern due to the ability of pesticides to pass the placental barrier, and the impact on the developing nervous system of the fetus and young infant (Meeker, 2012; Rice & Barone, 2000). Prenatal exposure to a number of neurotoxic agents, including pesticides, has been shown in animal and human studies to interfere with critical developmental processes that begin during this period, from neural proliferation to synaptogenesis (Costa, Giordano, Guizzetti, & Vitalone, 2008; Keifer & Firestone, 2007; Rice & Barone, 2000). This makes the prenatal period particularly vulnerable to the effects of neurotoxic chemicals.

Costa Rica is one of the three leading banana-exporting countries in the world (FAO, 2014) and the use of synthetic pesticides by banana-growing plantations in Costa Rica is among the highest in Central America (Bravo, de la Cruz, Herrera, & Ramirez, 2013; Bravo et al., 2011; Wesseling et al., 2001). Environmental health studies performed in Costa Rica within the last two decades have shown that banana plantations extensively apply a broad range of pesticides, which include highly neurotoxic organophosphate insecticides, herbicides, manganese-containing dithiocarbamates and other fungicides (Barraza et al., 2011; Munoz-Quezada et al., 2013). This includes the application of mancozeb, a fungicide and known neurotoxin, which is aerially sprayed on a weekly basis to protect banana plants from the Black Sigatoka disease (Barraza et al., 2011). Mancozeb is a suspected endocrine disrupter that has been linked to oppositional and hyperactivity disorders in children prenatally exposed to its metabolites (Bravo et al., 2011; Wesseling et al., 2001). A recent study showed five to 50 times greater concentrations of urinary ethelenethiouria (ETU), a main metabolite of mancozeb, in the pregnant women living nearby large-scale banana plantations in rural Costa Rica (van Wendel de Joode et al., *accepted*). In addition to mancozeb, the use of chlorpyrifos on bags used for the protection of fruit is also widespread and persistent on plantations (van Wendel de Joode et al., 2012). Chlorpyrifos is a controversial pesticide due to its strong neurotoxic effects, even at low levels (Eaton et al., 2008; Saunders et al., 2012; Wesseling et al., 2001), which led to its ban from residential use in the U.S. (U.S. EPA, 2000). A study by van Wendel de Joode and colleagues (2012) showed that children living on banana plantations with chlorpyrifos-treated bags had elevated urinary concentrations of 3,5,6-trichloro-2-pyridinol (TCPy), a metabolite of chlorpyrifos and biomarker for chlorpyrifos exposure. For more than half of the children, the estimated absorbed daily dose was more than two times the chronic reference dose recommended by the U.S. Environmental Protection Agency. The same study found that the general living environment of children living in banana-growing villages was contaminated with chlorpyrifos, concentrations of which were detected in numerous samples (i.e., air, soil, surface water, dust, hand and foot wash), thus suggesting that exposure occurs via multiple routes (i.e., respiratory, dermal, oral, etc.).

In Costa Rica, the province of Limón accounts for 99% of the national banana production (Sanchez & Zuniga, 2004). Limón is also one of the poorest regions in Costa Rica (Sanchez & Zuniga, 2004) and the impoverished living conditions, combined with associated risk factors (i.e., little knowledge of pesticide risks and use of risk-reduction practices) make the population of Limón particularly vulnerable to the risks of pesticide exposure. Most of the province is made up of rural farmland and many villages within the province are surrounded by plantations at only a few meters distance from banana plantations. The daily aerial spraying practices often violate provincial regulations that require a minimum distance of 30 metres in the presence of a natural barrier and 100 metres in the absence of one (Barraza et al., 2011); however, none of these regulations are followed in the province. Moreover, residences are often in close proximity to banana plantations. For example, a recent study (i.e., the Infants' Environmental Health study or ISA, which the present study is part of), found that 25 percent of the pregnant women in this region live within 50 metres of a banana plantation (van Wendel de Joode et al., *accepted*). Immigrants from neighbouring countries such as Nicaragua might be at particular risk for pesticide exposure in this region given that they live closer to banana plantations and have greater concentrations of ETU than native Costa Ricans (van Wendel de Joode et al., *in press*). Given that houses typically have an open structure, pesticide exposure is likely via multiple routes including air, ingestion and through contact with the skin. In addition, almost a quarter of the pregnant women from the ISA study reported drinking water from local wells (van Wendel de Joode et al., *in press*). While this was not found to be associated with concentrations of urinary ETU, a separate study found significantly higher concentrations of manganese in homes supplied with well water (Mora et al., 2014). Thus, drinking well water might pose an additional source of exposure, if not to pesticides, to other adverse neurotoxins. The multiple pathways of exposure in this region pose a significant environmental threat for the people residing in these villages.

In addition to pesticide exposure as a function of living near large-scale banana plantation farms, many women of childbearing age are employed at these farms where they are potentially exposed to high levels of pesticides. Some of these women continue to work throughout pregnancy and soon after the postpartum period. Maternal occupational exposure to pesticides has been associated with increased risk of birth defects in offspring (Cooper, 2005; Eskenazi, Bradman & Castorina, 1999), and delays in infant neurodevelopment (Eskenazi et al., 1999; Handal, Harlow, Breilh, & Lozoff, 2008; Harley, Marks, Bradman, Barr, & Eskenazi, 2008). Prenatal exposure to even low levels of pesticides increases the risk for developmental disorders, including problems with cognitive, motor and language development, emotional dysregulation, and increased social-emotional and behavioural problems that can persist through adolescence (Bouchard et al., 2011; Engel et al., 2007, 2011; Eskenazi et al., 1999, 2007, 2008; Gilbert, 2008; Gilbert, Miller, Martin, & Abulafia, 2010; Rauh et al., 2006, 2011; Rosas & Eskenazi, 2008; Young et al., 2005). The bulk of the evidence for the impact of prenatal pesticide exposure on children's neurodevelopmental outcomes comes from three large prospective birth cohort studies from the U.S., only one of which has been conducted with agricultural farm workers, approximating the study population in the present study. This study, conducted by the Center for the Health Assessment of Mothers and Children of Salinas (CHAMACOS) in the Salinas valley area in California, has shown significant associations between biomarkers of prenatal pesticide exposure and infant developmental outcomes on both the Mental Development Index (i.e., cognitive and language outcomes) and Psychomotor Development Index of the Bayley Scales of Infant Development (BSID), with increasing levels of exposure associated with poorer outcomes (Bouchard et al., 2011; Eskenazi et al, 1999, 2007, 2008).

Despite high levels of exposure, however, there is considerable variability in the extent to which children's developmental outcomes are affected by prenatal exposure to neurotoxins, and not all children are affected equally (Meeker, 2012; Munoz-Quezada et al., 2013). This suggests that exposure levels may account for a small proportion of the variance in neurodevelopmental outcomes of children, and that observed associations may be impacted by the combined influence of prenatal pesticide exposure and the postnatal rearing environment. Hence, the adverse effects of prenatal neurotoxin exposure on children's development may be exacerbated by other risk factors (e.g., maternal depression, poverty) or interact with protective factors (e.g., a positive caregiving environment) to promote better outcomes throughout development.

The importance of caregiver-infant interactions

Caregiving is widely recognized across cultures as having a significant influence on children's development, attachment, and relationships. In a comprehensive review by the World Health Organization (Richter, 2004), the quality of early caregiver-infant interactions was noted to be one of the most significant modifiable factors contributing to children's development and attachment security, across developed and developing countries. For infants, positive caregiver-infant interactions help with infants' stress regulation, until infants gradually progress towards self-regulation (Richter, 2004). Mary Ainsworth's ground-breaking study with caregiver-infant dyads from Uganda (Ainsworth, Blehar, Waters, & Wall, 1978) and the later work by John Bowlby (Bowlby, 1999) provided the first pieces of evidence for the importance of caregiver-infant interactions in fostering secure attachments between children and their caregivers, thus setting the foundation for positive developmental trajectories, and having long-standing impact on the adaptive development and relationships of children as they grow into adults (Bakeman & Brown, 1980; McCain, Mustard, & McCuaig, 2011; Shonkoff & Phillips, 2000).

While there are variations in caregiving practices and the measurement of caregiving quality, cross-cultural studies have identified several universal components of caregiving, which are associated with higher scores on various tests of social and cognitive development. These include caregiver sensitivity (i.e., caregivers' ability to accurately read their baby's cues and adjust their behaviour accordingly) and responsiveness (i.e., caregivers' ability to promptly and contingently respond to their baby), which have consistently emerged as significant correlates of early cognitive, language, and psychosocial development (Bakeman & Brown, 1980; Eshel, Daelmans, de Mello, & Martines, 2006; Landry, Smith, Swank, Assel & Vellet, 2001), as well as school achievement (Laucht, Esser, & Schmidt, 2001; Sroufe et al., 2005). Sensitive and synchronous interactions between infants and their caregivers lay the foundation for early markers of cognitive and social-emotional growth, and facilitate secure attachment (Love et al., 2005; Shonkoff & Phillips, 2000). Hence, studies often utilize the term “caregiving” interchangeably with these components of caregiving (i.e., “sensitivity,” “responsiveness” and “contingency”). Other aspects of caregiving have also been identified as important in the early development of children, including the encouragement of exploration, provision of a stimulating environment, and ample amounts of warmth and nurturance (Allhusen et al., 2001; Brooks-Gunn et al., 2002; Bakeman & Brown, 1980; Barnard & Eyres, 1979; Richter, 2004; Shonkoff & Phillips, 2000). Caregivers who provide responsive and stimulating care in the early years have children who perform better on cognitive and academic measures, irrespective of the absolute level of socioeconomic disadvantage (Bradley et al., 1989; Richter, 2004). Equally important is the social-emotional growth-fostering by the caregiver, consisting of the caregiver’s supportiveness and encouragement of the infant (Biringen & Robinson, 1991; Bornstein & Putnick, 2012), which is strongly associated with attachment security and important social-emotional developmental outcomes (Bakeman & Brown, 1980; Bretherton, 2000). Thus, showing sensitivity and responsiveness towards infants is crucial, but having warm, nurturing and stimulating interactions with infants is equally important for children’s neurodevelopment.

Moreover, it is well-acknowledged that the caregiver-infant interactions are bi-directional and dependent on the contributions of both the caregiver and child (Barnard & Eyres, 1979; Pardini, 2008; Pettit & Arsiwalla, 2008). Thus, most studies of components of caregiving interactions usually involve observation of mother-child interactions using coding or rating instruments in which the behaviour of the caregiver and child are separately categorized (Richter, 2004).

Positive associations between components of caregiving interactions and early developmental outcomes of children have been demonstrated across cultures and geographic regions. For example, in rural Ethiopia, mothers’ responsiveness was shown to be strongly predictive of preschool vocabulary development in their children (Aboud & Alemu, 1995). Similarly, in rural India, warm and stimulating caregiving by mothers was significantly associated with more positive cognitive and behavioural outcomes in 196 malnourished children aged 1 to 3 years (Agarwal et al., 1992). Moreover, early interventions to improve the quality of caregiver-infant interactions show positive and robust effects on children's cognitive outcomes (Achenbach, Howell, Aoki & Rauh, 1999; Cooper et al., 2002; Gardner, Walker, Powell & Grantham-McGregor, 2003), including in developing countries, where the benefits also extend to physical outcomes (Eshel et al., 2006).

In the context of poverty, deprivation and other negative environmental conditions, positive caregiver-infant interactions help buffer children against the negative impact of these adverse conditions, and contribute to increased resilience (Barnard & Eyres, 1979; Barnard et al., 1985; Engle et al., 2007; Eshel et al., 2006; Laucht et al., 2001; Love et al., 2005; Richter, 2004; Shonkoff & Phillips, 2000). Poverty, especially in developing countries, is recognized as a conglomerate of conditions that create pervasive hardship and stress (Richter, 2003). As such, poverty increases the likelihood that numerous risk factors will be present simultaneously within the environment, and puts children at greater risk for adverse developmental outcomes and trajectories (Brooks-Gunn et al., 2002; Richter, 2003; Shonkoff & Phillips, 2000). One of the ways in which poverty exerts its effect on infant neurodevelopment is indirectly via its impact on the home environment and the parent-child relationship, making it difficult for parents to provide sensitive, responsive and stimulating care for their children (Richter, 2003, 2004). Positive caregiver-child interactions in early life have the potential to alter the course of development of children (McCain, Mustard, & McCuaig, 2011), particularly for children living in poverty (Brooks-Gunn et al., 2002), and the positive impact can also be seen at the genetic level (Caldji, Hellstrom, Zhang, Diorio, & Meaney, 2011).

Attachment as a mechanism of impact

Positive caregiving practices are thought to exert their effects on infant development through the development of secure attachments between infants and their caregivers (Ainsworth et al., 1978; DeWolff & van IJzendoorn, 1997; van IJzendoorn, 2005). Secure patterns of attachment, which constitute the majority of caregiver-child relationships, are characterized by infants' comfort in exploring the environment in the presence of the caregiver, seeking contact with caregivers after separation, and showing signs of trust and delight in the caregiver's presence (Shonkoff & Phillips, 2000). An extensive body of literature has established a clear link between secure patterns of attachment in infancy (Bowlby, 1999; Schore, 2001) and later social adaptation, including better developmental outcomes in aspects such as self-reliance, self-efficacy, empathy and social competence (Grossmann & Grossmann, 2009; Sroufe, Egeland, Carlson, & Collins, 2005; Waters, Merrick, Treboux, Crowell, & Albersheim, 2000). Infants with insecure attachments are more prone to developing later psychopathology, including conduct disorder, aggression, depression and anti-social behaviour (Carlson, 1998; Cicchetti, Toth, & Bush, 1988; Sroufe, 1997). Studies have confirmed the important contribution of positive caregiving in fostering secure attachments and promoting positive development from childhood through adulthood (Bornstein et al., 1998; Grossmann, Grossmann, & Keppler, 2005; Grossmann & Grossmann, 2009; Love et al., 2005; McCain et al., 2011; van IJzendoorn & Sagi, 1999). This link has been established through studies that span many cultures, for example Spanish-speaking, high-risk populations in the U.S. such as Hispanic immigrants (Fuller et al., 2010; Leidy, Guerra, & Toro, 2010) and low-income Hispanic communities (Ayala et al., 2010; McCabe, Yeh, Lau, Argote, & Liang, 2010).

Caregiving in the context of prenatal exposures

The role of the quality of caregiver-infant interactions has not been studied to date in populations with prenatal environmental neurotoxin exposures. Two groups of studies have demonstrated strong relationships between early environmental factors, such as components of caregiving, and young children's development.

Firstly, studies with infants who experienced prenatal drug and/or alcohol exposure have shown that lack of caregiver sensitivity in addition to this type of exposure is associated with greater developmental and behavioural problems at later ages (O'Connor, Sigman, & Brill, 1987; Eiden, Schuetze, & Coles, 2011). In infants with in-utero cocaine exposure, low maternal sensitivity during infancy predicts greater infant reactivity to stress (Eiden et al., 2011) and significantly increases the risk of insecure attachment in children (Rodning, Beckwith, & Howard, 1991; Swanson, Beckwith, & Howard, 2000). Caregiving quality also affects cognitive outcomes of children with prenatal drug and/or alcohol exposure. Infant neurodevelopmental outcomes were positively related to parental caregiving behaviours in cocaine-exposed children, effects that were stronger than for infants without prenatal drug exposure (Black, Schuler, & Nair, 1993), suggesting that modifiable environmental factors such as caregiving may have a greater impact and exert protective effects on the development of vulnerable children who are most at risk.

However, infants with in-utero drug or alcohol exposure are markedly different from those with prenatal neurotoxin exposure. Caregiver-infant relationships in the former scenario may be compromised by caregivers' ongoing drug or alcohol use and their patterns of use, which may interfere with their role as parents and with their interactions with their children (O'Connor et al., 1987; Rodning et al., 1991). In contrast, for infants with prenatal exposure to neurotoxins such as pesticides, the exposure is an environmental neurotoxin and may continue to adversely affect the developing brain, particularly if the exposure is chronic, occurs via multiple pathways, and/or continues postnatally (Cooper, 2005). Thus, in the context of prenatal neurotoxin exposure, there is greater potential for modifiable environmental variables, such as caregiver-infant interactions, to exert effects on infant developmental outcomes.

The second group of studies, highly relevant to the present study, is from the field of children's environmental health. There is growing awareness of the significant impact of the early home environment on the development of children prenatally exposed to environmental chemicals. Studies have demonstrated large associations between the quality of stimulation afforded by the home environment, as measured by the Home Observation for the Measurement of the Environment (HOME) scale, and developmental outcomes in the context of prenatal exposure to neurotoxic compounds such as lead (Koller, Brown, Spurgeon, & Levy, 2004; Parajuli et al., 2014), arsenic (Parajuli et al., 2014), methylmercury (MeHg; Davidson, Myers, Shamlaye, Cox, &

Wilding, 2004), polychlorinated biphenyls (PCBs; Walkowiak et al., 2001), and chlorpyrifos (Horton, Kahn, Perera, Barr, & Rauh, 2012). Many of these studies assessed outcomes during infancy and toddlerhood using the BSID, and associations remained strong even after adjusting for known confounders, such as maternal IQ and SES. Some researchers purport that, in the context of neurotoxin exposure, covariates such as social and parenting factors account for 40% or more of the variance in children's neurocognitive outcomes (Weiss, 2000), and the combined effect of SES and the quality of the caregiving environment is far greater than exposure itself (Koller et al., 2004). In infants with in-utero PCB exposure, a stimulating home environment has been shown to counteract the adverse developmental effects of prenatal exposure to environmental neurotoxins (Walkowiak et al., 2001), and similar results have been reported for prenatal methylmercury exposure (Davidson et al., 2004). Some researchers (i.e., Bellinger, 2000) have even gone so far as to argue that the home environment has the potential to moderate the association between neurotoxicant exposure and developmental outcomes, via effect modification, an effect that is seen on cognitive outcomes of infants with prenatal lead exposure (Bellinger, 2000; Bellinger, Levition, Waternaux, Needleman, & Rabinowitz, 1989). Thus, it is likely that the home environment interacts with prenatal exposure to influence developmental outcomes. The studies above suggest that the quality of the home environment exerts as much or greater effect on the developmental outcomes of children, including overall cognitive development (Koller et al., 2004; Walkowiak et al., 2001) and language outcomes more specifically (Davidson et al., 2004). Much of the early home environment has to do with the amount of stimulation provided to children, an aspect that is strongly dependent on the quality of interactions between children and their caregivers. In the context of environmental health, this factor (i.e., the quality of caregiver-infant interactions) remains to be examined to provide direction for the aspects of caregiving that can be targeted and modified through early intervention.

The contribution of epigenetics

Important advances have been made in the burgeoning field of epigenetics, with its focus on the significant impact of the early environment in shaping child development through the alteration of gene expression. Animal research has shown that maternal nurturing has strong effects on the developmental outcomes of young rats as they grow into adulthood, by affecting the development of behavioural regulation and the hypothalamic-pituitary-adrenal (HPA) response to stress (Caldji et al., 2011; Kappeler & Meaney, 2010). Providing an enriching and nurturing postnatal environment, represented by high levels of licking and grooming by mothers towards young rats, is shown to decrease DNA methylation in the brain and increase gene expression, thus leading to a better overall stress response. Hence, postnatal maternal care serves to mediate the relationship between early environmental stress and behavioural regulation, which may in turn impact developmental outcomes. The handling and tactile stimulation provided by mother rats to pups during licking and grooming provides a positive, comforting experience, inducing permanent changes in stress hormones in the hypothalamus of pups (Kappeler & Meaney, 2010; Weaver et al., 2004). These pups also show less anxious behaviour and lower reactivity to stress during adolescence and adulthood (Caldji et al., 2011; Meaney & Szyf, 2006). Thus, epigenetic evidence lends further support for the strong role of early caregiving in the development of children as they grow into adults, but also expands the evidence by demonstrating a biological mechanism that can explain the observed behavioural changes.

Maternal nurturing in early life is shown to reverse the negative effects of prenatal adversity on young rats' behavioural regulation outcomes (Kappeler & Meaney, 2010). Moreover, caregiving has the potential to reverse DNA methylation patterns once pups, who are born into harsh environmental and rearing conditions, are cross-fostered and raised in stimulating early environmental conditions (Meaney & Szyf, 2006; Weaver et al., 2004). These findings are in line with the earlier evidence from research in children's environmental health and suggest a strong potential for early caregiving to buffer children against the negative impact of prenatal exposure to environmental chemicals. Hence, the quality of caregiver-infant interactions may show associations with the neurodevelopmental outcomes of infants who have experienced prenatal adversity via exposure to neurotoxic pesticides.

Social-environmental factors

Several social-environmental factors are known to confound the relationship between prenatal pesticide exposure and infant neurodevelopment, and between caregiving and child development, especially within conditions of poverty. Some of the main factors that have been identified include maternal depression, maternal intelligence, the quality of the home environment and perceived social support by the mother. Maternal depression often manifests as decreased emotional availability towards the child. Depressed mothers report that it is difficult to be nurturing, patient and involved with their children. They are observed to be withdrawn, passive and insensitive in interactions with their children (Richter, 2003). Young infants are observed to be sensitive to mothers' depressed mood and less contingently responsive to depressive behaviour (Shonkoff & Phillips, 2000). Thus, there is a general consensus in the child development literature to account for the effects of maternal depression, which may be highly prevalent in the presence of poverty (Richter, 2003). Maternal intelligence is also shown to mediate neurodevelopmental outcomes of infants who have sustained prenatal neurotoxin exposure, as it is thought to impact the developing young child's intelligence and cognitive status via neurotoxic effects on the mother (Rice & Barone Jr., 2000). The quality of the home environment, usually measured using the Home Observation for the Measurement of the Environment (HOME), is an important social factor that is associated with children's neurodevelopmental outcomes (Shonkoff & Phillips, 2000). The home environment also mitigates infant outcomes in the context of prenatal pesticide and other chemical exposures (e.g., Horton et al., 2012; Rauh et al, 2006; Parajuli et al., 2014); as such, it is often included in analyses examining neurodevelopmental outcomes. Moreover, aspects of the home environment, such as availability of developmentally stimulating materials, might indirectly exert effects on children's development as the lack of such available materials may affect caregivers' capacity to stimulate their children. Finally, social support is usually conceptualized in terms of perceived informational support, emotional support, and physical/material support (Broadhead et al., 1988). Caregiver social support can affect caregiving interactions directly (e.g., by providing help that allows the caregiver to spend more time with his/her child) or indirectly (e.g., by reducing parent's stress levels and thus fostering more positive caregiver-child interactions) (Richter, 2004). There is some evidence that perceived social support is lower in low-income mothers living in agricultural communities (Harley & Eskenazi, 2006). These and other variables were assessed and considered as potential confounders in the present study.

Rationale for current study

The quality of caregiving, and specifically caregiver-infant interactions, has been established across cultures as having a significant impact on neurodevelopmental and behavioural outcomes throughout infancy and childhood, particularly in the face of environmental adversity. In addition, maternal nurturing has been shown to result in better stress regulation and behavioural responses in animals by altering DNA methylation patterns. However, the impact of caregiver-infant interaction quality on infant neurodevelopmental outcomes has not been examined to date within the context of prenatal exposure to neurotoxins such as pesticides, which are known to negatively impact infant neurodevelopment. Given that caregiver-infant interactions are recognized as one of the strongest modifiable environmental factors known to have a long-lasting impact on the well-being of children and their parents, it is crucial to explore this factor and the aspects of caregiving interactions that are affected, particularly within this population facing the double burden of poverty and high levels of pesticide exposure. In other words, it is crucial to consider whether caregiving is associated with and has the potential to modify the developmental outcomes of infants growing up in these poor environmental conditions.

Research questions, objectives and hypotheses

The present study sought to answer the following two questions:

(1) What do caregiver-infant interactions look like in high-risk infants who have experienced prenatal exposure to neurotoxic pesticides and who are living in a poverty-stricken rural and agricultural environment (i.e., banana-growing villages)?

To address this question, the specific objectives were to:

a. Describe the quality of caregiver-infant interactions (i.e., domains and items of the interaction that are most affected and the caregiver and infant contributions to the interactions) in this sample of caregiver-infant dyads, using a standardized observational measure of caregiver-infant interaction (i.e., the Nursing Child Assessment Satellite Training Teaching Scale; NCATS). The aspects of caregiving quality that were examined included overall interaction quality, overall caregiver contribution, overall child contribution, number of contingent responses by caregivers and infants, caregiver-related subscales (i.e., sensitivity to cues, response to child's distress, social-emotional growth fostering, cognitive growth-fostering), and child-related subscales (i.e., clarity of cues, responsiveness to caregiver); and
b. Compare the caregiver-infant interaction scores to the NCATS normative data of U.S. Hispanic mother-infant dyads and U.S. adults with low education.

(2) Are there associations between aspects of early caregiver-infant interactions and infants' neurodevelopmental outcomes, and do these associations remain after adjusting for prenatal pesticide exposure level and important confounders?

Specifically, the second objective of this study was to examine the associations between the overall quality of caregiver-infant interactions and one-year infant neurodevelopmental outcomes (i.e., cognitive, language, motor, and parent-reported social-emotional development) as assessed by the Bayley Scales of Infant Development-Third Edition (Bayley-III; Bayley, 2006), before and after adjusting for prenatal pesticide exposure level and important covariates.

It was hypothesized that better quality caregiver-infant interactions (i.e., caregivers showing higher overall interaction scores) would be associated with better infant neurodevelopmental outcomes (i.e., greater standard scores) at one year of age on one or more Bayley-III indices of cognitive, language (receptive and expressive), motor (fine and gross), and parent-reported social-emotional functioning. These effects were expected to remain significant after controlling for pesticide exposure level and other important covariates. Both caregiver-related and child-related characteristics were expected to be associated with neurodevelopmental outcomes. While there were no specific hypotheses made with regard to which aspects of caregiver-infant interactions would be impacted or associated with Bayley-III outcomes, associations were expected to be most significant for cognitive and language outcomes given the existing literature on the impact of caregiving on infant developmental outcomes in high-risk populations.

Given that these questions have not been studied to date in human populations, the present study was exploratory and was carried out with a sub-sample from a larger, ongoing, prospective cohort study of the impact of prenatal pesticide exposure on the growth and neurodevelopmental outcomes of infants living in Matina county, Limón province, Costa Rica: the Infants' Environmental Health study or *Infantes y Salud Ambiental (ISA)*. The ISA is a longitudinal study which is situated within an eco-health and community-participatory framework, which is a novel methodology for addressing the impact of pesticide exposures within a developing country. The long-term goals of the ISA research study and program, apart from investigating the effects on infant neurodevelopmental outcomes, are to work with communities and stakeholders to reduce pesticide risks, improve education about pesticide risks, implement risk reduction practices, assess the impact of pesticide exposure on health and quality of life, and to contribute towards the development of sustainable alternatives to pesticides in these banana-growing communities. The community participatory and eco-health framework of the study has greatly contributed to the formation of trusting relationships between the study investigators and the communities as well as the community members. The details of the methods of the ISA study can be found in van Wendel de Joode et al. (2012).

METHODS

Study design

The present study was part of a larger, community-based, prospective birth cohort study led by Dr. Berna van Wendel de Joode from the Instituto Regional de Estudios en Sustancias Toxicas (IRET) at the Universidad Nacional (UNA) in Costa Rica, entitled, "*A holistic analysis of the sustainability of banana and plantain production systems regarding pesticide exposure and its effect on neurodevelopment in early life*: *The Infants' Environmental Health study (Infantes y Salud Ambiental; ISA).* As described previously, the ISA study is an ongoing, longitudinal study of the effects of prenatal pesticide exposure on the neurodevelopment of infants. The present study was approved by the York University Ethics committee and the Scientific Ethics Committee of the Universidad Nacional. The ISA study was approved by the Scientific Ethics Committee of the Universidad Nacional.

The ISA study population

The study took place within the Matina county of the Limón province of Costa Rica (Figures 1 and 2), where large-scale banana plantations constitute the main economic activity and represent 34% of the agricultural area (van Wendel de Joode et al., *accepted*). The recruitment of women into the ISA study took place between March 2010 and June 2011. To recruit women, several strategies were used (e.g., local groups, communal groups, advertisements and referral from educational and nutritional centres, and word-of-mouth) to identify pregnant women living within 5 km of banana plantations with large-scale production in Matina county. Women were eligible for the study if they were at least 15 years old and were less than 33 weeks pregnant at time of inclusion. A total of 480 women were identified and, of these, 451 (94%) participated. The women lived in one of 40 villages spread throughout the county of Matina. Written informed consent was obtained from each participant and from her parent or legal guardian for women under 18 years of age.

Figure 1: Map of Costa Rica

Figure 2: Map showing the counties within the province of Limón

Women were visited and interviewed at their homes one to three times during pregnancy, and samples of maternal blood, urine and hair were also collected at each visit for the neurotoxicological analyses of pesticide metabolites. Women were also visited shortly after the birth of their infant for an interview and to obtain infant growth parameters and additional samples of maternal urine and breastmilk. Following this visit, mother-infant dyads were visited when the infant was one year of age to complete an interview, questionnaires, and the assessment of infant neurodevelopmental outcomes via the Bayley Scales of Infant Development-Third Edition (Bayley-III; Bayley, 2006). The one-year Bayley assessments were completed as close as possible to each infant's first birthday.

Recruitment and retention strategies in the ISA study

To date, minimal attrition has affected the overall project. The ISA research team, over the course of the project, has established strong relationships with the families and communities involved in the study. The community-participatory nature of the study, coupled with the provision of ongoing feedback and recommendations to participants, have been significant motivators in establishing and maintaining alliances with families. With this said, the ISA research team has thus far faced a number of challenges, including dealing with a highly transient population, the logistics of scheduling the one-year assessment visits across remote geographic regions, transporting families to/from the assessment visits, and the burden of a two-hour neurodevelopmental assessment. However, relocation of families is usually within close proximity to their prior address and it has been possible to locate most families by asking neighbours and co-workers at the plantation. To prevent and overcome the aforementioned challenges, participants are contacted every six months by the ISA research team in order to keep demographic information updated.

The present study sample

The data collection for the present study took place over two field trips conducted in October 2012 and April 2013. The evaluations of caregiver-infant interactions were conducted in Spanish, during home visits with infants and their primary caregivers, who in most instances was the biological mother. The home visits were conducted by myself, accompanied by a field research assistant who was involved with the larger study and familiar with the study population and area. Since the research assistant was also known to the families and the study team had established strong relations with the families, this greatly assisted with recruitment of participants for the present study.

To recruit participants for the present study, infants with completed one-year Bayley-III assessments were first identified from the larger ISA study sample of 451 infants. From these, infants with more recent evaluations (i.e., with Bayley evaluations between March and September 2012) were identified for the first field trip. This was done in order to limit the effect of infant's age and the length of time since the Bayley-III was administered. A total of 97 infants were identified. From these, a random sub-sample of 30 infants was selected using a random number generator.[1] From these, the first five caregiver-infant dyads were used to pilot the measure of the quality of caregiver-infant interaction and make any necessary changes to facilitate the understanding of the task for the caregivers. A total of three families were excluded because they lived in one of the villages that were more than an hour's drive, or they no longer lived within the study area. A total of 9 families were excluded because they were unreachable by phone despite several attempts, were not home despite several attempts to visit, or were unable to be located. The first caregiver-infant dyad visited was also excluded due to a slight change to the task instructions following this visit, and due to the presence of several distractions during the time of the assessment. Thus, in the first field trip (i.e., in October 2012), a total of 17 caregiver-infant dyads consented to this study, were visited and had complete and usable data.

In preparation for the second field trip, once again infants were identified from the larger pool of 451, who had completed one-year Bayley assessments between October 2012 and April 2013. This pool was added to the remainder of the sample that had been identified prior to the first field trip, for a total of 172 infants. From these, a random sub-sample of 99 infants was selected using a random number generator. Of these, families were excluded if they lived too far or no longer lived in the study area (n=6) or if they were unable to be located or reached by phone (n=8). Attempts were made to visit as many of the remaining families as possible. Further exclusions were made if caregivers did not consent to participate in the study (n=2)[2], if infants were asleep at time of the

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[1] Note that a larger number of infants were intentionally selected in order to attempt to recruit and visit as many families as possible during the first field trip.

[2] Note that families who refused to participate did so because they were uncomfortable with the video-recording of the task.

visit (n=2), or if infants were uncooperative at time of the visit (n=1).[3] A total of 80 families consented and were visited at their homes. From these, three videos were excluded since they were unable to be coded due to the quality of the videos. Thus, in the second field trip (i.e., in April 2013), a total of 77 caregiver-infant dyads were visited and had complete and usable data. **The final study sample for the present study consisted of 94 caregiver-infant dyads.** The above information is summarized in a flow chart (Table 1).

Every attempt was made to obtain a sub-sample that was representative of the overall study sample, with respect to village distribution and varying levels of prenatal pesticide exposure (i.e., represented by the distance between residence and banana plantation). Recruitment and data collection were limited, however, by accessibility to villages during the periods of data collectidon, localization of participants, and convenience of scheduling the home visits. Nevertheless, experientially and from consulting with the field research assistant and site supervisor (BW), the sub-sample was highly representative of the larger study sample in terms of the spread of villages, socioeconomic conditions of villages, and prenatal pesticide exposure levels.

Once potential participants were identified, caregivers were contacted by telephone to explain the study, determine if they were interested and schedule a day/time for the home visit. At the home visit, written informed-consent was obtained from the mothers of the infants and the primary caregivers (if it was not the mother) prior to the assessment of caregiver-infant interactions. Written consent was also obtained from the parent or legal guardian of the mothers if they were under 18 years of age (Appendices A through D).

[3] Note that two or three repeated attempts were made to visit families at alternate times if infants were asleep or uncooperative; these exclusions are for families whose infants were asleep or who remained uncooperative at subsequent attempts.

Table 1: Flowchart of sample size

Description	**Exclusions**	***n***
Total study sample in ISA study		n=451
Identified and selected participants with completed 12-month Bayley-III evaluations between March and September 2012		n=97
Data collection field trip # 1 (October 2012)		
Selected random sub-sample		n=30
	Excluded participants who lived too far or no longer lived in the study area (n=3)	
	Excluded participants who were unreachable, not at home, or unable to be located (n=9)	
	Excluded the first video due to change in instructions following visit and presence of many distractions (n=1)	
Final sub-sample from first trip		n=17
Data collection field trip # 2 (April 2013)		
Identified and selected participants with completed 12-month Bayley-III evaluations between October 2012 and April 2013, and added this to participants remaining from previous selection		n=172
Selected random sub-sample		n=99
	Excluded participants who lived too far or no longer lived in the study area (n=6)	
	Excluded participants who were unreachable or unable to be located (n=8)	
	Excluded caregivers who refused to participate (n=2)	
	Excluded participants whose infants were asleep (n=2) or uncooperative (n=1) at time of home visit, despite repeated attempts	
	Excluded videos that had poor quality (i.e., were too dark) for coding (n=3)	
Final sub-sample from second trip		n=77
Final study sample from both trips with complete and usable data		***n=94***

Assessment of the quality of caregiver-infant interactions

The evaluations of caregiver-child interactions took place during home visits with primary caregivers when infants were between one and two years of age and after the one-year Bayley-III neurodevelopmental assessments had been completed. The evaluations, informed consent, and feedback following the measure were conducted in Spanish by myself in order to ensure consistency. It was ensured that I remained blind to the Bayley-III scores and the prenatal pesticide exposure levels of the infants until the data were coded and ready to be analyzed. During the time of the assessment, the field research assistant assisted with video-recording and/or attending to caregivers' other children.

The quality of caregiver-child interactions was assessed using the Parent-Child Interaction Teaching Scale of the Nursing Child Assessment Satellite Training (NCAST; Sumner & Spietz, 1994), a standardized observation task designed for use with children from birth to 36 months of age. The NCAST Teaching Scale (NCATS) is a widely used observational measure that has been shown to have high cross-cultural validity and reliability (Byrne & Keefe, 2003; Gaffney, Kodadek, Meuse, & Jones, 2001; Munson, 1996; Sumner & Spietz, 1994). It is also one of the few measures to have been validated in Spanish-speaking populations (i.e., a sample of U.S. Hispanic mother-infant dyads), with an available Spanish version and available normative data on this sample. Internal consistency reliabilities reported for the NCATS range from .52 to .80 for the subscales and from .76 to .87 for the total scales (Sumner & Spietz, 1994).

The NCATS is based on Barnard's model of child development (Barnard, 1997; Barnard & Eyres, 1979), which is based on the bi-directional and transactional interaction between the caregiver and child, and the contribution of each member to the interaction. In the interaction process, each member of the dyad is viewed as having responsibility in and for the interaction. Mothers must interpret the infants' cues, be responsive to the cues, provide stimulation and opportunities for the infant to interact, and in turn foster infants' growth and development. Infants must also provide clear cues and be responsive to their mothers (Barnard, 1997; Sumner & Spietz, 1994). Child development research shows strong evidence for the role of the bi-directional transactional framework in the developmental trajectories of children (Bornstein, 1985; Pardini, 2008; Pettit & Arsiwalla, 2008).

Since the development of the scale, the NCATS has been utilized in several high-risk study populations including rural, low-income samples (Horodynski & Gibbons, 2004; Letourneau, 2001; Schiffman, Omar, & McKelvey, 2003; Wacharasin & Barnard, 2001), African-Americans in the U.S. (Wallace, Robers, & Lodder, 1998), Hispanic samples in the U.S. (Fuller et al., 2010; Huang, Caughy, Genevro, & Miller, 2005; Zahr, 2000), Native Americans (Seideman, Haase, Primeaux, & Burns, 1992), Alaskan Inuit (MacDonald-Clark & Harney-Boffman, 1994), Canadian Aboriginals (Letourneau, Hungler, & Fisher, 2005), Japanese (Loo, Ohgi, & Howard, 2005) and Chinese infants (Zhu et al., 2007), and some of these studies (e.g., Fuller et al., 2010; Letourneau, 2001; Wacharasin & Barnard, 2001) have demonstrated moderate to strong relationships with infant neurodevelopmental outcomes (i.e., with the Bayley Scales of Infant Development Mental Development Index) in their samples. The NCATS has also been used in Barnard's own studies with low-income and high-risk samples in the U.S. (Barnard, 1997; Sumner & Spietz, 1994).

Due to concern for the burden of measurement, this measure was also chosen due to its feasibility (i.e., not requiring a lengthy administration time) and ease of understanding by parents, relative to other measures that were being considered for this study. In addition, the availability of a Spanish translation of the measure and of U.S. Hispanic normative data, and previous utilization of the NCATS in several studies with Spanish-speaking populations, also encouraged the use of this measure. Nevertheless, minor changes in wording were made to the instructions and the activity descriptions for the purpose of this study, in order to adapt the measure to the cultural context. These modifications were only made after obtaining permission from the developers of the instrument.

The NCATS consists of 73 items, each coded in a binary manner (i.e., 1 point if observed or 0 points if not observed), across six subscales. Four of the subscales measure the caregiver's contribution to the interaction (i.e., Sensitivity to cues, Response to distress, Social-Emotional growth fostering, and Cognitive growth fostering) and two subscales measure the child's contribution (i.e., Clarity of cues, and Responsiveness to caregiver). The number of observed behaviours is summated for each subscale and for the total scales, resulting in scores for the *Overall Caregiver-Child Interaction*, *Caregiver Total*, *Child Total*, and for each of the six subscales. A brief description of each subscale is provided here (Sumner & Spietz, 1994). The *Sensitivity to Cues* subscale measures the caregiver's ability to accurately read and respond to cues given by the infant. The *Response to Distress* subscale measures the caregiver's ability to recognize and respond to the infant's distress. This subscale is scored if an infant displays one or more potent disengagement cues (i.e., crying, fussing, pushing away) that indicate the infant's need to break or to disengage from the interaction. If infants do not display any potent disengagement cues, caregivers receive full points on this subscale as it is inferred that they are able to recognize and respond appropriately to more subtle disengagement cues from their child in order to prevent them from becoming potent. See Appendix E for the list of potent disengagement cues that are considered for this subscale. The *Social-Emotional Growth Fostering* subscale measures the caregiver's display of affectionate behaviours towards the infant, her ability to play affectionately with the infant, and her ability to provide appropriate social reinforcement of desirable behaviours. The *Cognitive Growth Fostering* subscale assesses the caregiver's awareness of the infant's developmental level of understanding and engaging with the infant using verbalization and behaviours that stimulate cognitive and language functioning. The *Clarity of Cues* subscale measures the infant's ability to display clear cues and behaviours that facilitate the caregiver's ability to "read" the infant's cues and adapt her behaviour accordingly. Finally, the *Responsiveness to Caregiver* subscale assesses the infant's ability to "read" the caregiver's cues and to respond to the caregiver and modify his/her behaviour in return. The NCATS subscales and items contributing to each subscale can be found in Appendix F.

The NCATS also provides three scores measuring contingency or reciprocity of interactions (i.e., *Caregiver Contingency Total, Infant Contingency Total,* and *Overall Contingency Total*), which are derived from specific items within each subscale that contribute to these scores. The contingency items represent those items that are immediately reliant or contingent upon the other member's behaviour. For example, a contingency item from the Social-Emotional Growth Fostering subscale is Item 21- Caregiver smiles or touches child within 5 seconds after the child smiles or vocalizes. The Caregiver Contingency Total is the sum of scores on all the contingency items across the Caregiver subscales. The Infant Contingency total is the sum of scores on all the contingency items across the Infant subscales, which derive solely from the Responsiveness to Caregiver subscale (i.e., the Clarity of Cues subscale does not contain any contingency items). The Overall Contingency Total is obtained by summing the Caregiver and Infant contingency total scores.

Interactions between infants and their primary caregivers were observed and videotaped during a structured teaching situation, in which caregivers were asked to select a novel activity from a list of activities and attempt to teach it to their child. In order to identify the primary caregiver, parents were asked if they were the main caregiver of the child. In most cases, this was the mother of the child. However, some mothers, due to working at the plantation for long hours, identified another family member (i.e., father, grandmother, aunt or close friend) as the primary caregiver. Caregivers were given a list of activities (Appendix G) and guided by myself to choose an age- and developmentally-appropriate activity that the child could not yet perform (i.e., the first activity on the list that they had not yet observed the child perform). They were given the materials needed to teach the activity to their child and asked to attempt to teach the activity to their child. It was emphasized that the child's successful completion of the activity was not important; rather, it was important that they try to engage and teach their child how to perform the activity. If the activity was found to be too easy or too difficult for the child, caregivers were guided in selecting a different activity. Care was taken to ensure the activity chosen was not more than six months in advance of the child's age. Interactions were videotaped for later coding. In the case that multiple trials were needed (i.e., if an easier/more challenging activity was selected), only the final trial was videotaped and coded.

At the completion of the task, caregivers were given a small token of appreciation (i.e., a children's story book) for participating in this study. In line with the community-participatory nature of the overall study and with NCATS recommended guidelines, participants were also provided with brief, individualized verbal feedback based on observations during the NCATS. Aspects of caregiving that were observed to be positive and areas for improvement during the interaction were conveyed to caregivers. Risky or maladaptive aspects of the interaction (i.e., determined a priori by the researchers as any harsh or maladaptive caregiving behaviour) were also conveyed to caregivers if any were observed. An informal discussion also took place with caregivers to discuss any concerns they had about their infant's development, caregiving or about their relationship with their children. They were provided with recommendations to promote positive caregiving practices and stimulate the healthy development of their children, as targeted to their concerns and/or observed areas for improvement.

Each video was independently coded at York University by two certified raters (i.e., myself and an undergraduate research assistant), who each underwent a three-day training on the NCATS. Scores on the reliability testing at the end of the training were compared with scores by the NCATS developers and raters achieved the required research reliability of 90% in the administration and scoring of the NCATS. Both raters were fluent in Spanish. For the first few (i.e., pilot) videos, raters consulted with each other after independently coding each video in order to discuss the process and resolve any differences. The remaining videos were independently coded and the raters compared scores after coding all videos. Given that the inter-rater reliability did not reach the minimum 0.80 threshold identified a priori, a histogram was constructed of the differences between raters on the total scores in order to identify outliers. A total of 11 outliers were identified where there were large discrepancies between raters' scores. The discrepant items were identified for the 11 videos and each rater then independently re-coded each of those videos, paying special attention to the discrepant items. Any further discrepancies were resolved by mutual agreement and a revised inter-rater reliability was calculated (ICC = 0.89).

Assessment of one-year infant neurodevelopmental outcomes

Infant neurodevelopmental outcomes were assessed when infants were one year of age and took approximately one hour. Every attempt was made to conduct the evaluation within 15 days of the infant's first birthday. The assessments had been completed with all infants in the study sample prior to the evaluation of caregiver-infant interactions. The neurodevelopmental outcomes were assessed using the Bayley Scales of Infant Development-Third Edition (Bayley-III; Bayley, 2006), which measures outcomes in the domains of cognitive, language (receptive and expressive communication), motor (gross and fine motor), and social-emotional development. The Bayley-III can be administered to children between 1 and 42 months of age, and was standardized on a demographically stratified sample of 1700 children, matched to the 2000 U.S. census sample (Bayley, 2006). The Bayley-III was selected as a measure in the larger study for several reasons, including its feasibility and wide application, the limited availability of other measures of infant neurodevelopment in the Spanish language, and the use of this measure in other longitudinal studies of prenatal pesticide exposure (e.g., Eskenazi et al., 2007).

Brief descriptions of each Bayley scale and subtest are provided here (Bayley, 2006). The social-emotional scale is measured by a parent questionnaire whereas the remaining scales are administered with child interaction. Items on the *Cognitive scale* of the Bayley-III assess how infants think, react and learn about the world around them (i.e., sensorimotor development, concept formation, memory, etc.). The *Language scale* consists of two subtests: Receptive and Expressive communication. The *Receptive Communication subtest* assesses infants' ability to recognize sounds and understand spoken words and directions, whereas the *Expressive Communication subtest* evaluates infants' ability to communicate using sounds, gestures or words. The *Motor scale* is also comprised of two subtests: Fine and Gross motor. The *Fine Motor subtest* measures infant's perceptual-motor integration and functional hand skills among other aspects. The *Gross Motor subtest* assesses movements of overall limbs and torso, including balance and motor planning. Finally, the *Social-Emotional scale/questionnaire* assesses infants' acquisition of important social and emotional milestones (i.e., self-regulation, communication of needs, use of emotional gestures, etc.). This parent-report questionnaire consists of 35 items in total, and each item is rated on a 6-point Likert scale (0=can't tell, 1=none of the time, 2=some of the time, 3=half of the time, 4=most of the time, and 5=all of the time).

The neurodevelopmental assessments were conducted by two trained research staff from the ISA research team at an office rented by the IRET program, and mother-infant dyads were transported by research staff from their home to the office within a research vehicle. Assessments were done at this office location rather than the infant's home due to lack of a quiet space and presence of many distractions in many homes. One member of the research team carried out the assessment with the child and parent whereas the other member assisted with child-minding. The research assistants/ evaluators of the Bayley-III received training by a neuropsychologist in the application and interpretation of the Bayley-III and were masked to the level of pesticide exposure of the infants and mothers.

Maternal and socio-demographic factors

Several child, maternal/caregiver, and social-environmental variables were considered as potential confounders in the statistical analyses. At the time of the infant neurodevelopmental assessment, mothers completed several questionnaires to assess their depression status, quality of the home environment, and perceived social support. All measures were translated and administered to mothers in Spanish.

Mothers completed the Centre for Epidemiological Studies-Depression Scale (CES-D; Radloff, 1977) to assess their level of depression. This self-report questionnaire consists of 20 items, each rated on a four-point Likert scale based on how often each feeling or behaviour associated with depression is experienced in the past week (i.e., rarely or none of the time, some or a little of the time, occasionally or a moderate amount of the time, most or all of the time). The scores range from 0 to 60, with a score of 16 used as a cutoff to indicate risk for depression in the general population (Radloff, 1977).

The Wechsler Abbreviated Scales of Intelligence (WASI; Wechsler, 1999), two-subtest version, was also administered to mothers at this visit in order to estimate mothers' overall intellectual functioning. The two-subtest version consists of the Vocabulary and Matrix Reasoning subtests, which contribute to an overall estimated intellectual quotient (IQ). Raw scores were converted to age-standardized scores using U.S. normative data.

A selection of items from the Short-Form of the Home Observation for Measurement of the Environment (HOME-SF), a modification of the HOME inventory for infants/toddlers (Caldwell & Bradley, 1984), was also administered during this visit. The selection of items followed what has been done in the CHAMACOS study (Eskenazi et al., 2007) and was adapted for use in the Matina county. The HOME-SF was utilized in the National Longitudinal Survey of Youth 1979 and developed in conjunction with the developers of the original HOME (see National Longitudinal Surveys Bureau of Labor Statistics, 1979 for details on methods). The HOME is designed to evaluate the perceived quality and quantity of stimulation and support available to the child in the home environment, as assessed by the mother. While the original HOME consists of 45 items, the HOME-SF consists of 18 items, 12 of which were selected and utilized in the questionnaire administered in the present study. The items that were not culturally relevant to the study population were not retained. Thus, the modified HOME-SF scale used in the present study consisted of 12 items in total (see Appendix H for the English version) and was completed by the mothers. Each item was recoded to a dichotomous (0/1) scoring scheme, in line with the scoring guidelines of the HOME-SF, and the sum was computed. The total possible score is 12, with higher scores reflecting a more favourable home environment.

Mothers also completed a measure to assess perceived level of social support. This measure was an adaptation of the Duke-UNC Functional Social Support

Questionnaire (FSSQ; Broadhead, Gehlback, De Gruy, & Kaplan, 1988), which has also been utilized in the CHAMACOS study (see Harley & Eskenazi, 2006 for complete details on the development of the modified version). Briefly, two additional items were added to the original version in order to measure instrumental support (i.e., assistance with tasks and material needs), an aspect that is not measured by the FSSQ (Harley & Eskenazi, 2006). The modified version consists of 10 items, each rated on a 5-point Likert scale based on how strongly one agrees with each item, ranging from 5 (as much as I would like) to 1 (much less than I would like) (see Appendix I for the English version). Total scores range from a minimum possible score of 10 to a maximum possible score of 50, with higher scores reflecting greater levels of perceived social support.

Information on socio-demographic factors was collected during previous home visits. This includes information on mother's and fathers' total years of education, immigrant status (native Costa Rican or immigrant), marital status (married/living together or single), total number of children, and total family income. Pregnancy-related information (i.e., whether the mother performed any agricultural work during pregnancy, substance use during pregnancy) was also obtained through previous home visits. During the NCATS assessment, information was also collected about the child's age, sex and parity, caregiver's age, the time taken to complete the NCATS, and whether other individuals were present during the assessment.[4]

Prenatal pesticide exposure level

The ISA research team is conducting analyses to determine the most sensitive predictor of the level of prenatal pesticide exposure. Maternal urine samples from the larger study sample show a strong inverse association between the concentration of urinary ethylenethiourea (ETU), a metabolite of mancozeb, and residential distance to

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[4] This information was noted as there were often others present during the time of the NCATS assessment; however, the presence of others was not always distracting and disruptive for the child. This information is also conveyed by one of the items on the NCATS (i.e., item 34).

the banana plantation (van Wendel de Joode et al., *accepted*), reflecting higher ETU concentrations for those living nearer to plantations. Geographic Information Systems (GIS) mapping was used to document residential coordinates and coordinates of banana plantations within a 5-kilometre radius of each home. Urine samples were analyzed at the Laboratory of the Department of Occupational and Environmental Medicine, Lund University Hospital, Sweden. Analyses of the other biological samples are currently underway. Thus, residential distance to banana plantation (in metres) was utilized as a proxy in the present study for the level of prenatal pesticide exposure, with shorter distances (i.e., greater immersion of the residence in the banana plantation area) indicative of higher levels of prenatal pesticide exposure.

Data analyses

Descriptive and socio-demographic characteristics of participants were examined, along with descriptive behaviours of the quality of caregiver-infant interactions. An item analysis was carried out to identify the items that most contributed to low scores on NCATS subscales, in order to determine negative aspects of caregiving interactions in the sample. This was done by identifying the items in each NCATS subscale that were observed in less than 50% of the study sample. The item analysis also identified items that were seen in the majority (i.e., in greater than 75%) of the study sample, in order to determine positive aspects of caregiving interactions in the sample. Caregiver-infant interaction scores were compared to the normative data for the U.S. Hispanic population, provided in the NCATS manual. The Hispanic normative group was selected as a comparison group in order to obtain a descriptive comparison of caregiving behaviours relative to a Spanish-speaking sample that was as similar as possible to the study sample. The 10th percentile cutoff for the Hispanic sample, for mothers having infants between 13 and 36 months, was used to determine the proportion of participants in our sample having Overall, Caregiver total, and Infant total scores at/below this cutoff.[5] These indicated the proportion of dyads with "worrisome scores" or less than optimal interactions (Sumner & Spietz, 1994). Data were also compared to given normative data for adult mothers aged 19 to 25 years with low education (i.e., less than 12 years) and t-tests were conducted to examine differences. Each independent and dependent variable was checked for assumptions of normality by visualization of histograms. To examine associations between the quality of caregiver-infant interactions and infant neurodevelopmental outcomes, two-tailed Pearson product-moment correlations were first used to examine associations between NCATS total and subscale scores and the Bayley-III scale scores. Two-tailed correlations were also conducted between maternal and socio-demographic factors and each of the Bayley-III outcome variables (i.e., cognitive, language, motor and social-emotional). Correlations were checked for multicollinearity (see Table 8) and, if variables were highly and significantly correlated (Pearsons' $r > 0.80$, $p < .01$), only one of them was entered into the regression analyses. The NCATS Caregiver-Child overall interaction total was found to be highly correlated with the Caregiver Total and with the Child Total; thus, only the Overall Interaction Total was considered in analyses. Maternal education was moderately correlated with paternal education and significantly correlated with family income, social support and with the NCATS overall interaction total. Given these associations and the availability of complete data for this variable, only maternal education was considered in analyses as a proxy for socioeconomic status.

Hierarchical linear regression analyses were performed separately for each of the Bayley-III outcome variables (i.e., the four scales and four subtests) to examine the independent associations between the overall quality of caregiver-infant interaction (i.e.,

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[5] The NCATS manual includes 10th percentile cutoffs for two other ethnic groups (Caucasians and African-Americans). The Hispanic group was deemed to be the most similar group for comparison and its cutoff scores were lower than that of the other two groups. However, the cutoff scores provided by the NCATS are based on the subsample of mothers who were at least 20 years of age and who had at least 12 years of education. Hence, our study sample significantly differs from the NCATS Hispanic sample with respect to the years of education. The comparisons are performed purely for a descriptive purpose as we were interested in identifying the proportion of families that were most at risk (i.e., proportion having scores at/below the 10th percentile cutoff).

NCATS Overall Interaction score) and each neurodevelopmental outcome, after adjusting for residential distance to banana plantation and important covariates. Each child-related, maternal and socio-demographic variable indicated above was considered as a potential covariate, and a variable was included in the multivariate model if its p-value was <0.05 in the bivariate analysis or if it was considered theoretically important to adjust for based on prior research. Care was taken to limit the amount of covariates in the model as a result of the low sample size as well as to keep all regression models consistent; thus, only those variables that were significant and/or deemed theoretically important were entered into the model, and all models were the same for each outcome variable. Residuals of regression models were checked for normality and outliers. Thus, eight separate regression models were created, one for each of the four Bayley-III scales (i.e., Cognitive, Language, Motor and Social-Emotional) and for each of the four subtests (i.e., Receptive Communication, Expressive Communication, Fine Motor and Gross Motor), with standardized scores utilized for each. The hierarchical regression models were designed in the following way for each outcome: child sex, caregiver age, and maternal education were entered as control variables in Block 1; residential distance to plantation was entered in Block 2; and the NCATS Caregiver-Infant Overall Interaction score was entered in Block 3. All data were analyzed using an alpha level of .05 and effect sizes were tabulated.

RESULTS

Descriptive characteristics of the study sample

Table 2 summarizes the descriptive characteristics of caregiver-infant dyads and socio-demographic characteristics of the study sample. All variables were normally distributed, with the exception of Maternal IQ, Maternal depression, and residential distance to banana plantation; these variables were all log-transformed before inclusion in the bivariate and multivariate linear regression analyses.

Infants were on average 13.12 months of age at the time of the Bayley-III assessments and 21.20 months at the time that the NCATS was administered. A total of 60% of the infants were male and 38.3% were first-born children. The average age of primary caregivers at the time of NCATS administration was 27.70 years, with a modal age of 21 years. The majority of caregivers (88.3%) were biological mothers of the children, and the remainder of caregivers included biological fathers, grandparents, extended family members or close friends of the mother.

In terms of maternal characteristics, 71.3% of mothers were married or living as married and had an average of 7.18 years of education. This was similar to fathers' level of education of 7.10 years. Mothers were given measures of IQ, depression and social support at the time of the Bayley-III assessments. Mothers' estimated mean IQ was well below the average range (Median Full Scale IQ = 65.50, IQR = 58 to 75), and they performed similarly on both the Vocabulary subtest (Median T score = 25.50, IQR = 20 to 31.75) and the Matrix Reasoning subtest (Median T score = 25.50, IQR = 20 to 34.75). On average, mothers reported symptoms of depression that fell within the normal range (Median CES-D score = 14, IQR = 7.50 to 25) and high levels of social support (Median score = 42 out of 50, IQR = 34 to 47). However, almost half the sample had CES-D scores equal to or above the cutoff score of 16, reflecting a risk for depression. Other maternal demographics were also examined, such as immigrant status, use of substances and performance of agricultural work during pregnancy. Approximately 18% of the mothers were immigrants from neighbouring countries. In terms of prenatal high-risk behaviour, few mothers (8.5%) reported using substances (i.e., smoking, drug or alcohol use) during pregnancy and 16% of mothers engaged in agricultural work during pregnancy.

With regard to socio-demographic characteristics, the median reported family income was $120 US per month (IQR = $82.87 to $175). The quality of the home environment, as measured by the modified HOME scale, was a mean score of 8.03 out of 12 (range = 5 to 11), indicating a moderate amount of cognitive stimulation and emotional support provided to the children by their families. Finally, the level of estimated exposure to pesticides, measured by the family's residential distance to the banana plantation, was a median distance of 266.86 metres (IQR = 43.50 to 712.31). A map of residential locations of the participants was constructed (Figure 3), which showed that participants in the present study came from 27 different villages spread throughout the Matina county, reflecting the range of the ISA study sample.

In order to better characterize the sample, birth outcomes were examined. Maternal report of birth outcome data (Table 3) showed that the mean gestational age of the child was 39.6 weeks (range = 31.4 to 43.6 weeks), and 7.5% of the infants were born premature (less than 37 weeks gestational age). A total of eight children (8.6%) were born via caesarian section. A significant proportion of women (15.1%) reported previous abortions. In contrast, the number of women reporting previous stillbirths was low (2.2%) as was the number of women reporting previous births who died within or after the first week (2.2%).

T-test analyses were performed to examine whether socio-demographic characteristics differed between levels of categorical variables, such as sex of child, parity, mothers' marital status, maternal immigrant status, use of substances during pregnancy, and performance of agricultural work during pregnancy. No significant differences were seen on any of the variables except immigrant status. Immigrant mothers lived on average nearer to the banana plantation (median distance = 72 metres) compared to native Costa Rican mothers (median distance = 318 metres) (p<.05).

The present study sample did not differ significantly from the overall ISA study sample, with regard to the main demographic characteristics (e.g., child's age at time of Bayley-III, child's sex, mother's age, marital status, maternal education, family income, residential distance), supporting the representativeness of the present study sample.

Figure 3: Map of study villages in Matina county showing residential locations of study participants

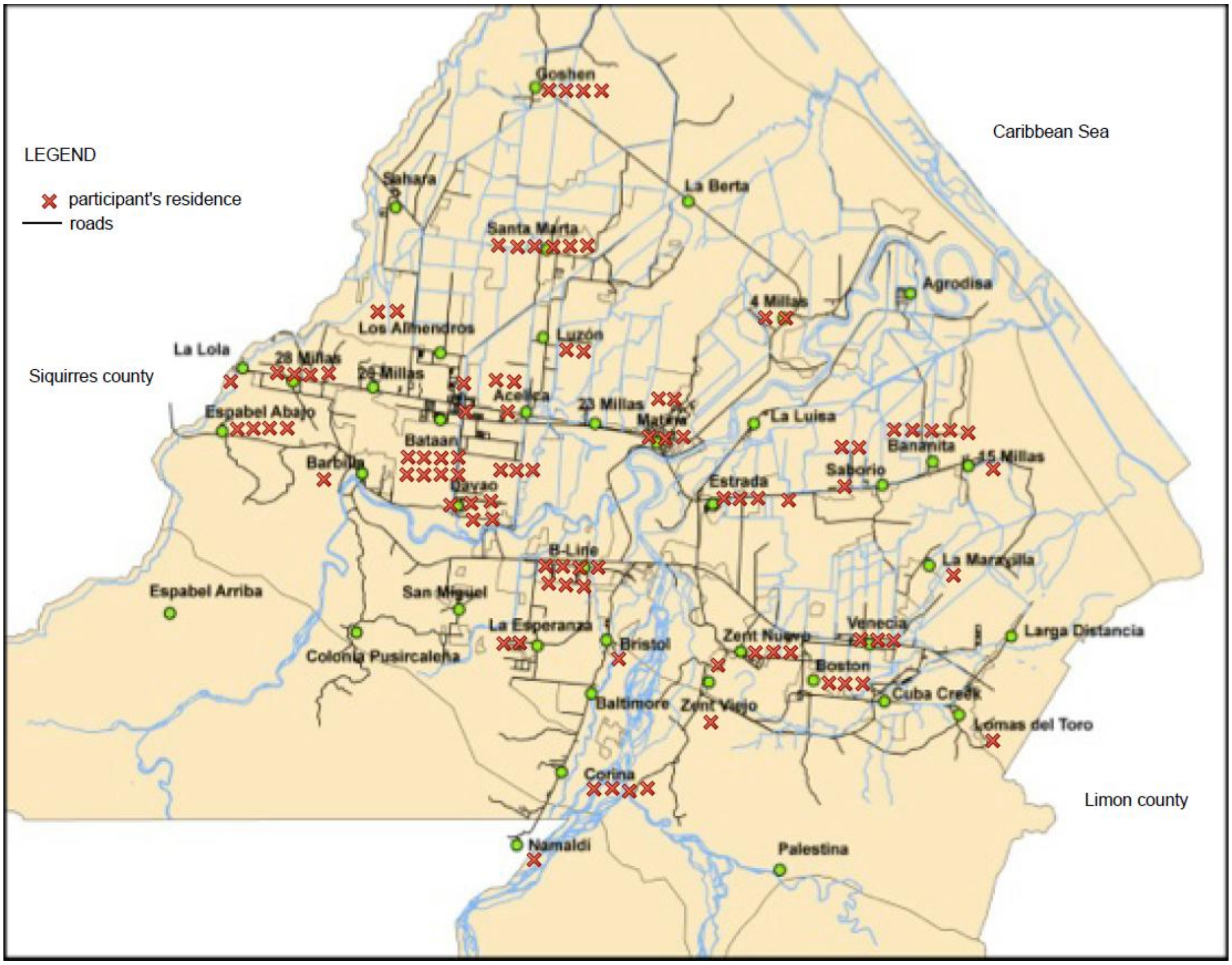

Table 2: Descriptive characteristics of study sample

Characteristic	*n*	Mean (SD) or *n* (%)	Range
Child characteristics			
Child's age at time of NCATS (months)	94	21.20 (3.45)	13 to 30
Child's age at time of Bayley-III (months)	94	13.12 (1.34) Mdn=12.64	11.43 to 17.20 IQR=12.06 to 14
Child's sex (% males)*	94	56 males (60%)	n/a
Child's birth order (% first-born)	94	36 (38.3%)	n/a
Caregiver/parent characteristics			
Proportion of caregivers who were biological mothers	94	83 (88.3%)	n/a
Caregiver's age at time of NCATS (years)	94	27.70 (9.70) Mo=21	13 to 70 IQR=21 to 31
Caregiver's age at time of NCATS for only biological mothers (years)	83	25.81 (6.05)	16 to 43
Mother's age at birth of child (years)*	94	24.33 (6.10)	15 to 41 IQR=19 to 29.25
Mother's marital status (% married or living as married)*	94	67 (71.3%)	n/a
Mother's level of education (total years)*	94	7.18 (2.50)	1 to 12
Father's level of education (total years)*	81	7.10 (2.88)	0 to 16
Mother's IQ (WASI Full Scale IQ)*	92	67.51 (10.53) Mdn=65.50	55 to 100 IQR=58 to 75
Maternal depression (CES-D total score out of 60)*	93	17.24 (11.41) Mdn=14	0 to 48 IQR=7.5 to 25
Maternal social support (score out of 50)*	93	39.31 (9.30) Mdn=42	15 to 50 IQR=34 to 47
Proportion of mothers who are immigrants (vs. native Costa Rican)*	94	17 (18.1%)	n/a
Proportion of mothers who used any substances (i.e., smoking, drugs or alcohol) during pregnancy*	94	8 (8.5%)	n/a
Proportion of mothers who performed any agricultural work (including work at banana plantation) during pregnancy*	94	15 (16.0%)	n/a
Social-environmental characteristics			
Family income per capita (USD per month)*	84	$139.33 (78.78)	$16 to 380
Residential distance to banana plantation (metres)*	94	538.9 (736.8) Mdn=266.9	0.30 to 3131.5 IQR=44 to 712
Quality of home environment (HOME score out of 12)*	94	8.03 (1.41)	5 to 11

Mdn=Median   Mo=Mode   IQR=Interquartile range
HOME=Home Observation for the Measurement of the Environment scale
**Not significantly different from the overall ISA study sample*

Table 3: Maternal report of birth outcomes (*n*=93)

	Mean (SD) or *n* (%)	**Range**
Gestational age (weeks)	39.62 (2.04)	31.4 to 43.6
Proportion of infants born premature (less than 37 weeks)	7 (7.5%)	n/a
Proportion of infants born via caesarian section	8 (8.6%)	n/a
Proportion of women reporting previous stillbirths	2 (2.2%)	n/a
Proportion of women reporting previous children who died within or after first week	2 (2.2%)	n/a
Proportion of women reporting previous abortions	14 (15.1%)	n/a

Quality of caregiver-infant interactions

The quality of caregiver-infant interactions, as measured by the distribution of scores on the NCATS assessments, can be seen in Table 4. Scores for the Overall Caregiver-Infant Interaction Total, Caregiver Total, Infant Total, and subscales were all normally distributed. Descriptive characteristics of the NCATS assessment context are not shown in a table but are described here. At the time the NCATS was administered, infants were on average 21.2 months old. The average teaching time taken by caregivers was around three minutes, which is within NCATS guidelines (Sumner & Spietz, 1994). A total of 17 caregivers (18%) needed more than one trial to teach the task. This was either because the task they initially chose for their children was too easy or too difficult, or because caregivers were uncertain and were assisted with choosing a task that was developmentally appropriate for the child. In the case that this task was too easy or too difficult, the next task on the list was attempted. The very last trial was coded in every case. The majority of infants (90.4%) were in the “quiet alert” state during the teaching interaction, which is considered the ideal state for the administration of this task. The remaining nine children were in the “active alert” state, which is also considered an acceptable state for this task.

The mean overall Caregiver-Infant Interaction score was 49 out of a maximum score of 73 points. The average Caregiver total score was 33.6 out of a maximum score of 50, and average Infant total score was 15.3 out of a maximum score of 23. Overall, the infants' contribution to the interaction, as represented by the Infant Total score and the infant subscale scores, was higher relative to caregivers' contribution.

For descriptive purposes, the NCATS subscale and total scores were compared to the normative data for the U.S. Hispanic sub-sample, provided within the NCATS manual. Descriptive characteristics of the study sample were compared to the NCATS Hispanic sub-sample (see Table 5). The two samples were similar with respect to child's sex, birth order, caregiver age, and mothers' marital status. They were different with respect to the child's age (i.e., the present study sample was older than the NCATS Hispanic sample), and to the mother's level of education (i.e., the present study sample had a lower level of education). Compared to the NCATS U.S. Hispanic sample, approximately 35% of the present study sample had overall Caregiver-Infant Interaction scores at or below the 10^{th} percentile cut-off score, indicating less than optimal interactions (i.e., 'worrisome cases'). A greater proportion of caregivers (47.9%) had less than optimal interactions (i.e., 47.9% of the Caregiver Total scores were at/below the 10^{th} percentile), compared to infants (i.e., 18.1% of the Infant Total scores were at/below the 10^{th} percentile).

A separate analysis was done to compare the results of this sample to normative data provided in the NCATS manual for a sub-sample of low education adult mothers (i.e., those who were between 19 and 25 years of age at the time of the child's birth and had less than 12 years of education, with an average level of education of 9.79 years). This normative data was adjusted for child's age (i.e., children ranged from 1 to 36 months of age at the time of the NCATS assessment). The results of this comparison can be seen in Table 6. These analysis showed that the mean Overall Interaction score was lower, compared to the normative data for mothers with low education (t=2.81, p<.01). While not significant, most of the infants in our sample had higher mean scores on the Infant scales, and the Infant Contingency total score was significantly higher in our sample (t=2.14, p<.05). In contrast, the caregivers in our sample had significantly lower mean scores on the Caregiver total (*t*=4.87, p<.0001), the Caregiver Contingency score (*t*=4.90, *p*<.0001), as well as most Caregiver scales (*p*<.001 for all). The exception to this was the Sensitivity to Cues subscale on which scores were similar.

An analysis of the items on each subscale (i.e., Table 7) showed that caregivers lost the greatest number points on the Cognitive Growth Fostering and Social-Emotional Growth Fostering subscales, as shown by the proportion of caregivers who displayed each item/behaviour. Items on the Social-Emotional Growth Fostering subscale that most contributed to low scores included items related to praising or cheerleading of child's effort, displaying non-verbal affection, and appropriate positioning of child (i.e., face-to-face for at least 60% of the interaction to allow for eye contact). Behaviours on the Cognitive Growth Fostering subscale that most contributed to low scores included items relating to describing perceptual qualities of materials, verbal acknowledgement of improvement (i.e., through verbal praise, smiling and/or nodding), allowing for non-task manipulation of task materials, and signalling completion to child verbally or non-verbally. Most caregivers responded sensitively to their infants' cues (i.e., Sensitivity to Cues subscale), with the exception of two items related to the allowance for exploration prior to the first instruction (i.e., 7 out of 94 caregivers allowed for exploration) and the provision of praise for child's successes or partial successes (i.e., 31 out of 94 caregivers provided praise during the interaction). On the Response to Child's Distress subscale, which was only scored if the child displayed potent distress cues (i.e., displayed by 61.7% of children), fewer than half of the caregivers diverted child's attention or paused the teaching episode in response to the distress (i.e., 36 and 40 out of 94 caregivers, respectively). However, the majority of caregivers avoided displaying negative responses to child's distress (i.e., by yelling, using abrupt movements, or making negative comments to the child).

An analysis of the two Infant subscales showed that the majority of infants displayed very clear cues during the interaction, including facial cues, motor activity, vocalizations and disengagement cues. With regard to infants' Responsiveness to Caregiver, several behaviours were displayed by less than half of the infants in the sample. These behaviours included items relating to smiling at caregiver following the caregiver's verbalization or non-verbal behaviour, and looking at caregiver when caregiver attempts to establish eye contact. Nevertheless, most infants were able to follow caregivers' alerting behaviour (i.e., 92 out of 94 infants) and approximately three-quarters of the sample vocalized or babbled in response to caregiver's vocalization (i.e., 67 out of 94 infants) or non-verbal behaviour (i.e., 69 out of 94 infants).

The profile of caregiver-infant interaction scores was examined for covariates. Overall, the Caregiver Total scores differed by sex of the child, with caregivers of female children (n=38) having higher Caregiver Total scores than caregivers of male children (n=56; $p<.05$). First-born children (n=36) also had slightly higher Caregiver Total scores than multiparous children (n=58; $p=.04$).

Table 4: NCATS scores in the study sample (*n*=94)

	Mean (SD) or *n* (%)	**Range**
Average time teaching (seconds)	181.6 (77.1)	81 to 452
Proportion of infants displaying potent distress	58 (61.7%)	n/a
Caregiver scales		
Sensitivity to cues (maximum=11)	8.32 (1.00)	6 to 11
Response to distress (maximum=11)	8.69 (2.09)	5 to 11
Social-emotional growth fostering (maximum=11)	7.26 (1.30)	4 to 11
Cognitive growth fostering (maximum=17)	9.36 (2.33)	3 to 15
Caregiver total (maximum=50)	33.63 (4.47)	23 to 44
Caregiver contingency items total (maximum=20)	11.44 (3.02)	3 to 18
Proportion with Caregiver total at/below 10th percentile cutoff score (score of 33 out of 50)*	45 (47.9%)	n/a
Infant scales		
Clarity of cues (maximum=10)	7.94 (1.37)	5 to 10
Responsiveness to caregiver (maximum=13)	7.38 (2.12)	2 to 13
Infant total (maximum=23)	15.32 (3.13)	8 to 23
Infant contingency items total (maximum=12)	6.89 (1.94)	2 to 12
Proportion with Child total at/below 10th percentile cutoff score (score of 11 out of 23)*	17 (18.1%)	n/a
Caregiver-Infant Interaction Overall Total (maximum=73)	48.95 (5.70)	35 to 61
Caregiver-Infant contingency items total (maximum=32)	18.70 (4.20)	7 to 29
Proportion with Overall total at/below 10th percentile cutoff score (score of 46 out of 73)*	33 (35.1%)	n/a

**Compared to NCATS U.S. Hispanic normative sub-sample (n=311); indicates the proportion of caregiver-child dyads most at risk (i.e., with “worrisome scores” or less than optimal interactions)*

Table 5: Descriptive characteristics of study sample compared to NCATS U.S. Hispanic subsample

Characteristic	**Study sample (n=94) M (SD) or *n* (%)**	**NCATS Hispanic subsample (n=311) M (SD) or *n* (%)**	***p***
Child's age at time of NCATS (mths)	21.2 (3.5)	14.2 (9.5)	<.001
Child's sex (% males)	56 (60%)	171 (55%)	n.s.
Child's birth order (% first-born)	36 (38.3%)	98 (31.5%)	n.s.
Caregiver's age at time of NCATS (years)	27.70 (9.70)	28.46 (5.14)	n.s.
Mother's marital status (% married or living as married/with partner)	67 (71.3%)	245 (79.0%)	n.s.
Mother's level of education (total years)	7.18 (2.50)	12.17 (2.85)	<.001

Table 6: Comparison of NCATS scores for study sample and NCATS subsample of low-education adults*

NCATS Teaching Scales	Study sample (n=94) Mean (SD)	NCATS Low Education Adults* (n=160) Mean (SD)	*t*	*p*
Caregiver scales				
Sensitivity to cues	8.32 (1.00)	8.56 (1.90)	1.14	n.s.
Response to distress	8.69 (2.09)	9.96 (1.88)	4.99	<.0001
Social-emotional growth fostering	7.26 (1.30)	8.27 (2.06)	4.28	<.0001
Cognitive growth fostering	9.36 (2.33)	10.95 (3.68)	3.77	<.001
Caregiver Total score	33.63 (4.47)	37.74 (7.43)	4.87	<.0001
Caregiver Contingency score	11.44 (3.02)	14.73 (4.21)	4.90	<.0001
Child scales				
Clarity of cues	7.94 (1.37)	7.85 (1.62)	0.45	n.s.
Responsiveness to caregiver	7.38 (2.12)	6.68 (3.60)	1.72	n.s.
Child total score	15.32 (3.13)	4.53 (4.85)	1.42	n.s.
Child Contingency score	6.89 (1.94)	6.08 (3.35)	2.14	<.05
Overall Interaction score	48.45 (5.70)	52.26 (10.55)	2.81	<.01

**NOTE: Low education adults were defined as 19 to 25 years of age (average age = 21.20 ± 1.86) with less than 12 years of education (average years of education = 9.79 ± 1.38); scores were adjusted for child's age (range 1 to 36 months)*

Positive and negative characteristics of caregiver-infant interactions

Based on the item analyses on the NCATS as well as general observations during the administration of the task, positive and negative characteristics were compiled. Table 7 shows the proportion of the study sample that displayed each behaviour (i.e., received a score of “1” on the NCAST item). Wide variation was seen across all subscales and differences were usually due to subtle aspects of the interaction.

With regard to the positive aspects of interactions, in general no harmful or negative caregiving behaviours (i.e., yelling, scolding, making negative comments about child) were displayed. Infants overall showed very clear cues and were generally quite responsive to their caregivers. The majority of caregivers used a soothing, calm and affectionate tone in their interactions. Moreover, some caregivers displayed a balance of warm and responsive behaviour, allowing time for infants to respond and reciprocate.

With regard to negative aspects of interactions, lack of verbalization was observed in many of the infants, and this appeared to be associated with the amount of verbalization displayed by caregivers during the interaction. Many caregivers also reported the lack of verbalization of their children as a concern for them. Few caregivers were observed to provide praise, cheerleading, encouragement or verbal or non-verbal acknowledgment of success, which is also concordant with the results of the item analyses. Many caregivers (i.e., 44 out of 94) did not position the child to provide for eye contact and, consequently, lost points on other items on the NCATS that were contingent upon positioning. Finally, other individuals (i.e., family members, relatives, friends) were present during 51.1 percent of the interactions, and there were other unavoidable distractions (i.e., traffic noise, animals) during other interactions. However, for the majority of the children, this was not observed to be disruptive or distracting and caregivers maintained a quiet immediate environment that was relatively free of disruptions.

Table 7: Items on NCATS and the proportion of study sample (out of *n*=94) displaying each behaviour

Item/behaviour	**Proportion of sample (out of *n*=94) displaying behaviour**
Sensitivity to cues subscale	
1. Caregiver positions child so child is safely supported.	94
2. Caregiver positions child so that child can reach and handle teaching materials.	93
3. Caregiver gets the child's attention before beginning the task, at the start of the teaching interaction.	94
4. Caregiver gives instruction only when child is attentive (90% of the time).	88
5. Caregiver allows child to explore the task material for at least five seconds before giving the first task-related instruction.	7
6. Caregiver positions child so that it is possible for them to have eye-to-eye contact with one another during the majority of the teaching episode (60% of the time).	68
7. Caregiver pauses when child initiates behaviours during episode.	70
8. Caregiver praises child's successes or partial successes	31
9. Caregiver asks for no more than three performances when child is successful at completing the task.	66
10. Caregiver changes position of child and/or materials after unsuccessful attempt by the child to do the task.	78
11. Caregiver avoids physically forcing the child to complete the task.	92
Response to Child's Distress subscale	
12. Caregiver stops or pauses the teaching episode.	40
13. Caregiver makes positive, sympathetic, or soothing verbalization.	56
14. Caregiver changes voice volume to softer or higher pitch, does not yell.	82
15. Caregiver rearranges the child's position and/or task materials.	79
16. Caregiver makes soothing non-verbal response, e.g., pat, touch, rock, caress, kiss.	57
17. Caregiver diverts the child's attention by playing games, introducing a new toy.	36
18. Caregiver avoids making negative comments to the child.	94
19. Caregiver avoids yelling at the child.	94
20. Caregiver avoids using abrupt movements or rough handling.	92
21. Caregiver avoids slapping, hitting or spanking.	94
22. Caregiver avoids making negative comments to home visitor about the child.	93
Social-emotional Growth Fostering subscale	
23. Caregiver's body posture is relaxed during the teaching episode (90% of the time).	93
24. Caregiver positions self face-to-face with the child during the teaching interaction (60% of the time).	44
25. Caregiver laughs or smiles at child during the teaching interaction.	90
26. Caregiver gently pats, caresses, strokes, hugs, or kisses child during episode.	27
27. Caregiver smiles, or touches child within five seconds after the child smiles or vocalizes.	67
28. Caregiver praises child's efforts or behaviours broadly (in general) at least once during the episode.	7

Item/behaviour	Proportion of sample (out of *n*=94) displaying behaviour
29. Caregiver makes cheerleading type statements to the child during the teaching interaction.	24
30. Caregiver avoids vocalizing to the child at the same time the child is vocalizing.	61
31. Caregiver avoids making general negative or uncomplimentary remarks about the child.	93
32. Caregiver avoids yelling at the child during the episode.	94
33. Caregiver avoids making critical or negative comments about the child's task performance.	80
Cognitive Growth Fostering subscale	
34. Caregiver provides an immediate environment which is free from distractions from animate sources (sibs, pets, other people, T.V.).	62
35. Caregiver focuses attention and child's attention on the task during most of the teaching (60% of the time).	84
36. After caregiver gives instructions, at least five seconds is allowed for the child to attempt the task before caregiver intervenes again.	57
37. Caregiver allows non-task manipulation of the task materials after the original presentation.	30
38. Caregiver describes perceptual qualities of the task materials to the child.	4
39. Caregiver uses at least two different sentences or phrases to describe the task to the child.	83
40. Caregiver uses explanatory verbal style more than imperative style in teaching the child.	22
41. Caregiver's directions are stated in clear, unambiguous language (i.e., ambiguous = "turn"; unambiguous = "turn the knob toward me").	33
42. Caregiver uses both verbal description and modeling simultaneously in teaching any part of the task.	72
43. Caregiver encourages and/or allows the child to perform the task at least once before intruding in on the use of the task materials.	51
44. Caregiver verbally praises child after child has performed better or more successfully than the last attempt.	23
45. Caregiver smiles and/or nods at the child after child performs better or more successfully than the last attempt.	34
46. Caregiver responds to the child's vocalizations with a verbal response.	67
47. Caregiver uses both verbal and non-verbal instruction in teaching the child.	89
48. Caregiver uses the teaching loop at least once.	51
49. Caregiver signals completion of task to child verbally or non-verbally.	30
50. Caregiver spends no more than 5 minutes and not less than 1 minute in teaching the child the task.	88

Item/behaviour	Proportion of sample (out of *n*=94) displaying behaviour
Clarity of Cues subscale	
51. Child is awake.	94
52. Child widens eyes and/or shows postural attention to task situation.	92
53. Child changes intensity or amount of motor activity when task material is presented.	73
54. Child's movements are clearly directed toward the task *or* task material *or* away from the task.	93
55. Child makes clearly recognizable arm movements during the teaching episode (clapping, reaching, waving, pounding, pointing, pushing away).	93
56. Child vocalizes while looking at the task materials.	67
57. Child smiles or laughs during the episode.	64
58. Child grimaces or frowns during the teaching episode.	18
59. Child displays potent disengagement cues during the teaching interaction.	58
60. Child displays subtle disengagement cues during the teaching interaction.	94
Responsiveness to Caregiver subscale	
61. Child gazes at caregiver's face or task materials after the caregiver has shown verbal or non-verbal alerting behaviour.	92
62. Child attempts to engage caregiver in eye-to-eye contact.	46
63. The child looks at the caregiver's face or eyes when caregiver attempts to establish eye-to-eye contact.	39
64. Child vocalizes or babbles within five seconds after caregiver's verbalization.	67
65. Child vocalizes or babbles within five seconds after caregiver's gesturing, touching or changing his/her facial expression.	69
66. Child smiles at caregiver within 5 seconds after caregiver's verbalization.	25
67. Child smiles at caregiver within 5 seconds after caregiver's gesture, touch, or facial expression changes.	25
68. When caregiver moves closer than 8 inches from the child's face, the child shows some subtle and/or potent disengagement cues.	34
69. Child shows subtle and/or potent disengagement cues within five seconds after caregiver changes facial expression or body movement.	94
70. Child shows subtle and/or potent disengagement cues within five seconds after caregiver's verbalization.	93
71. Child shows potent and/or subtle disengagement cues when caregiver attempts to intrude physically in child's use of the task materials.	43
72. Child physically resists or responds aggressively when caregiver attempts to intrude physically in child's use of the task materials.	18
73. The child stops displaying potent disengagement cues within 15 seconds after caregiver's soothing attempts.	49

Neurodevelopmental outcomes of infants

The one-year neurodevelopmental outcomes of infants, as measured by scores on the Bayley-III, can be seen in Table 8. All outcome scores were normally distributed; however, the scores on the Social-Emotional scale had a slight positive skew. All infants were evaluated at approximately one year of age (Mean assessment age = 13.12 months). According to the criteria provided by the Bayley-III manual, the overall composite scores and subtest scaled scores were within the average range, considered to be within one standard deviation (i.e., standard score between 85 and 115, and scaled score between 7 and 13). Relative to normative data, infants performed better overall on the Cognitive and Motor scales, and Gross Motor subtest scores were slightly higher than the Fine Motor subtest score. The mean Language and Social-Emotional composite scores, while within the average range, were relatively lower in the sample. Within the Language scale, infants performed more poorly on the Receptive Communication subtest than the Expressive Communication subtest, and a greater proportion of infants (12.8%) had scaled scores less than one standard deviation below the mean (i.e., less than 7) on the Receptive Communication subtest as compared with the Expressive Communication subtest (1.1 %). On the Social-Emotional scale of the Bayley-III, the mean composite score was also within the average range, and 20.2% of the sample had standard scores less than one standard deviation below the mean (i.e., less than 85). Few or none of the infants (i.e., less than or equal to 2%) performed less than one standard deviation on any of the other scales or subtests of the Bayley-III.

The profile of Bayley-III outcome scores was examined by covariates. Significant differences were noted between male and female children on the Bayley-III Language scale composite score, and on the Receptive Communication subtest scaled score, with females performing better in both cases ($p<.01$ for both). In addition, differences were seen with respect to prenatal substance use and agricultural work. Infants of mothers who used substances during pregnancy (n=8) had a lower Social-emotional scale composite score than those who did not ($p<.01$). Moreover, infants of mothers who performed agricultural work during pregnancy (n=15) had a higher Fine Motor subtest scaled score than those who did not ($p=.01$). No other significant differences were seen.

Table 8: One-year Bayley-III outcome scores for the study sample

Bayley-III Scales and Subtests	***n***	**Mean (SD)**	**Range**	**Percent < 1 SD [a]**
Cognitive scale composite (standard score)	94	100.85 (9.26)	75 – 120	2.1
Language scale composite (standard score)	93	91.74 (6.19)	74 – 109	12.9
Receptive communication subtest (scaled score) [b]	94	7.89 (1.38)	4 – 12	12.8
Expressive communication subtest (scaled score) [b]	93	9.25 (1.25)	6 – 13	1.1
Motor scale composite (standard score)	91	100.73 (8.08)	85 – 118	0
Fine motor subtest (scaled score) [c]	91	9.56 (1.68)	7 – 14	0
Gross motor subtest (scaled score) [c]	94	10.64 (1.87)	7 – 15	0
Social-emotional scale composite (standard score)	94	93.62 (12.06)	60 – 115	20.2

[a] Percent of sample having a standard or scaled score less than one standard deviation below the mean (i.e., Standard score < 85 or Scaled score < 7)

[b] Correlations between Receptive and Expressive subtests r=.34 (p=.001); Correlations between each subtest and the Language scale composite are: Receptive r=.84 (p<.001), Expressive r=.80 (p<.001)

[c] Correlations between Fine motor and Gross motor subtests r=.10 (n.s.); Correlations between each subtest and the Motor scale composite are: Fine motor r=.71 (p<.001), Gross motor r=.77 (p<.001)

Bivariate associations between independent variables and Bayley-III scores

The results of the bivariate analyses between independent variables and the Bayley-III scales and subtests are shown in Tables 9a and 9b, respectively. With regard to the NCATS, the Caregiver-Infant Interaction total score was significantly associated with the Language scale composite (r=0.237, p<.05) and the Expressive Communication subtest of this scale (r=0.293, p<.01). Moreover, infants who had a Language scale composite below one standard deviation (n=12) had significantly lower NCATS overall interaction scores (mean score = 45.50, SD = 5.14) than the remainder of infants (mean = 49.46, SD = 5.66) (p<.05). The Caregiver Total score was associated with the Motor scale composite (r=.294, p<.01), and with both the Fine and Gross Motor subtests (r=0.252, p<.05 and r=0.212, p<.05, respectively). The Caregiver and Child Total scores were both associated with the Expressive Communication subtest (r=0.207 and r=0.238, respectively; both significant at p<.05). Thus, the Expressive Communication subtest was the only Bayley-III outcome that was associated with all three NCATS total scores.

In terms of associations of outcome scores with other variables, the pattern of associations was different for each outcome. The Cognitive scale composite was associated with the child's age and caregiver's age, with older children and older caregivers having higher scores. The Language scale composite was associated with child sex, with females having higher scores, and the total number of children living in the household, with lower scores for a greater number of children. The Motor scale composite was associated with the child's age and caregiver's age, with older children and older caregivers having higher scores. The Social-Emotional scale composite was negatively associated with caregiver's age and use of substances during pregnancy, whereas it was positively associated with home environment and perceived social support.

With regard to Bayley-III subtest scores, the Receptive Communication subtest of the Language scale showed associations with child's age and child's sex, with older and female children having higher scores. The Expressive Communication subtest was negatively associated with gestational age, with higher scores seen in infants with a lower gestational age. The Fine Motor subtest was significantly associated with the age of the child, maternal intelligence and mothers' performance of agricultural work during pregnancy. Finally, the Gross Motor subtest showed a significant association with caregiver's age, with infants of older caregivers having higher scores.

Independent variables were examined in a prior analysis for multicollinearity (see Table 10). The NCATS Caregiver Total and Child Total scores were each strongly associated with the NCATS Overall Interaction score. Thus, only the Overall Interaction score was entered in the multivariate models. Maternal and Paternal levels of education were also moderately associated with each other. Maternal education was also associated with family income and social support. Given these associations as well as the availability of complete data, maternal education was entered in the multivariate models. No other variables were noted to be multicollinear.

Table 9a: Bivariate associations between independent variables and Bayley-III composite scores

Independent variables	Bayley-III scales: Cognitive scale composite (SS)	Language scale composite (SS)	Motor scale composite (SS)	Social-emotional scale composite (SS)
NCATS Caregiver-Child Interaction Overall total	.053	**.237***	.174	.119
NCATS Caregiver total	.159	.174	**.294****	.122
NCATS Child total	-.131	.184	-.101	.043
Child's age (months)	**.211***	.184	**.306****	-.196
Child's sex: Male	.077	**-.283****	-.082	-.158
Child's parity: Firstborn	-.059	.112	.110	.082
Mother's age at birth of child (years)	.142	.016	.099	-.026
Caregiver's age	**.280****	.127	**.206***	**-.276****
Maternal education (years)	-.055	.064	.051	.163
Paternal education (years)	-.074	.089	.066	.082
Maternal intelligence (Log WASI Full Scale IQ)	-.080	.108	.173	.099
Maternal depression (Log CES-D total score)	-.105	.124	.078	-.003
Mother's marital status: Married/living as married	-.018	-.138	-.058	-.103
Mother is immigrant (non-native Costa Rican)	-.173	.086	-.004	-.084
Mother used substances during pregnancy	-.063	-.015	.018	**-.267****
Mother performed agricultural work during pregnancy	.005	.057	.189	-.071
Total number of children	.018	**-.222***	-.024	-.057
Family income (USD/capita/month)	-.079	.113	-.135	.110
Residential distance to banana plantation (Log metres)	.110	.031	.063	-.054
Gestational age	-.012	-.181	.102	.046
HOME score	-.116	-.006	-.039	**.249***
Social support score	-.092	.050	-.076	**.214***

SS=Standard score
Values in **bold** indicate significance of the association:
*p<.05 **p<.01

Table 9b: Bivariate associations between independent variables and Bayley-III subtest scaled scores

Independent variables	Bayley-III subtests			
	Language scale		Motor scale	
	Receptive Communication subtest (SS)	Expressive Communication subtest (SS)	Fine motor subtest (SS)	Gross motor subtest (SS)
NCATS Caregiver-Child Interaction Overall score	.108	**.293****	.155	.127
NCATS Caregiver total	.087	**.207***	**.252***	**.212***
NCATS Child total	.072	**.238***	-.075	-.071
Child's age (months)	**.296****	-.016	**.329****	.176
Child's sex: Male	**-.297****	-.154	-.165	-.052
Child's parity: Firstborn	.088	.094	.157	-.023
Mother's age at birth of child (years)	.001	.018	.014	.135
Caregiver's age (years)	.127	.086	.062	**.269****
Maternal education (years)	.028	.076	.112	-.030
Paternal education (years)	.077	.069	.049	.043
Maternal intelligence (Log WASI Full Scale IQ)	.126	.035	**.219***	.060
Maternal depression (Log CES-D total score)	.190	-.002	.054	.064
Mother's marital status: Married/living as married	-.131	-.082	.068	-.138
Mother is immigrant (non-native Costa Rican)	.114	-.003	-.029	.027
Mother used substances during pregnancy	.049	-.076	.045	.096
Mother performed agricultural work during pregnancy	.137	-.060	**.259***	.002
Total number of children	-.212	-.171	-.042	-.007
Family income (USD/capita/month)	.075	.114	-.033	-.162
Residential distance to banana plantation (Log metres)	.038	.018	.067	.035
Gestational age	-.040	**-.266***	.091	.060
HOME score	-.090	.086	-.050	-.044
Social support score	.154	-.102	.029	-.120

SS=Scaled score
Values in **bold** indicate significance of the association:
*p<.05 **p<.01

Table 10: Correlations among independent variables

	Mother's age at birth of child	Caregiver's age	Child's age	Gestational age	Mother's years of education	Father's years of education	Total # of children	Family income	Residential distance to plantation (log)	CES-D score (log)	HOME score	Social support	Caregiver-Child Overall total	Caregiver total	Child total
Mother's age at birth of child	1	**.543****	.056	-.063	**-.257***	-.113	.033	-.090	.067	.037	-.083	-.093	-.140	-.126	-.076
Caregiver's age		1	.142	.016	-.050	-.169	-.008	-.049	0	-.005	-.021	.026	-.012	.027	-.061
Child's age			1	.194	-.076	-.061	-.079	-.157	.111	.055	.012	.139	-.054	.070	-.199
Gestational age				1	-.050	-.102	-.145	-.040	**.217***	-.039	.089	.126	.117	.188	-.056
Mother's years of education					1	**.444****	-.120	**.268***	-.153	-.094	.184	**.312****	**.270****	**.276****	.097
Father's years of education						1	**-.307****	.224	-.140	.014	.025	.139	.244*	**.233***	.109
Total # of children							1	-.089	-.065	.049	**-.253***	**-.346****	-.036	-.031	-.023
Family income								1	-.184	-.100	.153	.207	**.224***	.154	.189
Residential distance to plantation (log)									1	.067	-.029	.025	.038	.121	-.103
CES-D score (log)										1	-.030	**-.353****	.040	.095	-.065
HOME score											1	.082	.165	.147	.091
Social support												1	.073	.029	.093
NCATS Caregiver-Child Overall total													1	**.838****	**.624****
NCATS Caregiver total														1	.096
NCATS Child total															1

Values in **bold** indicate significance of the association: *p<.05 **p<.01

Multivariate, adjusted associations with Bayley-III outcomes

To assess the relationship between caregiver-infant interaction scores and Bayley performance, separate hierarchical linear regression models were constructed for each Bayley-III composite score (i.e., Cognitive, Language, Motor and Social-Emotional) and subtest scaled score (i.e., Receptive Communication, Expressive Communication, Fine Motor and Gross Motor). Child sex, caregiver age and maternal education were entered as control variables; residential distance to the banana plantation was entered in Block 2, to determine the effect of exposure after accounting for control variables; and the NCATS Caregiver-Infant Overall Interaction score was entered in Block 3, to determine the effect of caregiver-infant interaction, after controlling for control variables and pesticide exposure. These results are provided in Tables 11a through 11h.

The results of the multivariable regression analyses showed that the significant bivariate association between the NCATS overall interaction score and the Bayley-III Language scale did not hold. However, the association between caregiver-infant interaction and performance on the Expressive Communication subtest remained significant in the adjusted hierarchical model, accounting for 7.2 percent of the total variance in the overall model ($p<.05$). Infants' scores on this subtest were one point higher for every 0.26 point increase in the NCATS overall interaction score (Std. β = 0.26, 95% CI = 0.02 to 0.09), and no other variables were significant. An exploratory analysis was performed to test if the effects held even after controlling for gestational age, which was significant in the bivariate results. The model remained significant after adjusting for gestational age, and both gestational age and caregiver-infant interaction contributed significantly to the Expressive Communication subtest score, accounting for 15 percent of the variance ($p<.05$); however, the effects of caregiver-infant interaction were slightly stronger (Std. β = 0.29, 95% CI = 0.03 to 0.10) than the effects of gestational age (Std. β = -0.27, 95% CI = -0.30 to -0.05).

Sex-stratified analyses were conducted for the outcomes of Language composite, Receptive Communication scaled score and Expressive Communication scaled score to explore sex as an effect modifier. They were no significant differences between males and females in the pattern of associations and none of the associations were statistically significant or approached significance. The results of these additional analyses are included in Appendix J for reference.

Infants' scores on the Social-Emotional scale, which were significantly associated with caregiver's age in the bivariate analyses, remained significant in the adjusted model, with a one point higher composite score seen for every 0.23 year (i.e., approximately three months) decrease in caregiver age (95% CI = -0.70 to -0.04) . In an exploratory analysis including home environment in the model, the effects were stronger and home environment contributed an approximately similar proportion to the variance (Std. β = 0.20, 95% CI = -0.10 to 3.46).

None of the other Bayley-III outcomes were significant in the multivariate regression analyses.

Additional analyses were conducted to examine the pattern of associations adjusting for age of child along with the other covariates. The multivariate regression analyses stated above were repeated including age of child as an additional covariate. The inclusion of child age as a covariate did not significantly change the pattern of results. Hence, this variable was not retained in the primary analyses in order to limit the number of variables in the final regression models. The results of these additional analyses are included in Appendix K for reference.

Table 11a: Linear regression of Bayley-III Cognitive Scale composite score

	R^2	*F*	*p*	Std. *β*	*t*	95% CI
Block 1	0.041	1.30	.28			
Male sex				0.14	1.31	-1.32 to 6.42
Caregiver age				0.15	1.48	-0.07 to 0.45
Maternal education				0.02	0.15	-0.71 to 0.83
Block 2	0.057	1.35	.26			
Male sex				0.15	1.41	-1.13 to 6.62
Caregiver age				0.17	1.66	--0.04 to 0.48
Maternal education				0.03	0.33	-0.65 to 0.90
Log residential distance				0.13	1.23	-0.79 to 3.30
Block 3	0.057	1.07	.38			
Male sex				0.15	1.39	-1.18 to 6.73
Caregiver age				0.17	1.65	-0.05 to 0.48
Maternal education				0.03	0.28	-0.69 to 0.92
Log residential distance				0.13	1.21	-0.81 to 3.32
NCATS Interaction score				0.01	0.10	-0.34 to 0.37

Values in **bold** indicate significance of the test of association (p<.05)
^ marginally significant (p=.05 to .10)

Table 11b: Linear regression of Bayley-III Language Scale composite score

	R^2	*F*	*p*	**Std. β**	*t*	**95% CI**
Block 1	0.063	1.99	.12			
Male sex				-0.21^	-2.02	-5.17 to -0.04
Caregiver age				-0.10	-1.00	-0.26 to 0.09
Maternal education				0.06	0.61	-0.35 to 0.67
Block 2	0.028	1.67	.17			
Male sex				**-0.22**	-2.07	-5.27 to -0.11
Caregiver age				-0.12	-1.13	-0.27 to 0.08
Maternal education				0.05	0.48	-0.39 to 0.64
Log residential distance				-0.09	-0.85	-1.95 to 0.78
Block 3	0.034	1.65	.16			
Male sex				-0.19	-1.17	-5.02 to 0.21
Caregiver age				-0.12	-1.17	-0.28 to 0.07
Maternal education				0.02	0.14	-0.50 to 0.57
Log residential distance				-0.10	-0.95	-2.01 to 0.71
NCATS Interaction score				0.13	1.23	-0.09 to 0.38

Values in **bold** indicate significance of the test of association (p<.05)
^ marginally significant (p=.05 to .10)

Table 11c: Linear regression of Bayley-III Receptive Communication subtest Scaled score

	R^2	*F*	*p*	**Std. β**	*t*	**95% CI**
Block 1	0.039^	2.25	.09			
Male sex				**-0.25**	-2.45	-1.27 to -0.13
Caregiver age				-0.07	-0.64	-0.05 to 0.03
Maternal education				0.03	0.28	-0.10 to 0.13
Block 2	0.033	1.79	.14			
Male sex				**-0.26**	-2.49	-1.29 to -0.14
Caregiver age				-0.08	-0.74	-0.05 to 0.02
Maternal education				0.02	0.18	-0.10 to 0.12
Log residential distance				-0.07	-0.68	-0.41 to 0.20
Block 3	0.022	1.42	.23			
Male sex				**-0.25**	-2.42	-1.29 to -0.13
Caregiver age				-0.08	-0.74	-0.05 to 0.03
Maternal education				0.02	0.15	-0.11 to 0.13
Log residential distance				-0.07	-0.68	-0.41 to 0.20
NCATS Interaction score				0.02	0.11	-0.05 to 0.05

Values in **bold** indicate significance of the test of association (p<.05)
^ marginally significant (p=.05 to .10)

Table 11d: Linear regression of Bayley-III Expressive Communication subtest Scaled score

	R^2	***F***	***p***	**Std. *β***	***t***	**95% CI**
Block 1	0.026	0.78	.51			
Male sex				-0.07	-0.68	-0.71 to 0.35
Caregiver age				-0.11	-1.00	-0.05 to 0.02
Maternal education				0.08	0.75	-0.07 to 0.14
Block 2	0.030	0.69	.60			
Male sex				-0.08	-0.73	-0.73 to 0.34
Caregiver age				-0.12	-1.09	-0.06 to 0.02
Maternal education				0.07	0.65	-0.07 to 0.14
Log residential distance				-0.07	-0.66	-0.37 to 0.19
Block 3	**0.072**	2.35	.03			
Male sex				-0.04	-0.38	-0.63 to 0.43
Caregiver age				-0.12	-1.17	-0.06 to 0.01
Maternal education				0.01	0.11	-0.10 to 0.11
Log residential distance				-0.09	-0.82	-0.39 to 0.16
NCATS Interaction score				**0.26**	2.05	0.03 to 0.09

Values in **bold** indicate significance of the test of association (p<.05)
^ marginally significant (p=.05 to .10)

Table 11e: Linear regression of Bayley-III Motor Scale composite score

	R^2	*F*	*p*	Std. β	*t*	95% CI
Block 1	0.016	0.47	.71			
Male sex				-0.02	-0.16	-3.74 to 3.17
Caregiver age				0.02	0.21	-0.21 to 0.25
Maternal education				0.12	1.16	-0.30 to 1.12
Block 2	0.051	1.17	.33			
Male sex				-0.03	-0.29	-3.92 to 2.92
Caregiver age				-0.01	-0.10	-0.24 to 0.22
Maternal education				0.10	0.92	-0.38 to 1.03
Log residential distance				-0.19^	-1.79	-3.43 to 0.18
Block 3	0.065	1.19	.32			
Male sex				-0.01	-0.10	-3.64 to 3.29
Caregiver age				-0.01	-0.12	-0.24 to 0.22
Maternal education				0.06	0.57	-0.52 to 0.94
Log residential distance				-0.20^	-1.86	-3.49 to 0.12
NCATS Interaction score				0.13	1.13	-0.14 to 0.50

Values in **bold** indicate significance of the test of association (p<.05)
^ marginally significant (p=.05 to .10)

Table 11f: Linear regression of Bayley-III Fine Motor subtest Scaled score

	R^2	*F*	*p*	Std. *β*	*t*	95% CI
Block 1	0.044	1.33	.27			
Male sex				-0.12	-1.11	-1.11 to 0.31
Caregiver age				-0.07	-0.63	-0.06 to 0.03
Maternal education				0.14	1.36	-0.05 to 0.24
Block 2	0.052	1.18	.33			
Male sex				-0.12	-1.17	-1.13 to 0.29
Caregiver age				-0.08	-0.77	-0.07 to 0.03
Maternal education				0.13	1.23	-0.06 to 0.24
Log residential distance				-0.09	-0.84	-0.53 to 0.22
Block 3	0.057	1.02	.41			
Male sex				-0.11	-1.04	-1.10 to 0.35
Caregiver age				-0.08	-0.77	-0.07 to 0.03
Maternal education				0.11	1.00	-0.08 to 0.21
Log residential distance				-0.09	-0.87	-0.54 to 0.21
NCATS Interaction score				0.07	0.67	-0.04 to 0.09

Values in **bold** indicate significance of the test of association ($p<.05$)
^ marginally significant ($p=.05$ to .10)

Table 11g: Linear regression of Bayley-III Gross Motor subtest Scaled score

	R^2	*F*	*p*	Std. *β*	*t*	95% CI
Block 1	0.013	0.38	.77			
Male sex				0.08	0.74	-0.50 to 1.09
Caregiver age				0.07	0.69	-0.03 to 0.07
Maternal education				0.05	0.50	-0.12 to 0.20
Block 2	0.055	1.29	.28			
Male sex				0.06	0.59	-0.55 to 1.02
Caregiver age				0.04	0.37	-0.05 to 0.06
Maternal education				0.02	0.22	-0.14 to 0.17
Log residential distance				-0.21^	-1.99	0.83 to 0
Block 3	0.064	1.20	.32			
Male sex				0.08	0.74	-0.50 to 1.09
Caregiver age				0.04	0.35	-0.04 to 0.06
Maternal education				-0.01	-0.03	-0.17 to 0.16
Log residential distance				-0.21^	-2.05	-0.85 to 0
NCATS Interaction score				0.10	0.93	-0.04 to 0.11

Values in **bold** indicate significance of the test of association ($p<.05$)
^ marginally significant (p=.05 to .10)

Table 11h: Linear regression of Bayley-III Social-Emotional Scale composite score

	R^2	*F*	*p*	Std. *β*	*t*	95% CI
Block 1	**0.093**	3.08	.03			
Male sex				-0.14	-1.42	-8.41 to 1.39
Caregiver age				**-0.22**	-2.14	-0.67 to -0.03
Maternal education				0.13	1.25	-0.36 to 1.58
Block 2	0.097^	2.38	.06			
Male sex				-0.15	-1.46	-8.56 to 1.31
Caregiver age				**-0.23**	-2.20	-0.69 to -0.04
Maternal education				0.12	1.15	-0.42 to 1.55
Log residential distance				-0.06	-0.59	-3.38 to 1.84
Block 3	0.100^	1.96	.09			
Male sex				-0.14	-1.33	-8.39 to 1.67
Caregiver age				**-0.23**	-2.21	-0.70 to -0.04
Maternal education				0.10	0.94	-0.54 to 1.51
Log residential distance				-0.07	-0.63	-3.46 to 1.79
NCATS Interaction score				0.07	0.63	-0.31 to 0.59

Values in **bold** indicate significance of the test of association (p<.05)
^ marginally significant (p=.05 to .10)

DISCUSSION

The present study was part of a large longitudinal study examining the effects of prenatal pesticide exposures on neurodevelopmental outcomes of children living nearby banana plantations in rural Costa Rica. Given the dearth of research available on the topic of caregiver-infant interactions within the context of environmental exposures, this research was designed to be exploratory in nature. This study had two primary objectives: first, we sought to describe the quality of caregiver-infant interactions in a high-risk subsample (*n*=94) of infants living in banana-growing areas in rural Costa Rica (i.e., in the Matina county of the Limon province) who had been prenatally exposed to pesticides; this also entailed a comparison of the caregiver-infant interaction data in our sample to normative data provided for U.S. Hispanic mother-child dyads and for low education adults in the U.S. Second, we sought to examine the associations between the overall quality of caregiver-infant interactions and one-year neurodevelopmental outcomes of infants.

The quality of caregiver-infant interactions, including several frequently studied aspects of interactions (i.e., sensitivity, growth-fostering, contingency), were measured using a brief, standardized observational measure, the Nursing Child Assessment Satellite Training – Parent-Child Interaction Teaching Scale (NCATS), which was administered during home visits with caregiver-infant dyads. Analysis of the NCATS data showed that, on average, infants in this sample displayed very clear verbal and non-verbal cues and appropriately responded to caregivers, a finding that was consistent with infants' one-year neurodevelopmental outcomes (as measured by the Bayley-III), which were all within the average range for the group. Further, most caregivers showed appropriate sensitivity to infants' cues and responsiveness to infants' distress, at levels that were similar to the U.S. normative data provided by the NCATS. However, many caregivers in the study sample struggled with some aspects of caregiving, involving stimulation and the fostering of infants' cognitive and social-emotional development. The areas that were found to contribute most to low scores were caregivers' insufficient use of verbal and non-verbal praise and cheerleading, limited face-to-face contact, little recognition of infants' success, limited use of a variety of descriptive words during the task, and infrequent allowance for task exploration. The results also showed that parents appeared to lose points on contingency items, which reflect dyadic behaviours that are contingent upon and responsive to the other partner's behaviour (i.e., contingency items on the Caregiver subscales are those that show timely responsiveness to infant cues and behaviour). The developers of the NCATS identify contingency as a major component of caregiving and a key process in the shaping of behaviour (Sumner & Spietz, 1999). Positive contingent responses are seen to help create behavioural patterns by providing a mechanism by which children begin to understand the relationship between behaviour and environment. Thus, while most caregivers in our sample were responsive to children when they showed distress cues, the results suggest that many caregivers had difficulty responding immediately to infants' non-distress cues. On the other hand, infants' responsiveness to caregivers might also have also contributed to the interactions since this Infant subscale (i.e., Responsiveness to Caregiver) consists almost exclusively of contingency items, reflecting the bi-directional transactional nature of caregiving. Moreover, infants' responsiveness to their caregivers was moderately associated with caregivers' ability to foster social-emotional growth, suggesting that infant behaviours contribute to and are dependent to some extent on the caregiver's capacity to stimulate the infant.

The results were compared to the 10^{th} percentile cutoff scores (i.e., the score obtained by ten percent or less of the subsample) provided in the NCATS manual for the U.S. Hispanic subsample, which was deemed to be the most appropriate comparison group as opposed to the U.S. Caucasian and African-American subsamples. The cutoff scores provide an indication of the proportion of our study sample with the most worrisome scores and who are the most at risk. When compared to the U.S. Hispanic subsample, over one-third of the overall caregiver-infant interaction scores in our sample were at or below the cutoff score, and about half of the scores representing the caregivers' contribution were at or below the cutoff, compared to only 18% of the scores reflecting the infants' contribution. These results suggest that caregiver behaviours contributed most to the overall interaction quality. Although the

U.S. Hispanic subsample was chosen as the comparison group, they differed from the present study sample on two important characteristics: the age of children at the time of the NCATS assessment (i.e., the U.S. Hispanic infants were younger by about seven months), and the level of education of the mothers (i.e., the U.S. Hispanic mothers had an average of 12 years of education, compared to an average of seven years in our sample). Thus, the low scores in the current sample should be interpreted with caution because these are relative to the Hispanic normative group to which it was compared. If the higher cutoff scores from the other NCATS ethnic subsamples (i.e., U.S. Caucasians and African-Americans) were used instead, an even greater number of individuals in the current sample would have been identified with "worrisome" scores.

As expected, in the additional analyses comparing the quality of caregiving interactions in our sample to norms provided by the NCATS for adults with low levels of education (i.e., mothers with less than 12 years of education), the mean overall interaction score was lower in our sample, as were the Caregiver Total and Caregiver Contingency scores. Scores measuring the infant's contribution to the interaction, in contrast, were comparable to or slightly higher than the normative data for low education adults. These results are interesting as they suggest that, compared to infants of U.S. adults with low education, the infants in our sample displayed clearer cues and showed slightly more contingent responses to their caregivers. Infants may have displayed clearer cues in part due to their older age (i.e., 21.2 months). However, as the normative data were based on a sample of infants that ranged in age from one to 36 months, age is likely not the sole factor. It is probable that infants performed better as a result of the novel nature of the NCATS task for this sample. Observationally, most infants responded enthusiastically when presented with the task and readily engaged in the task with their caregiver, which provided caregivers the opportunity to engage in play with their children. The novel activity and experience of this task for the children in our sample, who may not have had prior exposure in their home environment to the developmentally stimulating toys and materials that were utilized during the Teaching task, may have contributed to the higher scores (i.e., relative to normative data) on scales measuring the infant contribution to the interactions. This pattern of results is also consistent with the overall results, which showed higher scores on infant-related subscales than on caregiver-related subscales, and with behavioural observations of caregiver-infant interactions, during which many infants were observed to display clear and unambiguous cues and show a keenness to perform the task. Observationally, it was also evident that many families did not have children's toys, book or other developmentally stimulating materials in their homes. Further, some families lived in poorer villages, where homes were smaller and in poorer condition, and even fewer children's toys were observed. These findings and observations suggest that one important area for early intervention in this study population might be to provide access to low-cost stimulating materials, which may assist parents and other caregivers to care for and stimulate their children. Other researchers (e.g., Eshel et al., 2006; Mejia, Calam, & Sanders, 2012; Richter, 2004) also indicate that this approach (i.e., combining parenting intervention with the provision of resources) might be the most promising when implementing early interventions in developing countries. Nevertheless, parenting quality can have an impact on the development of young children, even after the resources in the home are taken into account. For example, Lugo-Gil & Tamis-LeMonda (2008) studied the effects of parenting quality on the cognitive development of over 2000 low-income, at-risk children in the U.S. They found that parenting quality predicted children's cognitive performance at 24 and 36 months, after controlling for the amount of family resources. Thus, ensuring availability of adequate stimulating materials may be important for these families but this needs to be coupled with interventions focused on enhancing the quality of caregiving.

Our results are comparable to results reported in studies that have evaluated caregiving using the NCATS with other ethnic groups, such as Native Americans (Seideman et al., 1992), Alaskan Inuit (MacDonald-Clark & Harney-Boffman, 1994), and Canadian Aboriginals (Letourneau et al., 2005). All of the latter documented lower than average quality of interaction when compared to NCATS normative data. The authors hypothesized that these results were related to cultural differences in caregiving as well as the lower socioeconomic status overall of their study samples. Culture and socioeconomic status likely also exert effects in our study. For example, certain cultural modifications needed to be made to the NCATS task (i.e., changing words to more culturally and regionally relevant words, and elaborating on instructions) in order to adapt the task to the cultural context of Costa Rica, and of Limon in particular. Factors such as maternal education and availability of stimulating materials, which are intrinsically linked with socioeconomic status, also might have impacted the results. Our sample was on the whole a low-educated sample, with no more than primary school education, as well as a sample living in one of the poorest provinces of Costa Rica (Sanchez & Zuniga, 2004). Environmental exposures in this region, as in other poor regions, are significantly linked with other important social determinants of health, and likely exert a combined effect on development of children (Cooper, 2005; Horton et al., 2012; Shonkoff & Phillips, 2000).

There is evidence that parents living in developing countries (Bornstein & Putnick, 2012; Engle et al., 2007; Eshel et al., 2006) and even those living in low SES contexts within developed countries (McCain, Mustard, and McCuaig, 2011), due to being resource-deprived and having lower education overall, engage in less cognitively stimulating activities (e.g., joint book reading, story-telling, verbal interactions with children) than social-emotional caregiving activities (e.g., playing with children, singing, taking children outside) (Bornstein & Putnick, 2012). In the present study, we observed that many parents, when given a children's storybook as a token of appreciation at the end of the study, were grateful and remarked that it was the first book they owned for their children. Both caregivers and children appeared eager to read together upon receiving the book. Thus, providing developmentally stimulating materials such as children's books may encourage caregivers to engage in more interactions with their children. However, one of the components that most contributed to low interaction scores in our sample was the caregiver's ability to stimulate and foster social-emotional growth in their infants. Specifically, few caregivers engaged in behaviours such as cheerleading, encouraging and praising their children's efforts and/or success. These activities are different from the social-emotional caregiving activities identified by Bornstein and Putnick above. Encouragement and praise of children's efforts have more to do with the caregiver's ability to engage in warm and nurturing interactions with children in order to facilitate their growth and development (Sumner & Spietz, 1994). These findings suggest some areas that could be targeted when developing interventions with this population as caregivers could be provided with education to highlight the importance of stimulation and growth-fostering as well as being taught strategies to do so.

Caregivers' capacity to stimulate and foster cognitive and social-emotional growth in their children may be affected by the interactive effects of several factors, including caregivers' exposure to contaminants, their lower education levels, and the stressors experienced by living in poverty. Exposure to environmental contaminants can affect caregivers' cognitive abilities (e.g., Menezes-Filho, de O. Novaes, Moreira, Sarcinelli, & Mergler, 2011), which may in turn impact their parenting capacity. Caregiver's lower education levels may reflect less knowledge about child development and in turn impact their ability to provide growth-fostering situations for their child (Barnard, 1997). Maternal education is also a proxy for socioeconomic status and was significantly associated in our study with another indicator of socioeconomic status: family income. It is likely that the stressors that go hand in hand with poverty exert the greatest effects on caregiver's capacity to parent. Many caregivers living in developing countries experience chronic levels of stress that depletes their capacity to cope, making them feel tired and worn out (Richter, 2003). Parents living in low socioeconomic conditions might be too preoccupied by economic pressures and with meeting basic needs for the family to invest much time in their parenting role. The chronic stress can make it difficult for caregivers to provide sensitive, responsive and stimulating care for their children (Halpern, 1990; Richter, 2003). For the women living in the county of Matina, the additional burden of long workdays and hard labour at banana plantations may also limit the time they can spend with their children. Despite the impact of living in a resource-deprived environment with high levels of pesticide exposure, there is evidence that focusing early intervention within such environments on improving caregiving capacity, rather than solely focusing on meeting children's physical and material needs, can help to engage and foster exploration in children, while relieving some of caregivers' stress (Fitzgerald, Lester, & Zuckerman, 1995; Richter, 2003). Moreover, building caregivers' capacities can help to offset some of the negative effects of poverty on children's cognitive and social development and promote resilience in these children (Richter, 2003, 2004; Shonkoff & Phillips, 2000).

Analyses of the Bayley-III results showed that infants performed within the average range across all outcomes, with the lowest scores (i.e., albeit still within the average range) on the Language and Social-Emotional scales of the Bayley-III. Further, infants showed poorer receptive communication than expressive communication skills, and females displayed better receptive communication ability than males. In the multivariate analyses, overall caregiver-infant interaction quality was associated only with infants' expressive language ability, after adjusting for important covariates (i.e., child sex, caregiver age, and maternal education) and pesticide exposure (i.e., as measured by residential distance to the banana plantation).

While caregiver-infant interactions were expected to be associated with infant neurodevelopmental outcomes, no hypothesis was advanced about the specific outcomes with which these would be associated given the lack of research on this topic and the exploratory nature of the current study. However, we expected associations to be most significant for cognitive and language outcomes. It was interesting that infants performed more poorly (low end of average range) on the measure of receptive language than on the measure of expressive language ability (average range), yet caregiving interaction quality was related to infants' expressive language ability. Moreover, infants' average performance on the measure of expressive communication was inconsistent with parents' self-reported concerns about their children, with many parents informally reporting that their primary concern was their children's lack of verbalization.

Since many of the previous studies in the environmental health literature utilized the first or second edition of the Bayley Scales (BSID-I or BSID-II), it is difficult to compare these results to the previous literature since earlier editions of the Bayley Scales did not differentiate between Cognitive and Language outcomes, and used the Mental Development Index (MDI) as a composite score to indicate these abilities. Most studies of environmental exposure effects on neurodevelopmental outcomes show significant associations with the MDI (Eskenazi et al., 2007, 2008; Rosas & Eskenazi, 2008; Munoz-Quezada et al., 2013); however, it is not known which abilities were most impacted in these samples. Given this research evidence as well as the evidence from the literature on parenting effects, we expected cognitive and language abilities, both of which are measured by the MDI, to be impacted in this sample.

These findings cannot be interpreted without considering the low socioeconomic status of our study sample. The reason why language was the outcome most affected in this sample of infants may be in part due to the lack of availability of stimulating materials (e.g., books, toys) at the homes of many infants, as mentioned previously. This may explain why some infants are behind similar aged peers in terms of their language skills, particularly receptive communication skills, which were towards the low end of the average range. Delays in language development are among the most consistent outcomes found among children living in poverty (Perkins, Finegood, & Swain, 2013). In addition, studies with low SES samples in South America provide some evidence that language ability is the earliest outcome to be affected. For example, a study of infants living in low SES communities in Brazil found that receptive communication was the only outcome affected at 9 to 12 months of age (de Paiva, de Souza Lima, de Carvalho Lima, & Eickmann, 2010). However, other studies in this area have shown language to be impacted at an early age, not differentiating between receptive and expressive language skills (Perkins et al., 2013). Within the children's environmental health literature, one study from Ecuador reported effects on language (i.e., communication) abilities among pesticide-exposed children (Handal et al., 2008). The researchers studied young children of agricultural flower-workers in rural Ecuador, who sustained prenatal pesticide exposures via maternal occupational exposure during pregnancy. Occupational exposure was measured by maternal report and infant neurodevelopment was measured using the Ages and Stages Questionnaire. The researchers found that children of mothers who reported working in the cut-flower industry during pregnancy had lower communication scores at 3 to 23 months of age, after adjusting for child's age and mother's education, compared to those who did not perform such work during pregnancy. However, the authors acknowledged that other factors apart from pesticide exposure likely played a role in the developmental outcomes.

The finding of language outcomes being the most affected in our sample of infants is particularly relevant when considering the low education levels of mothers. There is evidence that less educated parents are more likely to use fewer words, less complicated syntax, and less diversity in words compared to parents with higher education (Hart & Risley, 1995). These attributes were also noted observationally in our sample, which might explain why caregiver-infant interaction quality, and in particular caregivers' stimulation of social-emotional and cognitive growth in their children, were associated with infants' expressive language skills. These two subscales of the NCATS (i.e., Cognitive Growth-Fostering and Social-Emotional Growth-Fostering) emphasize the parent's ability to provide verbal and non-verbal stimulating experiences that facilitate infant growth and development (Sumner & Spietz, 1994). This includes stimulation in the form of use of a variety of words, reading to and with children, providing praise, encouragement and cheerleading to children, and providing non-verbal feedback and acknowledgment of children's efforts (Sumner & Spietz, 1994). The NCATS developers state that, in order for caregivers to stimulate growth fostering in their children, they need to have three essential ingredients: first, caregivers must be able to understand the importance of social, emotional, and cognitive stimulation for a child; second, they must have knowledge of child development and their child's current level of functioning and needs; and third, caregivers must be able to put their knowledge into action. These ingredients make for interactions that are warm and nurturing, but also verbally and non-verbally stimulating at the same time. Aspects of caregiving, such as stimulation and responsiveness, have been shown to contribute to children's language acquisition (Oxford & Spieker, 2006; Perkins et al., 2013), even after considering mother's expressiveness and other confounds (Eshel et al., 2006). Moreover, aspects of the early home environment such as early language exposure, which is a component of stimulation, have been shown to predict the size of children's growing vocabulary (Hart & Risley, 1999; Perkins et al, 2013) and later verbal and literacy skills (Huttenlocher, 1991), skills that were noted in one study to be the best determinant of reading performance at the entry to primary school, irrespective of socioeconomic status (Dionne, 2010).

Early caregiving behaviours play a significant role in the development of language abilities for children growing up in poverty. In particular, the level of cognitive and language stimulation provided to children is strongly associated with the development of cognitive and language abilities (Allhusen et al., 2001; Brooks-Gunn et al., 2002). A study of low SES children in rural Ethiopia found that greater maternal responsiveness to children, an aspect that is measured in the NCATS via the contingency score, was associated with higher vocabulary scores at the preschool age (Aboud & Alemu, 1995). In another study, Taylor and colleagues (2009) showed that low parent-child interaction scores contributed to lower expressive language skills in two-year-old children. Specifically, young children having lower interaction scores tended to use fewer words in sentences, fewer grammatical word types, and different word roots, than those with higher interaction scores. The authors hypothesized that a large part of parent-child interaction is related to the amount of stimulation and learning provided by the parents to their children. Parental stimulation and growth-fostering also help with the development of attachment security and self-esteem in children facing environmental stressors (Bakeman & Brown, 1980; Bretherton, 2000; van Ijzendoorn, 2005). Researchers agree that high quality caregiver-child interactions in the early years, which are marked by sensitivity and the provision of growth-fostering situations, are crucial in mitigating the impact of poverty on language, and helping to foster the underlying skills required for language development (Perkins et al., 2013).

Infants' social-emotional development was found to be within the average range, yet 20 percent of children scored less than one standard deviation from the normative value. However, this is not atypical given that 16% of the general population would score within this range. Moreover, unlike the other scales of the Bayley-III, this scale is measured via parental report of the frequency of behaviours corresponding to the social-emotional development of children, and may be subject to the reporting bias that is common across self-report instruments. The scale measures a wide variety of behaviours ranging from sensory processing to mastery of functional emotional skills (i.e., self-regulation, interest in the world), to communication and use of emotions (Bayley, 2006). Thus, it is difficult to determine the specific aspects of social-emotional development that were less frequently observed by mothers in our study. Scores on this scale were positively associated with other self-report measures in the study, including the HOME and Social Support scales. In other words, caregivers who perceived a more favourable home environment and experienced greater social support were more likely to rate their infants as having better social-emotional development outcomes. We also observed an effect of caregiver age on these scores, with children of older caregivers having lower scores overall. This finding suggests that older caregivers express greater difficulty with their children's behaviour than younger caregivers. Possible reasons for this observed relationship may include increased stress perceived by older caregivers or the greater likelihood of older (vs. younger) women having a child with more difficulties; for example, certain types of birthing complications, which may adversely affect child development, are known to increase with increasing maternal age (Bornstein, Putnick, Suwalsky, & Gini, 2006). It is important to note, however, that, while the Bayley-III Social-Emotional scale was completed by the biological mother of the child, the NCATS was conducted with the primary caregiver of the child, as it was felt that the task should be attempted by the person who performs the bulk of the caregiving. In the majority of cases, this was the biological mother of the child. However, the significant association does not necessarily represent the older age of the mother, as several of the older caregivers were grandparents of the children.

Our results add further evidence to the burgeoning literature showing the impact of the early environment on the development of children who have sustained prenatal neurotoxin exposures. However, the present study extends the research evidence in three ways: first, by examining, within a context of potential neurotoxicity, a specific aspect of the early home environment, the quality of caregiver-infant interactions; second, by providing evidence of specific areas of infant neurodevelopment that are associated with caregiver-infant interactions, in this case expressive communication; and third, by using a validated and standardized observational task to measure the quality of caregiver-infant interactions, rather than relying solely upon self-report measures.

The current study was exploratory since our research question of modifiable and mitigating environmental factors is novel within the children's environmental health literature, and infant neurodevelopmental outcomes were assessed at one year of age, when these abilities are just beginning to form and have not yet consolidated. Birth cohort studies of children with prenatal pesticide exposure have shown that, as these children become older, they show lack of age-expected maturation of neurocognitive abilities compared to same-aged peers (e.g., Munoz-Quezada et al., 2013; Rauh et al., 2006; Rosas & Eskenazi, 2008). This is a result of the increase with age of the psychometric quality of developmental testing (Winneke, 2007) and of the compounding effects of multiple risk factors that are maintained in the postnatal environment (i.e. poverty, postnatal chemical exposure, etc.). Recent studies of prenatal exposure to environmental neurotoxins (e.g., Koller et al., 2004) have examined the effects on neurodevelopment of the early home environment independently from in-utero exposure, rather than treating this variable as a confounder. These studies suggest that the effects of factors related to the home environment, such as the quality of caregiving, are stronger and more prominent than those of neurotoxin exposure. For example, a study of in-utero polychlorinated biphenyl (PCB) exposure (Walkowiak et al., 2001) examined neurodevelopmental outcomes at 7, 18, 30 and 42 months of age using the Bayley Scales of Infant Development (BSID). The researchers found that the home environment (i.e. HOME score) exerted stronger effects on BSID scores than the negative effect of PCB exposure, and the associations became stronger at later ages. Thus, while our associations are small, these effects might become more prominent at later ages, and the quality of caregiver-infant interactions may help to buffer exposed children against age-related loss in the progression of abilities. These hypotheses remain to be investigated.

The results of this study must be interpreted within the context of its limitations. First, there is a scarcity of culturally sensitive measures of caregiver-infant interaction and the existing measures have been created in developed countries (Byrne & Keefe, 2003; Gaffney et al., 2001; Richter, 2004). Additionally, our research was limited to instruments that had been validated in Spanish-speaking populations and one whose materials had been translated to Spanish. The fact that several other researchers who have utilized the NCATS with minority and low-income populations found scores to be lower than the provided normative data, suggest that there are cultural and socioeconomic differences that may make the instrument less sensitive to populations outside the U.S. and Canada. Moreover, the Teaching task does not approximate a naturalistic environmental setting to promote more natural interactions between caregivers and children, particularly in front of a stranger. In conversations with caregivers, several had difficulty understanding the task, viewing it more as a measure of their children's ability and less about the interaction with their children. It needed to be clarified and emphasized to caregivers that this was not a measure of children's ability or success. However, despite the limitation of the NCATS and the Teaching task in particular, it does impose, as stated by the developers, some pressure on the caregiver to interact with their child, as it is a novel task in which they attempt to teach their child a novel ability (Barnard & Eyres, 1979; Sumner & Spietz, 1994). The main strengths of this measure are that it provides a great wealth of information about the caregiver-infant interaction dynamics within a brief activity, does not intrude significantly with parents' time, and was relatively easily accepted within this study population, as compared to a lengthier and more extensive naturalistic observation. Moreover, the activities appeared to be mutually enjoyed by both caregivers and children, and by the whole family in some cases. For example, in one household, parents expressed their enjoyment and appreciation for this task, as, while one of them attempted to teach their child to do a novel task, the whole family enjoyed the time "to play together as a family." An additional limitation of our study is related to the implications of having a non-native, foreign researcher, unknown to the families visit your home and ask you to participate in an activity with your child. Social desirability of the participants may have played a role, as may the lack of cultural understanding of a non-native researcher. These effects were minimized by the non-Caucasian ethnicity and Spanish fluency of the researcher, as well as by having a research assistant who was familiar with the study population and known to the families accompany the researcher during home visits. A further limitation is related to our proxy of pesticide exposure (i.e., residential distance to banana plantation), which was not a biomarker and thus may reflect other aspects (i.e., postnatal exposure) apart from prenatal exposure to pesticides. As analyses are still underway to determine the most sensitive predictor of prenatal pesticide exposure levels, we did not have access to biomarker data. Nevertheless, residential distance to banana plantation was shown to have a strong negative association with urinary concentrations of ETU in a study by the ISA group (van Wendel de Joode et al., 2013), thus supporting the inclusion of this variable in our analyses. Our results are limited by the small sample size, which did not allow us to look at interactive and moderating effects. We are also limited by the sensitivity and predictive validity of standardized developmental tests in the first three years of life (Winneke, 2007). Finally, as with all cross-sectional studies, causality cannot be inferred from these findings.

With regard to culture, cultural and regional differences in caregiving exert limitations on the assessment of caregiver-infant interactions, particularly within developing countries (Bornstein & Putnick, 2012; Richter, 2004). Nevertheless, the study of caregiving in diverse cultures is afforded by the many commonalities to caregiving that manifest in all cultures as a result of the universal needs of infants (Richter, 2004). After all, it cannot be forgotten that Mary Ainsworth did the first systematic observational study of mother-infant interaction and attachment in Uganda and urged others to consider her sample as “merely one of human infants, and disregard the fact that they were African (for I believe the sample principles of development apply for infants regardless of specific racial or cultural influences)” (Ainsworth, 1964, p. 51).

Despite the limitations of this study, there are several strengths. To our knowledge, this is the first study to explore the influence of caregiver-infant interaction quality, via an observational measure, within the context of environmental health exposures. While other studies have reported strong associations of neurodevelopmental outcomes with factors related to the home environment, this study extends those findings by focusing on the caregiving context. In addition, the findings of our study implicate specific areas of caregiving, such as enhancing caregivers' capacity to stimulate and foster growth in their children, which could be targeted as part of early intervention in order to promote positive and high-quality caregiver-infant interactions within this population. Targeting a modifiable aspect of the environment such as the quality of caregiver-infant interaction is recognized across countries to have the strongest impact on developmental outcomes via the promotion of secure attachments between caregivers and children (Richter, 2004). Another strength of our study is the use of two raters for the rating of the NCATS, and ensuring that high inter-rater reliability was sustained. This has rarely been done in previous studies that have used the NCATS. Our study is also the first study to utilize the NCATS in a Spanish-speaking population outside the U.S. The data on this specific, low-income, rural agricultural sample from Costa Rica, should contribute towards the database for use of the NCATS in various cultural settings.

Future studies will examine the associations between quality of caregiver-infant interactions and neurodevelopmental outcomes at later ages in this sample, and also with behavioural outcomes (e.g., the Achenbach Child Behaviour Checklist). Studies should also use a reliable and sensitive biomarker for prenatal exposure when controlling for exposure level in the analyses. Replication of this study with other populations with prenatal environmental chemical exposures is warranted, given the exploratory nature of this study, and studies within the area of children's environmental health should attempt to consider the role of the early caregiving environment as an important contributor to developmental outcomes. Furthermore, future studies would benefit from the inclusion of a qualitative component to the study, conducting interviews with caregivers about their caregiving experiences. While informal conversations were conducted with all caregivers within the present study, this was not assessed systematically, and would have contributed valuable information to this study. Finally, all future studies examining the role of caregiving within the context of environmental exposures, particularly within developing countries, should consider situating this objective within a holistic and community participatory framework, and aim to provide knowledge translation for the study participants, as will be carried out within the present study. We believe this framework, which was utilized in the overall ISA study, greatly assisted in soliciting the trust and participation of caregivers to this study, and strengthened the international research collaboration.

Clinical and policy implications

Our findings show that aspects of caregiver-infant interactions exert an influence on neurodevelopmental outcomes at an early age, and after accounting for important confounds as well as pesticide exposure. While our effects are small and only showed associations with one outcome (i.e., expressive communication), these early effects may reflect the ongoing development of the brain and children's abilities, particularly in the early years. Our findings implicate caregiving as a potential area for early intervention in this population, and other populations with environmental health exposures, in order to help divert a negative trajectory associated with the cumulative effects of high levels of pesticide exposure and poverty. Our results also show that the caregivers in our sample are doing many things well, such as being attuned and responsive to their children's distress, sensitive to their children's cues, and not engaging in negative or harmful behaviour. The specific instrument utilized, the NCATS, though not without its limitations, helps identify areas of caregiving (i.e., the amount of cognitive and social-emotional stimulation provided to children, the allowance for child-directed play and exploration, and the contingency of caregiving responses to child cues) that could be targeted in early intervention with this population in order to enhance the quality of caregiver-child interactions and have a positive impact on the developing abilities of these vulnerable children. Some of the evidence-based recommendations are indicated in the lay-language Research Summary and Recommendations document (see Appendix L for the Spanish version) that will be distributed to mothers participating in the ISA study who express interest in receiving this information. These recommendations include strategies known to stimulate children's cognitive, language, and social-emotional abilities, such as looking at one's child while talking to him/her, following the child's lead during play, allowing time for their child to explore, describing novel objects and actions, engaging with their child in daily play and book-reading activities, and encouraging and praising their child's efforts.

Although not directly the focus of this study, this research underscores the public health problem of pesticides, reflecting many social inequities even within a less developed country such as Costa Rica. Pesticide exposures, particularly at the high and toxic levels as in Matina, co-occur with other forms of inequities (e.g., poorer diet, house structure and neighbourhoods, greater stress, lower household income) that are associated with the poverty levels within such communities (Cooper, 2005; Shonkoff & Phillips, 2000; Weiss, 2000). Moreover, those living in poor agricultural communities face higher levels of exposure to environmental toxins than inhabitants of non-agricultural communities (Cooper, 2005; Gilbert, 2008). It is well-established that pesticide and other neurotoxin exposures are directly linked to adverse health effects in the inhabitants of such communities (see review by Cooper, 2005) and increase the risk for developmental disorders in children (e.g., Bouchard et al., 2011; Gilbert, 2008; Gilbert et al., 2010). While young and unborn children remain the most vulnerable, adequate health and development of children is also linked to and depends on the health of their caregivers, particularly mothers, and the health of communities overall (Richter, 2004). Pesticide and adverse neurotoxin exposures reflect a social, cultural, political and ethical problem, which is intrinsically linked to the economy of a country (Gilbert et al., 2010). Barraza and colleagues' (2011) research, undertaking focus groups with various stakeholders within banana-growing regions in the province of Limón, highlights that opinions vary across diverse stakeholders on the topic of health risks associated with pesticide use. While many stakeholders, including plantation owners, are aware of the risks, risk reduction is not viewed as a high priority given the contribution of banana crops to employment and the economy of the Limón region and of Costa Rica overall. Moreover, wages remain poor relative to the work done by plantation workers, which contributes towards the sustenance of the poor living conditions within this region, and continuing inequities within Costa Rica as well as within other countries.

It is important that consumers of bananas and other crops become aware about the social inequities that are part of and contribute to the prevalence of pesticide use on bananas and other crops, sustaining the poor living conditions in these rural communities. Social movements have been a crucial part of putting the health and environmental risks of pesticides, particularly within agricultural communities, on the agenda (Barraza, 2013). It is time that consumers begin to put pressure on their own government and on banana-growing countries like Costa Rica to make pesticide and neurotoxin reduction a high priority in their countries, as well as to reduce social inequities within their country, in accordance with the United Nations Millennium Development Goals of eradicating poverty and ensuring environmental sustainability.

Conclusion

It is well recognized that exposures to environmental health hazards tend to co-occur with other forms of chronic psychosocial adversity and social and health inequities (Cooper, 2005; Horton et al., 2012), particularly in underdeveloped countries (Shonkoff & Phillips, 2000; Wright, 2009). Hence, in order for caregiving interventions to have the greatest long-term impact within resource-deprived communities such as the villages of Matina, they should ideally be integrated with other environmental supports (i.e., providing developmentally stimulating materials, targeted support for meeting nutritional and health needs of children) and supports for caregivers (i.e., enhancing social support and knowledge of child development, improving maternal health, empowering caregivers) within a holistic manner (Engle et al., 2007; Eshel et al., 2007; Mejia et al., 2012; Richter, 2004). Pesticide reduction, the reduction of social inequities, and the development of sustainable alternatives to pesticides should remain a high priority for developing countries such as Costa Rica that are significantly impacted by the burden of pesticides. However, this effort may take several years. In the meantime, targeting certain modifiable aspects of the early environment, such as the quality of caregiver-infant interactions, may help buffer children over time against the negative effects of exposure to pesticides and/or other environmental chemicals, as well as against the cumulative negative impact of growing up in poor, resource-deprived environments.

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APPENDICES

Appendix A: Informed consent for mothers 18 years and older

Anexo 1: CONSENTIMIENTO INFORMADO MADRES MAYORES DE 18 AÑOS

La exposición a plaguicidas y su relación con el neurodesarrollo de recién nacidos e infantes de 0 a 2 años del cantón de Matina de la provincia de Limón durante el periodo 2010-2013: Programa Infantes y Salud Ambiental (ISA)

Addendum: Efecto de la crianza sobre el desarrollo de bebés participando en Programa ISA

¿Por qué esta parte adicional?

La crianza es muy importante para el desarrollo de los niños. Usted está participando en el estudio 'La exposición a plaguicidas y su relación con el neurodesarrollo de recién nacidos e infantes de 0 a 2 años del cantón de Matina de la provincia de Limón durante el periodo 2010-2013', también llamado Programa Infantes y Salud Ambiental (ISA). En el contexto de este Programa tenemos la oportunidad de hacer una actividad adicional en colaboración con la Universidad de York de Canadá.

El fin de esta actividad es poder entender mejor cómo las madres, o las personas quienes cuidan, se relacionan con los bebés y cómo esto ayuda al desarrollo de los mismos.

Si usted está de acuerdo en participar en esta actividad adicional, se hará lo siguiente:

Le visitaremos en su casa y una psicóloga de Canadá (Ameeta Dudani) le pedirá a usted enseñar un juego a su bebé durante unos 5 minutos. Esto es para entender cómo usted y su bebé se relacionan. Es necesario filmar el juego con una cámara de video para poder revisarlo de nuevo después. Los videos se manejarán con mucho cuidado y de forma confidencial y solamente serán usados para fines de este estudio. Los videos serán destruidos después de un año.

Beneficios

Al final de la visita, Ameeta le dará unas recomendaciones personales sobre cómo podría mejorar la relación entre usted y su bebé. Su participación ayudará a entender mejor cómo la crianza puede ayudar al desarrollo de bebés que viven en Matina. Devolveremos la información general del estudio a la población de Matina a través de materiales informativos.

Confidencialidad

Si usted decide participar, le aseguramos que sus resultados serán usados con mucho cuidado y de forma confidencial.

Solicitud de colaboración, libre participación

Pedimos su colaboración en esta actividad adicional del estudio. Usted es libre de decidir si quiere participar en esta actividad adicional o no. Si decidiera no participar, esto no le afectaría de ninguna manera, ni a usted ni a su bebé. **En caso de que usted sea menor de edad, necesitamos también el permiso de uno de sus padres o de su representante legal.**

¿Qué pasa si tengo dudas más adelante?

Si tiene alguna duda o pregunta, puede llamar a las oficinas del Programa ISA en Heredia al teléfono 2263-6375, 2237-0683 extensión 113 ó 114 o al celular de las oficinas 8385-8279 y preguntar por la doctora Berna van Wendel u otra persona del equipo de trabajo (Leonel Córdoba, Camilo Cano, Claudia Hernández, Rosario Quesada, Ana María Mora). Si lo considera necesario puede llamar al Comité Ético de la Universidad Nacional (Raquel Campos, secretaria CECUNA, 2263-6375, 2237-0683 extensión 101).

Anexo 1: CONSENTIMIENTO INFORMADO MADRES MAYORES DE 18 AÑOS

La exposición a plaguicidas y su relación con el neurodesarrollo de recién nacidos e infantes de 0 a 2 años del cantón de Matina de la provincia de Limón durante el periodo 2010-2013: Programa Infantes y Salud Ambiental (ISA)

Addendum: Efecto de la crianza sobre el desarrollo de bebés participando en Programa ISA

He leído la información sobre este estudio. He hablado con el investigador y me ha contestado todas mis preguntas en un lenguaje comprensible para mí. Entiendo que mi participación y la de mi hijo(a) es voluntaria y que tenemos derecho a retirarnos cuando así lo deseemos en cualquier momento, sin que esto nos perjudique de ninguna manera. Participo voluntariamente y autorizo voluntariamente a que mi hijo(a) participe en esta actividad adicional del Programa ISA.

Para cualquier pregunta puedo llamar a doctora Berna van Wendel o a otra persona del equipo de trabajo a las oficinas del programa ISA en Heredia al teléfono 2263-6375 extensión 113 ó 114 o al celular de las oficinas 8385-8279.

He recibido una copia de este consentimiento para mi uso personal.

Nombre y apellidos de la participante	Cédula	Firma	Fecha
Nombre y apellidos del investigador	Cédula	Firma	Fecha
Nombre y apellidos del testigo	Cédula	Firma	Fecha

Appendix B: Informed consent for primary caregivers 18 years and older

Anexo 2: CONSENTIMIENTO INFORMADO CUIDADORAS MAYORES DE 18 AÑOS

La exposición a plaguicidas y su relación con el neurodesarrollo de recién nacidos e infantes de 0 a 2 años del cantón de Matina de la provincia de Limón durante el periodo 2010-2013: Programa Infantes y Salud Ambiental (ISA)

Addendum: Efecto de la crianza sobre el desarrollo de bebés participando en Programa ISA

¿Por qué esta parte adicional?

La crianza es muy importante para el desarrollo de los niños. Usted está participando en el estudio 'La exposición a plaguicidas y su relación con el neurodesarrollo de recién nacidos e infantes de 0 a 2 años del cantón de Matina de la provincia de Limón durante el periodo 2010-2013', también llamado Programa Infantes y Salud Ambiental (ISA). En el contexto de este Programa tenemos la oportunidad de hacer una actividad adicional en colaboración con la Universidad de York de Canadá.

El fin de esta actividad es poder entender mejor cómo las madres, o las personas quienes cuidan, se relacionan con los bebés y cómo esto ayuda al desarrollo de los mismos.

Si usted está de acuerdo en participar en esta actividad adicional, se hará lo siguiente:

Le visitaremos en el lugar donde usted cuida al bebé / a la bebé y una psicóloga de Canadá (Ameeta Dudani) le pedirá a usted enseñar un juego al / a la bebé durante unos 5 minutos. Esto es para entender cómo usted y el/la bebé se relacionan. Es necesario filmar el juego con una cámara de video para poder revisarlo de nuevo después. Los videos se manejarán con mucho cuidado y de forma confidencial y solamente serán usados para fines de este estudio. Los videos serán destruidos después de un año.

Beneficios

Al final de la visita, Ameeta le dará unas recomendaciones personales sobre cómo podría mejorar la relación entre usted y el/la bebé. Su participación ayudará a entender mejor cómo la crianza puede ayudar al desarrollo de bebés que viven en Matina. Devolveremos la información general del estudio a la población de Matina a través de materiales informativos.

Confidencialidad

Si usted decide participar, le aseguramos que sus resultados serán usados con mucho cuidado y de forma confidencial.

Solicitud de colaboración, libre participación

Pedimos su colaboración en esta actividad adicional del estudio. Usted es libre de decidir si quiere participar en esta actividad o no. Si decidiera no participar, esto no le afectaría de ninguna manera, ni a usted ni a su bebé. **En caso de que usted sea menor de edad, necesitamos también el permiso de uno de sus padres o de su representante legal.**

¿Qué pasa si tengo dudas más adelante?

Si tiene alguna duda o pregunta, puede llamar a las oficinas del Programa ISA en Heredia al teléfono 2263-6375, 2237-0683 extensión 113 ó 114 o al celular de las oficinas 8385-8279 y preguntar por la doctora Berna van Wendel u otra persona del equipo de trabajo (Leonel Córdoba, Camilo Cano, Claudia Hernández, Rosario Quesada, Ana María Mora). Si lo considera necesario puede llamar al Comité Ético de la Universidad Nacional (Raquel Campos, secretaria CECUNA, 2263-6375, 2237-0683 extensión 101).

Anexo 1: CONSENTIMIENTO INFORMADO CUIDADORAS MAYORES DE 18 AÑOS

La exposición a plaguicidas y su relación con el neurodesarrollo de recién nacidos e infantes de 0 a 2 años del cantón de Matina de la provincia de Limón durante el periodo 2010-2013: Programa Infantes y Salud Ambiental (ISA)

Addendum: Efecto de la crianza sobre el desarrollo de bebés participando en Programa ISA

He leído la información sobre este estudio. He hablado con el investigador y me ha contestado todas mis preguntas en un lenguaje comprensible para mí. Entiendo que mi participación y la del(la) bebé que cuido es voluntaria y que tenemos derecho a retirarnos cuando así lo deseemos en cualquier momento, sin que esto nos perjudique de ninguna manera. Participo voluntariamente.

Para cualquier pregunta puedo llamar a doctora Berna van Wendel o a otra persona del equipo de trabajo a las oficinas del programa ISA en Heredia al teléfono 2263-6375 extensión 113 ó 114 o al celular de las oficinas 8385-8279.

He recibido una copia de este consentimiento para mi uso personal.

____

Nombre y apellidos de la participante   Cédula   Firma   Fecha

____

Nombre y apellidos de la investigadora   Cédula   Firma   Fecha

____

Nombre y apellidos del testigo   Cédula   Firma   Fecha

Appendix C: Informed consent for legal guardians of minors (less than 18 years of age)

Anexo 3: CONSENTIMIENTO INFORMADO REPRESENTANTES LEGALES

La exposición a plaguicidas y su relación con el neurodesarrollo de recién nacidos e infantes de 0 a 2 años del cantón de Matina de la provincia de Limón durante el periodo 2010-2013: Programa Infantes y Salud Ambiental (ISA)

Addendum: Efecto de la crianza sobre el desarrollo de bebés participando en Programa ISA

¿Por qué esta parte adicional?

La crianza es muy importante para el desarrollo de los niños. Su hija/esposa está participando en el estudio 'La exposición a plaguicidas y su relación con el neurodesarrollo de recién nacidos e infantes de 0 a 2 años del cantón de Matina de la provincia de Limón durante el periodo 2010-2013', también llamado Programa Infantes y Salud Ambiental (ISA). En el contexto de este Programa tenemos la oportunidad de hacer una actividad adicional en colaboración con la Universidad de York de Canadá.

El fin de esta actividad es poder entender mejor cómo las madres, o las personas quienes cuidan, se relacionan con los bebés y cómo esto ayuda al desarrollo de los mismos.

Si usted está de acuerdo en que su hija/esposa participe en esta actividad adicional, se hará lo siguiente:

Le visitaremos su hija/esposa en su casa y una psicóloga de Canadá (Ameeta Dudani) le pedirá enseñar un juego a su bebé durante unos 5 minutos. Esto es para entender cómo ella y su bebé se relacionan. Es necesario filmar el juego con una cámara de video para poder revisarlo de nuevo después. Los videos se manejarán con mucho cuidado y de forma confidencial y solamente serán usados para fines de este estudio. Los videos serán destruidos después de un año.

Beneficios

Al final de la visita, Ameeta le dará unas recomendaciones personales a su hija/esposa sobre cómo podría mejorar la relación entre ella y su bebé. Su participación ayudará a entender mejor cómo la crianza puede ayudar al desarrollo de bebés que viven en Matina. Devolveremos la información general del estudio a la población de Matina a través de materiales informativos.

Confidencialidad

Si usted decide que su hija/esposa pueda participar, le aseguramos que sus resultados serán usados con mucho cuidado y de forma confidencial.

Solicitud de colaboración, libre participación

Pedimos la colaboración de su hija/esposa en esta actividad adicional del estudio. Usted es libre de decidir si está de acuerdo con la participación de ella en esta actividad o no. Si no estuviera de acuerdo con su participación, esto no le afectaría de ninguna manera, ni a su hija/esposa ni a su bebé.

¿Qué pasa si tengo dudas más adelante?

Si tiene alguna duda o pregunta, puede llamar a las oficinas del Programa ISA en Heredia al teléfono 2263-6375, 2237-0683 extensión 113 ó 114 o al celular de las oficinas 8385-8279 y preguntar por la doctora Berna van Wendel u otra persona del equipo de trabajo (Leonel Córdoba, Camilo Cano, Claudia Hernández, Rosario Quesada, Ana María Mora). Si lo considera necesario puede llamar al Comité Ético de la Universidad Nacional (Raquel Campos, secretaria CECUNA, 2263-6375, 2237-0683 extensión 101).

Anexo 3: CONSENTIMIENTO INFORMADO REPRESENTANTES LEGALES

La exposición a plaguicidas y su relación con el neurodesarrollo de recién nacidos e infantes de 0 a 2 años del cantón de Matina de la provincia de Limón durante el periodo 2010-2013: Programa Infantes y Salud Ambiental (ISA)

Addendum: Efecto de la crianza sobre el desarrollo de bebés participando en Programa ISA

He leído la información sobre esta actividad adicional del estudio. He hablado con el investigador y me ha contestado todas mis preguntas en un lenguaje comprensible para mí. Entiendo que la participación de mi (hija/esposa) y de mi (nieto/nieta/hijo/hija) es voluntaria y que tienen derecho a retirarse de esta actividad adicional del Programa ISA cuando así lo deseen. Mi (hija/esposa) participa voluntariamente y autoriza voluntariamente a que mi (nieto/nieta/hijo/hija) participa en esta actividad adicional. Tengo el derecho a negarme a que ellos participen en esta actividad y el derecho a discontinuar su participación, sin que esto les perjudique de ninguna manera.

Para cualquier pregunta puedo llamar a doctora Berna van Wendel o a otra persona del equipo de trabajo del estudio a las oficinas del proyecto ISA en Heredia al teléfono 2263-6375 extensión 113 ó 114 o al celular de las oficinas 8385-8279.

He recibido una copia de este consentimiento para mi uso personal.

Nombre y apellidos de la participante	Cédula	Firma	Fecha
Nombre y apellidos del investigador	Cédula	Firma	Fecha
Nombre y apellidos del testigo	Cédula	Firma	Fecha

Appendix D: Informed assent for mothers younger than 18 years

Anexo 4: ASENTIMIENTO INFORMADO PARA MADRES MENORES DE 18 AÑOS

La exposición a plaguicidas y su relación con el neurodesarrollo de recién nacidos e infantes de 0 a 2 años del cantón de Matina de la provincia de Limón durante el periodo 2010-2013: Programa Infantes y Salud Ambiental (ISA)

Addendum: Efecto de la crianza sobre el desarrollo de bebés participando en Programa ISA

¿Por qué esta parte adicional?

La crianza es muy importante para el desarrollo de los niños. Usted está participando en el estudio 'La exposición a plaguicidas y su relación con el neurodesarrollo de recién nacidos e infantes de 0 a 2 años del cantón de Matina de la provincia de Limón durante el periodo 2010-2013', también llamado Programa Infantes y Salud Ambiental (ISA). En el contexto de este Programa tenemos la oportunidad de hacer una actividad adicional en colaboración con la Universidad de York de Canadá.

El fin de esta actividad es poder entender mejor cómo las madres, o las personas quienes cuidan, se relacionan con los bebés y cómo esto ayuda al desarrollo de los mismos.

Si usted está de acuerdo en participar en esta actividad adicional, se hará lo siguiente:

Le visitaremos en su casa y una psicóloga de Canadá (Ameeta Dudani) le pedirá a usted enseñar un juego a su bebé durante unos 5 minutos. Esto es para entender cómo usted y su bebé se relacionan. Es necesario filmar el juego con una cámara de video para poder revisarlo de nuevo después. Los videos se manejarán con mucho cuidado y de forma confidencial y solamente serán usados para fines de este estudio. Los videos serán destruidos después de un año.

Beneficios

Al final de la visita, Ameeta le dará unas recomendaciones personales sobre cómo podría mejorar la relación las entre usted y su bebé. Su participación ayudará a entender mejor cómo la crianza puede ayudar al desarrollo de bebés que viven en Matina. Devolveremos la información general del estudio a la población de Matina a través de materiales informativos.

Confidencialidad

Si usted decide participar, le aseguramos que sus resultados serán usados con mucho cuidado y de forma confidencial.

Solicitud de colaboración, libre participación

Pedimos su colaboración en esta actividad adicional del estudio. Usted es libre de decidir si quiere participar en esta actividad adicional o no. Si decidiera no participar, esto no le afectaría de ninguna manera, ni a usted ni a su bebé. Tampoco afectaría la participación en el estudio de los plaguicidas. **Como usted es menor de edad, necesitamos también el permiso de uno de sus padres o de su representante legal.**

¿Qué pasa si tengo dudas más adelante?

Si tiene alguna duda o pregunta, puede llamar a las oficinas del Programa ISA en Heredia al teléfono 2263-6375, 2237-0683 extensión 113 ó 114 o al celular de las oficinas 8385-8279 y preguntar por la doctora Berna van Wendel u otra persona del equipo de trabajo (Leonel Córdoba, Camilo Cano, Claudia Hernández, Rosario Quesada, Ana María Mora). Si lo considera necesario puede llamar al Comité Ético de la Universidad Nacional (Raquel Campos, secretaria CECUNA, 2263-6375, 2237-0683 extensión 101).

Anexo 4: ASENTIMIENTO INFORMADO PARA MADRES MENORES DE 18 AÑOS

La exposición a plaguicidas y su relación con el neurodesarrollo de recién nacidos e infantes de 0 a 2 años del cantón de Matina de la provincia de Limón durante el periodo 2010-2013: Programa Infantes y Salud Ambiental (ISA)

Addendum: Efecto de la crianza sobre el desarrollo de bebés participando en Programa ISA

He leído la información sobre esta actividad adicional. He hablado con el investigador y me ha contestado todas mis preguntas en un lenguaje comprensible para mí. Entiendo que mi participación y la de mi hijo(a) es voluntaria y que tenemos derecho a retirarnos cuando así lo deseemos en cualquier momento, sin que esto nos perjudique de ninguna manera. Participo voluntariamente y autorizo voluntariamente a que mi hijo(a) participe en esta actividad adicional del Programa ISA.

Para cualquier pregunta puedo llamar a doctora Berna van Wendel o a otra persona del equipo de trabajo a las oficinas del programa ISA en Heredia al teléfono 2263-6375 extensión 113 ó 114 o al celular de las oficinas 8385-8279.

He recibido una copia de este consentimiento para mi uso personal.

Nombre y apellidos de la participante   Cédula   Firma   Fecha

---

Nombre y apellidos del investigador   Cédula   Firma   Fecha

Nombre y apellidos del testigo   Cédula   Firma   Fecha

Appendix E: List of NCATS potent disengagement cues

__ Back arching

__ Choking

__ Coughing

__ Crawling away

__ Cry face

__ Fussing

__ Halt hand

__ Lateral head shake

__ Maximal lateral gaze aversion

__ Overhand beating movements

__ Pale/red skin

__ Pulling away

__ Pushing away

__ Saying “no”

__ Spitting

__ Tray pound

__ Vomiting

__ Walking away

__ Whining

__ Withdraw from alert to sleep state

Appendix F: NCATS subscales and items

NCAST
TEACHING SCALE
Birth to Three Years Only

Information applies to parent only
Mother's Ethnic Heritage (See back page)
Marital/Partner Status ☐ Married ☐ Single

Person Observed ____ Age ____ Educ.
☐ Mother ☐ Father
☐ Other ____________
Major Caregiver ☐ Yes ☐ No
Name of Task ____________
Length of Time Teaching (***minutes***)
1 or Less 2 3 4 5 6 or More

Setting
☐ Home
☐ Clinic
☐ Other ____________
Were Others Present?
☐ Yes
☐ No
If yes, specify____________

Child's Name ____________
Child's Age (***in months***)____________
Child's Sex ____________
Child's Birth Order (***circle***)
1 2 3 4 5 or More
Child's State at Beginning of Teaching (*circle*)
Quiet Sleep Active Sleep Drowsy
Quiet Alert Active Alert Crying

I. SENSITIVITY TO CUES

	YES	NO
1. Caregiver positions child so child is safely supported.		
2. Caregiver positions child so that child can reach and handle teaching materials.		
3. Caregiver gets the child's attention before beginning the task, at the start of the teaching interaction.		
4. Caregiver gives instruction only when child is attentive (90% of the time).		
5. Caregiver allows child to explore the task material for at least five seconds before giving the first task related instruction.		
6. Caregiver positions child so that it is possible for them to have eye-to-eye contact with one another during the majority of the teaching episode (60%).		
7. Caregiver pauses when the child initiates behaviors during the teaching episode.		
8. Caregiver praises child's successes or partial successes.		
9. Caregiver asks for no more than three performances when child is successful at completing the task.		
10. Caregiver changes position of child and/or materials after unsuccessful attempt by the child to do the task.		
11. Caregiver avoids physically forcing the child to complete the task.		
TOTAL YES ANSWERS		

II. RESPONSE TO CHILD'S DISTRESS
☐ Yes ☐ No (Potent disengagement cues observed)

	YES	NO
12. Caregiver stops the teaching episode.		
13. Caregiver makes positive, sympathetic, or soothing verbalization.		
14. Caregiver changes voice volume to softer or higher pitch, does not yell.		
15. Caregiver rearranges the child's position and/or task materials.		
16. Caregiver makes soothing non-verbal response, e.g. pat, touch, rock, caress, kiss.		
17. Caregiver diverts the child's attention by playing games, introduces a new toy.		
18. Caregiver avoids making negative comments to the child.		
19. Caregiver avoids yelling at the child.		
20. Caregiver avoids using abrupt movements or rough handling.		
21. Caregiver avoids slapping, hitting or spanking.		
22. Caregiver avoids making negative comments to home visitor about the child.		
TOTAL YES ANSWERS		

III. SOCIAL-EMOTIONAL GROWTH FOSTERING

	YES	NO
23. Caregiver's body posture is relaxed during the teaching episode (90%).		
24. Caregiver positions self face-to-face with the child during the teaching interaction (60%).		
25. Caregiver laughs or smiles at child during the teaching interaction.		
26. Caregiver gently pats, caresses, strokes, hugs, or kisses child during episode.		
27. Caregiver smiles, or touches child within five seconds after the child smiles or vocalizes.		
28. Caregiver praises child's efforts or behaviors broadly (in general) at least once during the episode.		
29. Caregiver makes cheerleading type statements to the child during the teaching interaction.		
30. Caregiver avoids vocalizing to the child at the same time the child is vocalizing.		
31. Caregiver avoids making general negative or uncomplimentary remarks about the child.		
32. Caregiver avoids yelling at the child during the episode.		
33. Caregiver avoids making critical or negative comments about the child's task performance.		
TOTAL YES ANSWERS		

IV. COGNITIVE GROWTH FOSTERING

	YES	NO
34. Caregiver provides an immediate environment which is free from distractions from animate sources (sibs, pets, other people, T.V.).		
35. Caregiver focuses attention and child's attention on the task during most of the teaching (60%).		
36. After caregiver gives instructions, at least five seconds is allowed for the child to attempt the task before caregiver intervenes again.		
37. Caregiver allows non-task manipulation of the task materials after the original presentation.		
38. Caregiver describes perceptual qualities of the task materials to the child.		
39. Caregiver uses at least two different sentences or phrases to describe the task to the child.		
40. Caregiver uses explanatory verbal style more than imperative style in teaching the child.		
41. Caregiver's directions are stated in clear, unambiguous language (i.e. ambiguous = "turn"; unambiguous = "turn the knob toward me").		
42. Caregiver uses both verbal description and modeling simultaneously in teaching any part of the task.		
43. Caregiver encourages and/or allows the child to perform the task at least once before intruding in on the use of the task materials.		
44. Caregiver verbally praises child after child has performed better or more successfully than the last attempt.		
45. Caregiver smiles and/or nods at the child after child performs better or more successfully than the last attempt.		
46. Caregiver responds to the child's vocalizations with a verbal response.		
47. Caregiver uses both verbal and non-verbal instruction in teaching the child.		
48. Caregiver uses the teaching loop at least once.		
49. Caregiver signals completion of task to child verbally or nonverbally.		
50. Caregiver spends no more than five minutes and not less than one minute in teaching the child the task.		
TOTAL YES ANSWERS		

V. CLARITY OF CUES

	YES	NO
51. Child is awake.		
52. Child widens eyes and/or shows postural attention to task situation.		
53. Child changes intensity or amount of motor activity when task material is presented.		
54. Child's movements are clearly directed toward the task *or* task material *or* away from the task		
55. Child makes clearly recognizable arm movements during the teaching episode (clapping, reaching, waving, pounding, pointing, pushing away).		
56. Child vocalizes while looking at the task materials.		
57. Child smiles or laughs during the episode.		
58. Child grimaces or frowns during the teaching episode.		
59. Child displays potent disengagement cues during the teaching interaction.		
60. Child displays subtle disengagement cues during the teaching interaction.		
TOTAL YES ANSWERS		

VI. RESPONSIVENESS TO CAREGIVER

	YES	NO
61. Child gazes at caregiver's face or task materials after the caregiver has shown verbal or non-verbal alerting behavior.		
62. Child attempts to engage caregiver in eye-to-eye contact.		
63. The child looks at the caregiver's face or eyes when caregiver attempts to establish eye-to-eye contact.		
64. Child vocalizes or babbles within five seconds after caregiver's verbalization.		
65. Child vocalizes or babbles within five seconds after caregiver's gesturing, touching or changing his/her facial expression.		
66. Child smiles at caregiver within five seconds after caregiver's verbalization.		
67. Child smiles at caregiver within five seconds after caregiver's gesture, touch, or facial expression changes.		
68. When caregiver moves closer than eight inches from the child's face the child shows some subtle and/or potent disengagement cues.		
69. Child shows subtle and/or potent disengagement cues within five seconds after caregiver changes facial expression or body movement.		
70. Child shows subtle and/or potent disengagement cues within five seconds after caregiver's verbalization.		
71. Child shows potent and/or subtle disengagement cues when caregiver attempts to intrude physically in the child's use of the task materials.		
72. Child physically resists or responds aggressively when caregiver attempts to intrude physically in child's use of the task materials.		
73. The child stops displaying potent disengagement cues within 15 seconds after caregiver's soothing attempts.		
TOTAL YES ANSWERS		

To use this scale for research or clinical practice requires training. For more information write or call: NCAST Programs
University of Washington
Box 357920
Seattle, WA 98195-7920
Phone 206-543-8528
www.ncast.org

Enter the total yes answers from each subscale and compare it with the possible score:

	SUBSCALE Items Possible	SUBSCALE Items Actual	CONTINGENCY Items Possible	CONTINGENCY Items Actual
SENSITIVITY TO CUES	11		5	
RESPONSE TO DISTRESS	11		6	
SOCIAL-EMOTIONAL GROWTH FOSTERING	11		3	
COGNITIVE GROWTH FOSTERING	17		6	
CAREGIVER TOTAL	**50**		**20**	
CLARITY OF CUES	10		0	
RESPONSIVENESS TO CAREGIVER	13		12	
INFANT TOTAL	**23**		**12**	
CAREGIVER/INFANT TOTAL	**73**		**32**	

Check the Potent Disengagement Cues (PDC's) observed during the teaching interaction (excluding PDC's that terminate the teaching or occur after the caregiver has terminated the teaching).

- ___ Back arching
- ___ Choking
- ___ Coughing
- ___ Crawling away
- ___ Cry face
- ___ Crying
- ___ Fussing
- ___ Halt hand
- ___ Lateral head shake
- ___ Maximal lateral gaze aversion
- ___ Overhand beating movements
- ___ Pale/red skin
- ___ Pulling away
- ___ Pushing away
- ___ Saying "no"
- ___ Spitting
- ___ Spitting up
- ___ Tray pound
- ___ Vomiting
- ___ Walking Away
- ___ Whining
- ___ Withdraw from alert to sleep state

Ethnic Heritage. Place a checkmark next to the mother's ethnic heritage and write in her specific group identity.

- ___ African-American
- ___ Asian Indian or A.I.- American
- ___ Chinese or Chinese-American
- ___ Filipino or Filipino-American
- ___ Japanese or Japanese-American
- ___ Korean or Korean-American
- ___ Pacific Islander or P.I.- American
- ___ Vietnamese or Vietnamese-American
- ___ Other Asian
- ___ Cuban or Cuban-American
- ___ Mexican, Chicano, or Mex. American
- ___ Puerto Rican
- ___ Other Hispanic/Latin
- ___ Native American or Alaskan Native
- ___ White/Caucasian (non-Hispanic)
- ___ Other

Specific group identity:___________________________

Clinical Notes:

Date of Observation ____________________

Recorder's Signature ____________________

Appendix G: List of activities in the NCATS

1. Child can hold on to the rattle
2. Child can follow the rattle with his/her eyes
3. Child can imitate caregiver's showing of tongue
4. Child can reach for the rattle
5. Child can transfer block from one hand to another
6. Child can squeak the squeak toy
7. Child can pick up a food object such as a cookie or cracker and eat it
8. Child can scribble on the piece of paper
9. Child can turn the page of the book
10. Child can pull the car by the string
11. Child can play pat-a-cake
12. Child can stack the blocks on top of each other
13. Child can pretend to drink from the cup
14. Using the picture book, child can point to a body part (hand, foot, eye, nose) when asked
15. Child can take the lid off the small container
16. Child can imitate a line on the paper using crayon
17. Child can string beads
18. Child can put together the 3-piece puzzle
19. Child can button the button
20. Child can pull a zipper up and down
21. Child can balance on one foot
22. Using the picture book, child can find a piece of clothing such as shirt, pants, socks when asked
23. Child can sort the blocks by colour
24. Child can make sets of the blocks by numbers (1's, 2's, 3's)
25. Child can draw a shape (circle, line) using crayon
26. Child makes letter of the alphabet using crayon
27. Child can cut out a pre-drawn shape (square or circle) using the safety scissors
28. Child can print his/her first name using crayon
29. Child can hop on one foot
30. Child can tie a shoelace

Appendix H: Modified version of the Home Observation for Measurement of the Environment-Short Form (HOME-SF) used in present study [English translation]

We would like you to respond to some questions about activities regarding your child, including whichever toy(s) that he/she uses to play. There are no correct or incorrect responses, please be as honest as possible.

1. About how many times per week does your child leave the house? This can be to play outside, go to the daycare, or to do an errand. — __ __ TIMES/WEEK

Does your baby have any of the following types of toys to play with at home or at any other place?

2.	Any toy that he/she can push or pull?	NO .... 0 YES 1
3.	Any teddy bear or doll?	NO .... 0 YES 1
4.	Any book that belongs to him/her?	NO .... 0 YES 1
a.	How many books does he/she have?	1 or 2 books............ 1 From 3 to 9 books............ 2 10 books or more............ 3
5.	How many times in a week do you read or look at a book with your child?	__ __ TIMES/WEEK
6.	Some parents spend time teaching their children how to do new things whereas other parents believe that children learn better by themselves. Which of the following statements best describes what you believe?	Parents must always spend time teaching things to their children .... 1 Parents must generally spend time teaching things to their children .... 2 Parents must generally allow their children to learn by themselves............ 3 Parents must always allow their children to learn by themselves............ 4

7.	While you are doing housework (i.e., cooking or cleaning), how often do you talk to your child?	Very often ....1 At times…………………………………………….2 Almost never...3 Never 4
8.	How many people, apart from you, take care of your child when you are not able to? This can be while you are at work, cleaning, or when running errands.	__ __ PEOPLE
9.	How often does the father of your child (or a man who is like a father) play with or take care of your child?	Daily or very often...1 Less than once a day ....2 Never 3
10.	How often does your child eat together with you and his/her father (or a man who is like a father)?	Daily or very often...1 Less than once a day ....2 Never 3
11.	How often do you take your child outside with you to the store or the supermarket?	More than once a week ....1 Once a week...2 Once a month ....3 Almost never...4
12.	How many times a week do you or another person physically punish (i.e., shake or spank) your child?	__ __ TIMES/WEEK

Appendix I: Social Support scale used in present study [English translation]

Here is a list of some things that other people do for us or give us that may be helpful or supportive. We would like to know if you feel you have enough of these things in your life right now or if you feel that you don't. Please read each statement carefully and circle a number for each from 1 to 5, based on what is closest to your situation.

I receive/have…	As much as I would like ↓				Much less than I would like ↓
1. People who care what happens to me	5	4	3	2	1
2. Love and affection	5	4	3	2	1
3. Opportunities to talk to someone about problems at work or with my housework	5	4	3	2	1
4. Opportunities to talk to someone I trust about my personal or family problems	5	4	3	2	1
5. Opportunities to talk to someone about money problems	5	4	3	2	1
6. Opportunities to go out and do things with other people	5	4	3	2	1
7. Useful advice about important things in life	5	4	3	2	1
8. Help when I am sick in bed	5	4	3	2	1
9. Help at home or with taking care of children	5	4	3	2	1
10. People who can help me when money is not sufficient	5	4	3	2	1

Appendix J: Results of sex-stratified regression analyses for Bayley-III Language scale and subtests (Tables 1 through 6)

Table 1: Linear regression of Bayley-III Language Scale composite score for Males (n=56)

	R^2	*F*	*p*	Std. *β*	*t*	*p*
Block 1	0.025	0.67	.52			
Caregiver age				-0.16	-1.12	.27
Maternal education				0.01	0.03	.98
Block 2	0.028	0.50	.69			
Caregiver age				-0.17	-1.17	.25
Maternal education				-0.01	-0.06	.95
Log residential distance				-0.06	-0.41	.69
Block 3	0.051	0.68	.61			
Caregiver age				-0.17	-1.18	.25
Maternal education				-0.05	-0.34	.73
Log residential distance				-0.08	-0.57	.57
NCATS Interaction score				0.16	1.10	.28

Values in **bold** indicate significance of the test of association ($p<.05$)
^ marginally significant (p=.05 to .10)

Table 2: Linear regression of Bayley-III Language Scale composite score for Females (n=38)

	R^2	*F*	*p*	Std. *β*	*t*	*p*
Block 1	0.022	0.40	.68			
Caregiver age				-0.07	-0.44	.66
Maternal education				0.13	0.80	.43
Block 2	0.042	0.50	.68			
Caregiver age				-0.09	-0.54	.59
Maternal education				0.13	0.75	.46
Log residential distance				-0.14	-0.85	.40
Block 3	0.050	0.43	.79			
Caregiver age				-0.10	-0.57	.57
Maternal education				0.10	0.57	.57
Log residential distance				-0.14	-0.83	.42
NCATS Interaction score				0.09	0.50	.62

Values in **bold** indicate significance of the test of association ($p<.05$)
^ marginally significant ($p=.05$ to .10)

Table 3: Linear regression of Bayley-III Receptive Communication subtest Scaled score for Males (n=56)

	R^2	*F*	*p*	Std. *β*	*t*	*p*
Block 1	-0.027	0.27	.77			
Caregiver age				-0.10	-0.68	.50
Maternal education				0.01	0.10	.92
Block 2	-0.039	0.32	.81			
Caregiver age				-0.12	-0.80	.43
Maternal education				-0.01	-0.04	.97
Log residential distance				-0.09	-0.65	.52
Block 3	-0.052	0.33	.86			
Caregiver age				-0.11	-0.79	.44
Maternal education				-0.03	-0.19	.85
Log residential distance				-0.11	-0.73	.47
NCATS Interaction score				0.09	0.60	.55

Values in **bold** indicate significance of the test of association ($p<.05$)
^ marginally significant ($p=.05$ to $.10$)

Table 4: Linear regression of Bayley-III Receptive Communication subtest Scaled score for Females (n=38)

	R^2	***F***	***p***	**Std. *β***	***t***	***p***
Block 1	-0.053	0.06	.94			
Caregiver age				-0.05	-0.27	.79
Maternal education				0.04	0.25	.80
Block 2	-0.081	0.078	.97			
Caregiver age				-0.05	-0.30	.77
Maternal education				0.04	0.23	.82
Log residential distance				-0.06	-0.33	.74
Block 3	-0.106	0.110	.98			
Caregiver age				-0.05	-0.26	.79
Maternal education				0.06	0.35	.73
Log residential distance				-0.06	-0.34	.74
NCATS Interaction score				-0.08	-0.46	.65

Values in **bold** indicate significance of the test of association (*p*<.05)
^ marginally significant (*p*=.05 to .10)

Table 5: Linear regression of Bayley-III Expressive Communication subtest Scaled score for Males (n=56)

	R^2	*F*	*p*	Std. *β*	*t*	*p*
Block 1	0.028	0.74	.48			
Caregiver age				-0.16	-1.19	.24
Maternal education				-0.01	-0.04	.97
Block 2	0.028	0.49	.69			
Caregiver age				-0.16	-1.12	.27
Maternal education				-0.01	-0.01	.99
Log residential distance				0.02	0.12	.91
Block 3	0.048	0.64	.64			
Caregiver age				-0.16	-1.13	.27
Maternal education				-0.04	-0.28	.78
Log residential distance				-0.01	-0.04	.97
NCATS Interaction score				0.15	1.04	.31

Values in **bold** indicate significance of the test of association ($p<.05$)
^ marginally significant (p=.05 to .10)

Table 6: Linear regression of Bayley-III Expressive Communication subtest Scaled score for Females (n=38)

	R^2	*F*	*p*	Std. *β*	*t*	*p*
Block 1	0.037	0.68	.51			
Caregiver age				-0.07	-0.40	.69
Maternal education				0.19	1.12	.27
Block 2	0.074	0.91	.45			
Caregiver age				-0.09	-0.55	.59
Maternal education				0.18	1.06	.30
Log residential distance				-0.19	-1.17	.25
Block 3	0.140	1.35	.27			
Caregiver age				-0.11	-0.68	.50
Maternal education				0.10	0.61	.55
Log residential distance				-0.19	-1.16	.26
NCATS Interaction score				0.26	1.59	.12

Values in **bold** indicate significance of the test of association (p<.05)
^ marginally significant (p=.05 to .10)

Appendix K: Results of linear regression analyses including child's age in model (Tables 1 through 8)

Table 1: Linear regression of Bayley-III Cognitive Scale composite score

	R^2	*F*	*p*	Std. *β*	*t*	*p*
Block 1	0.042	0.96	.43			
Male sex				0.14	1.29	.20
Child age				-0.01	-0.07	.94
Caregiver age				0.15	1.47	.15
Maternal education				0.02	0.15	.88
Block 2	0.057	1.07	.38			
Male sex				0.15	1.39	.17
Child age				-0.003	-0.03	.97
Caregiver age				0.17	1.64	.11
Maternal education				0.03	0.32	.75
Log residential distance				0.13	1.22	.23
Block 3	0.057	0.88	.51			
Male sex				0.15	1.38	.17
Child age				-0.003	-0.03	.98
Caregiver age				0.17	1.63	.11
Maternal education				0.03	0.28	.78
Log residential distance				0.13	1.20	.23
NCATS Interaction score				0.01	0.10	.92

Values in **bold** indicate significance of the test of association ($p<.05$)
^ marginally significant ($p=.05$ to .10)

Table 2: Linear regression of Bayley-III Language Scale composite score

	R^2	*F*	*p*	Std. *β*	*t*	*p*
Block 1	0.063	1.49	.21			
Male sex				0.21^	-2.01	.05
Child age				-0.02	-0.23	.82
Caregiver age				-0.10	-1.00	.34
Maternal education				0.06	0.61	.56
Block 2	0.071	1.33	.26			
Male sex				**-0.22**	-2.07	.04
Child age				-0.03	-0.26	.80
Caregiver age				-0.12	-1.08	.28
Maternal education				0.05	0.46	.65
Log residential distance				-0.09	-0.86	.39
Block 3	0.087	1.36	.24			
Male sex				-0.19^	-1.83	.07
Child age				-0.02	-0.21	.83
Caregiver age				-0.12	-1.13	.26
Maternal education				0.02	0.14	.34
Log residential distance				-0.10	-0.05	.91
NCATS Interaction score				0.13	1.23	.23

Values in **bold** indicate significance of the test of association (p<.05)
^ marginally significant (p=.05 to .10)

Table 3: Linear regression of Bayley-III Receptive Communication subtest Scaled score

	R^2	*F*	*p*	Std. *β*	*t*	*p*
Block 1	0.090	2.21^	.07			
Male sex				**-0.24**	-2.37	.02
Child age				0.15	1.42	.16
Caregiver age				-0.09	-0.85	.40
Maternal education				0.04	0.38	.71
Block 2	0.095	1.84	.11			
Male sex				**-0.25**	-2.40	.02
Child age				0.14	1.40	.17
Caregiver age				-0.10	-0.93	.35
Maternal education				0.03	0.28	.78
Log residential distance				-0.07	-0.64	.53
Block 3	0.095	1.52	.18			
Male sex				**-0.24**	-2.32	.02
Child age				0.15	1.40	.17
Caregiver age				-0.10	-0.93	.35
Maternal education				0.02	0.23	.82
Log residential distance				-0.07	-0.64	.52
NCATS Interaction score				0.02	0.17	.86

Values in **bold** indicate significance of the test of association (p<.05)
^ marginally significant (p=.05 to .10)

Table 4: Linear regression of Bayley-III Expressive Communication subtest Scaled score

	R^2	*F*	*p*	Std. *β*	*t*	*p*
Block 1	0.068	1.60	.18			
Male sex				-0.08	-0.79	.43
Child age				-0.20^	-1.98	.05
Caregiver age				-0.08	-0.75	.46
Maternal education				0.06	0.60	.55
Block 2	0.074	1.38	.24			
Male sex				-0.08	-0.84	.40
Child age				-0.21^	-2.00	.05
Caregiver age				-0.09	-0.86	.39
Maternal education				0.05	0.48	.64
Log residential distance				-0.08	-0.75	.46
Block 3	0.112	**2.44**	.04			
Male sex				-0.05	-0.50	.62
Child age				-0.20^	-1.97	.05
Caregiver age				-0.10	-0.94	.35
Maternal education				0.01	-0.04	.97
Log residential distance				-0.09	-0.91	.37
NCATS Interaction score				**0.28**	2.28	.03

Values in **bold** indicate significance of the test of association ($p<.05$)
^ marginally significant (p=.05 to .10)

Table 5: Linear regression of Bayley-III Motor Scale composite score

	R^2	*F*	*p*	**Std. β**	*t*	*p*
Block 1	0.036	0.81	.52			
Male sex				-0.01	-0.07	.95
Child age				0.15	1.35	.18
Caregiver age				0.02	0.21	.99
Maternal education				0.13	1.23	.22
Block 2	0.070	1.29	.28			
Male sex				-0.03	-0.29	.85
Child age				0.14	1.32	.19
Caregiver age				-0.01	-0.10	.78
Maternal education				0.10	0.92	.33
Log residential distance				-0.19^	-1.76	.08
Block 3	0.084	1.29	.27			
Male sex				-0.01	-0.10	.99
Child age				0.14	1.33	.19
Caregiver age				-0.03	-0.30	.76
Maternal education				0.07	0.65	.52
Log residential distance				-0.20^	-1.83	.07
NCATS Interaction score				0.13	1.14	.26

Values in **bold** indicate significance of the test of association (p<.05)
^ marginally significant (p=.05 to .10)

Table 6: Linear regression of Bayley-III Fine Motor subtest Scaled score

	R^2	*F*	*p*	**Std. *β***	*t*	*p*
Block 1	0.10	2.36^	.06			
Male sex				-0.10	-0.97	.33
Child age				**0.24**	2.29	.02
Caregiver age				-0.10	-0.98	.33
Maternal education				0.16	1.51	.14
Block 2	0.11	2.01^	.09			
Male sex				-0.11	-1.02	.31
Child age				**0.24**	2.26	.03
Caregiver age				-0.12	-1.09	.28
Maternal education				0.15	1.38	.17
Log residential distance				-0.08	-0.79	.43
Block 3	0.11	1.74	.12			
Male sex				-0.09	-0.89	.38
Child age				**0.24**	2.26	.03
Caregiver age				-0.12	-1.10	.27
Maternal education				0.12	1.14	.26
Log residential distance				-0.09	-0.87	.41
NCATS Interaction score				0.08	0.69	.49

Values in **bold** indicate significance of the test of association ($p<.05$)
^ marginally significant (p=.05 to .10)

Table 7: Linear regression of Bayley-III Gross Motor subtest Scaled score

	R^2	*F*	*p*	**Std. β**	*t*	*p*
Block 1	0.014	0.31	.87			
Male sex				0.08	0.72	.48
Child age				-0.04	-0.34	.74
Caregiver age				0.08	0.73	.47
Maternal education				0.05	0.47	.64
Block 2	0.056	1.05	.39			
Male sex				0.06	0.56	.58
Child age				-0.04	-0.40	.69
Caregiver age				0.05	0.42	.67
Maternal education				0.02	0.19	.85
Log residential distance				-0.21^	-1.99	.05
Block 3	0.065	1.01	.42			
Male sex				0.08	0.71	.48
Child age				-0.04	-0.36	.72
Caregiver age				0.04	0.39	.70
Maternal education				-0.01	-0.05	.96
Log residential distance				**-0.22**	-2.05	.04
NCATS Interaction score				0.10	0.93	.37

Values in **bold** indicate significance of the test of association (p<.05)
^ marginally significant (p=.05 to .10)

Table 8: Linear regression of Bayley-III Social-Emotional Scale composite score

	R^2	***F***	***p***	**Std. *β***	***t***	***p***
Block 1	**0.12**	3.02	.02			
Male sex				-0.15	-1.53	.13
Child age				-0.17^	-1.64	.10
Caregiver age				-0.19^	-1.90	.06
Maternal education				0.12	1.15	.26
Block 2	**0.12**	2.49	.04			
Male sex				-0.16	-1.58	.12
Child age				-0.17^	-1.65	.10
Caregiver age				-0.20^	-1.97	.05
Maternal education				0.11	1.04	.30
Log residential distance				-0.07	-0.65	.52
Block 3	0.13^	2.10	.06			
Male sex				-0.15	-1.45	.15
Child age				-0.17	-1.62	.11
Caregiver age				-0.20^	-1.98	.05
Maternal education				0.09	0.86	.39
Log residential distance				-0.07	-0.68	.50
NCATS Interaction score				0.06	0.54	.59

Values in **bold** indicate significance of the test of association ($p<.05$)
^ marginally significant (p=.05 to .10)

Appendix L: Research summary and recommendations document (Spanish version) to be distributed to mothers in the ISA study

El efecto de la crianza sobre el desarrollo de bebés participando en Programa Infantes y Salud Ambiental (ISA)

¿Por qué hicimos este estudio?

La crianza, o la relación entre el bebé y su madre/padre (o la persona que cuida al bebé), es muy importante para el desarrollo de los niños. Es reconocido por la Organización de Salud Mundial como uno de los factores más importantes que afecta el desarrollo de los niños, especialmente en los años primeros. Estuvimos interesados a determinar cómo puede afectar la crianza el desarrollo de los infantes que viven en Matina y que estuvieron expuestos a plaguicidas. El fin de este proyecto era entender mejor si hay aspectos de la crianza que podemos modificar para estimular y ayudar el desarrollo de los niños de Matina.

¿Qué hicimos?

Visitemos a 94 bebés y sus madres, que participan en la Programa ISA, en sus casas. Hicimos una actividad corta, que fue como un juego entre los bebés y sus madres, y los recordemos para revisar los videos después. El fin de esta actividad fue poder identificar aspectos positivos y negativos de la manera en que relacionan los padres a sus hijos, para que podemos dar recomendaciones a las familias que viven en Matina.

¿Qué descubrimos?

Hay muchos aspectos positivos de las interacciones entre los bebés y sus madres que se observó. Las madres entendieron y respondieron a las necesidades de sus hijos, y hablan y relacionan a sus hijos con mucho cariño y amor.

Muchas madres estuvieron preocupadas sobre como estimular la capacidad lingüística de su bebé. También, observamos que aspectos de la crianza afectan aspectos del lenguaje de los niños que tuvieron entre 1 y 2 años de edad.

¿Cómo pueden ustedes usar los resultados de este estudio?

Si ya no hacen, hay cosas que padres en Matina pueden hacer para estimular las capacidades cognitivas y lingüísticas de sus bebés, porque sabemos que las plaguicidas y otros factores socioeconómicos pueden afectar estas capacidades de los niños. También, sabemos que es mejor implementar las recomendaciones siguientes lo más temprano que sea posible en la vida del niño.

Para estimular las capacidades lenguaje y cognitiva de su bebé, les recomendamos hacer las siguientes:

- ✓ Mirar a su bebé cuando habla con él/ella – los bebés aprenden mejor cuando pueden ver sus expresiones al mismo tiempo que se les habla
- ✓ Juege con su bebé con frecuencia, le permite a iniciar las acciones y sigue su ejemplo
- ✓ Mantiene paciencia y le permite a su bebé tiempo para explorar
- ✓ Copiar lo que hace su bebé
- ✓ Hablar sobre lo que están haciendo juntos
- ✓ Hablar con su bebé usando palabras diferentes – por ejemplo, descubre los objetos (en usando palabras que descubren los colores, la forma, la cantidad, etc.) y las acciones de su bebé…luego ESPERA…para que él/ella puede imitarlo
- ✓ Repetir nuevas palabras en contexto y resalta las palabras importantes
- ✓ Alentar a su bebé y elogia o celebra lo que su bebé puede hacer si él/ella intenta hacer alguna cosa
- ✓ Descubre las expresiones de su bebé para mostrar a él/ella que entiende sus sentimientos – le dice que comprende cómo se siente
- ✓ Si tiene libro(s), intenta leer cada día con su bebé usando expresiones y preguntarle que le muestra objetos y personas en el libro

¿Quiénes son los investigadores?

Ameeta Dudani es una estudiante doctorado de psicología en la Universidad de York en Canadá. Ella hizo este estudio en colaboración con la doctora Berna van Wendel del Programa ISA en la Universidad Nacional de Costa Rica.