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Exploring the Effect of Early Motor Delay and Physical Therapy Interventions on the Parent-Child Relationship

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A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University.

by

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Dedication

To my Miles: it was through you that I had the courage to pursue my PhD and the strength to push through when times were hard. I happily wrote this dissertation from the sidelines of your soccer games, from the outfield during your baseball games, and from the rocking chair in your room when you wanted me to stay just a little bit longer while you fell asleep.

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Becky – you just finished your dissertation what are you going to do next?

I'm going to Disney World – oh wait, I already went 😊

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ABSTRACT

EXPLORING THE EFFECT OF EARLY MOTOR DELAYS AND PHYSICAL THERAPY INTERVENTIONS ON THE PARENT-CHILD RELATIONSHIP

By Rebecca Molinini, PT, DPT, PhD Candidate
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Emotional availability (EA) or the ability of the parent-child dyad to engage emotionally and partake in congruent and mutually enjoyable interactions, is essential for familial health and well-being. EA is considered the “connective tissue” of healthy parent-child relationships and is associated with secure attachment, maternal mental health, and children’s adaptive development. Most evidence supporting the integral role of EA on healthy outcomes is supported by typically developing populations in which adults present with a social or biological risk factor such as experiencing past traumas of adversities with mental health. In line with the transactional model of development, children are equal members of the dyad and play and active and integral role in dyadic interactions. Caregivers’ actions are rarely spontaneous but rather they are in response to children’s actions. EA is hypothesized to be 80-90% non-verbal highlighting the importance of children’s motor abilities in establishing the dyadic reciprocity of the

relationship. Children with delayed or atypical motor skills are surmised to have difficulties with EA.

This dissertation aimed to understand the relationship between emotional availability, children's development, and early physical therapy interventions in young children with motor delays. Specifically, we were addressing gaps in knowledge on the relationship between early motor delays and the developmental change in emotional availability (Chapter 2), the bidirectional relationship between adult EA and children's gross motor and problem-solving development (Chapter 3), and the effect of early physical therapy interventions on EA in young children with motor delays and their caregivers (Chapter 4). Our findings in Chapter 2 suggests that dyads with motor delay have different developmental trajectories of emotional availability than dyads with children with typical motor development. Chapter 3 highlights that in our young sample, Adult EA and child development influenced future performance within each domain respectively, but there were no current or future associations between the two variables. Lastly, results from Chapter 4 propose that early physical therapy interventions may uniquely affect dyadic emotional availability depending on how the intervention was delivered. Taken together, these studies provide critical information for the urgency to measure and treat qualities of the parent-child relationship as part of routine early therapy services in children with motor delay. We will discuss clinical implications for our findings as well opportunities for future translational research opportunities.

Chapter 1

Children's development is a dynamic, complex process that is embedded within reciprocal interactions between children and their social environments (Figure 1) (Bronfenbrenner 1979; Sameroff, 1975, 2009). There is a strong consensus that a relationship that is synchronous between parent's (defined as primary caregiver) and children's affective and behavioral states forms the foundation for children's neurological, behavioral, and emotional development, fosters resiliency, and moderates the effects of early adverse life experiences (Feldman, 2015; Fenning & Baker, 2012). Developmental Delay or Disability (DD) is an early adverse life experience that can impact the synchrony of the relationship and may exaggerate the undesired effects of adverse contextual risk factors (Figure 1) (Belsky, 1997, 2005). Children with DD commonly receive physical, occupational, and/or speech therapy services as part of The Individual's with Disabilities Education Act – Part C Early Intervention (hereafter referred to as early intervention, EI), which aims to optimize children's development and parent's capacity to meet their children's needs (Individuals with Disabilities Education Act, 2004; McManus et al., 2020). Due to the integral and moderating role of the relationship on children's healthy development, supporting the parent-child relationship needs to be at the forefront of EI.

The purpose of this paper is to highlight evidence of the profound impact the parent-child relationship has on global development in children of all abilities and describe implications for assessment and intervention during infancy and early childhood. To underscore the urgency for EI professionals to act, we provide evidence for 3 key tenets:

1. Relationship synchrony foster adaptive development in children of all abilities
2. Parenting can buffer adverse effects of contextual risk factors
3. Early Intervention lacks rigor in assessing and intervening on the parent-child relationship

1. Relationship synchrony fosters adaptive development in children of all abilities

Children's development is embedded in day-to-day interactions with their parents (Bronfenbrenner 1979; Sameroff, 1975, 2009). The first 1000 days of life (birth-3 years old) provides parents and children with countless opportunities to intimately shape one another's lives during the mundane routines of life (Holden, 1997; Maccoby, 1992). A seemingly simple event such as mealtime is more than just parents attending to children's basic needs. Shared engagement during bottle, breast, or table feeding permits affectionate touch with mutual gazing, introduction of songs or foods that are culturally important, boosts feelings of parental competence and allows children to feel as if their needs are being met. It is during these minute-by-minute daily routines that parents and children can have their most emotionally intimate and socially playful moments which foster development (Bornstein et al., 2020).

Early childhood is a time of great neural plasticity as well as a time in which children are dependent on their caregivers for survival, nurturing, and learning (Bernier et al., 2016; Bornstein, 2014; Stack et al., 2010). The intrinsic relationship between experience-dependent brain development and the experiences provided by parents supports the long-standing impact that early relationships have on children's neurological, behavioral, and emotional development (Bernier et al., 2016; Bornstein, 2014). Genetics and personality were once seen as the blueprint for one’s life, but now they are simply seen as a set of possibilities that is driven by the interaction between an individual and the experiences provided by their caregiving and social environments (Figure 1) (Sameroff, 1975, 2009; Stack et al., 2010). Although birth to three only represents a small portion of one’s life, this sensitive period of development yields longstanding impacts and underscores the urgency to identify and intervene on dyads with risks to the relationship (Bornstein, 2014).

The transactional model of development posits both parents and children are equal partners within the relationship such that children are constantly influencing parents while simultaneously being influenced by parents, and vice versa (Sameroff, 1975, 2009). Parents and children bring distinctive biological and behavioral characteristics to shared interactions and leave each interaction as changed individuals (Bornstein, 2009; Sameroff, 1975). This theory guides our understanding of how any adversity in parents, children or contextual factors can impact the relationship synchrony which can contribute to adverse developmental outcomes.

1.1 Parenting behaviors

The two most frequently cited parenting behaviors around the world that contribute to global development are sensitivity and responsiveness (Bornstein, 2013; Deans, 2020; Pastorelli et al., 2016). When viewed together or separately, sensitivity and responsiveness have been found to foster short- and long-term development in almost every developmental domain, including language, cognition, and socio-emotional (Bornstein et al., 2008; Deans, 2020; Tamis-LeMonda et al., 2007). The hypothesized mechanism of sensitive and responsive parenting on development is that parent’s prompt, contingent affectual and behavioral responses to children's cues, provide children with feedback that their needs are valued, and they are loved (Merz et al., 2017; Rice & Grusec, 1975). Children then perceive themselves as effective agents which promotes self-regulation, prosocial skills, self-efficacy, and mastery motivation, all of which contribute to adaptive development (Merz et al., 2017; Rice & Grusec, 1975).

Sensitivity was first conceptualized by Ainsworth et al. (1971) in the attachment literature as parents that are "capable of perceiving things from the child's point of view", regard the child "as a separate person", and "use information from the child's outward behavior to make accurate inferences about the mental states governing that behavior". For this paper, sensitivity is conceptualized as parent's nonverbal and affective response to children's nonverbal and affective signaling (Biringen et al., 2014). Responsiveness is conceptualized as the congruent (in agreement with children's actions) and contingent (prompt and reciprocal to children's actions) physical or verbal action that the parent takes in response to children's physical or verbal actions (Ainsworth et al., 1974; Bornstein, 1989). It is through these types of shared daily experiences that responsiveness fosters children's sense of self/sense of control, executive function, verbal ability, and intellectual achievement (Bornstein et al., 2008; Merz et al., 2017; Rice & Grusec 1975; Tamis-LeMonda et al., 2001). In contrast, associations between difficulties in sensitivity or responsiveness and maladaptive development during childhood have been consistently identified (Bohr et al., 2018; Goldstein et al., 2009; Lyons-Ruth & Jacobvitz, 1999; Mountain et al., 2017; Wakschlag & Hans, 1999).

As parents exhibit sensitivity and responsiveness, they are also likely to demonstrate a lack of intrusive behaviors. Allowing children time and space to lead interactions, talking and teaching in a way that suggests rather than demands, and joining children naturally during play rather than interrupting are all examples of physical and verbal non-intrusiveness (Biringen et al., 2014). Parents low on intrusive behaviors are able to guide their child to the next developmental level in a way that does not diminish their child's autonomy. When intrusive behaviors are observed, it's important to consider the context and the intentions behind these behaviors. Often times, intrusive behaviors can be the result of parents trying too hard, in that they assume the responsibility for teaching and leading their child and lose sight of the reciprocal nature of the relationship (Biringen et al., 2014). Although parents' intentions may be benign, the child is still impacted. As parents lead, stimulate, or support too much, children may withdraw from the interaction or their sense of efficacy may be diminished (Biringen et al., 2014). Lack of intrusiveness is associated with better academic achievement, less externalizing behaviors, fewer difficulties with executive function, and lower prevalence of anxiety disorders in elementary school (Broomell et al., 2020; Egeland et al., 1993).

1.2 Child behaviors

Infants are born to socialize as seen by their ability to focus and look at caregivers within minutes of being born (Bowlby, 1969). Criticisms of previous parenting and developmental science theories center around the lack of emphasis on children's influential role within the relationship (Emde, 2012; Sameroff, 1975). Historically, parent-child interactions were viewed as a unidirectional event in which children were passive recipients of parenting (Bell, 1971). Newer theoretical models highlight that parent's behavior is rarely spontaneous but rather elicited by children's interaction behaviors, thus the consideration of children's biological and behavioral factors are essential to better understand the mechanism of the transactional relationship (Bronfenbrenner, 1979; Sameroff 1975, 2009).

Children's active response coupled with their ability to involve parents during interaction are two child centered interaction behaviors that impact the quality and synchrony of the relationship (Biringen et al., 2014; Bornstein et al., 2011). A child that is responsive and involving is eager to engage their parent, let them know they are needed and appreciated, and ultimately makes greater demands on their parent thus enriching the interaction (Bornstein et al., 2011; Wendland-Carro et al., 2017). When considering children's interaction skills, emphasis is placed on children's ability to balance interacting with their parent and engaging in their own autonomous pursuits and explorations (Biringen et al., 2014). Alterations in relationship behaviors can be seen in two ways; first, children may respond or involve their parent too frequently, reflecting an overly-dependent and compliant relationship which may limit self-initiated exploration and problem-solving (Biringen et al., 2014). Or secondly, children may respond too little and rely more on themselves for regulation than their parent, thus missing out on opportunities to learn from their parent (Biringen et al., 2014).

Responsive and involving interaction behaviors include looking, vocalizing, pointing, handing objects to parents, or approaching parents (Bornstein et al., 2020). Developmental cascades underscores that developmental milestones act as a catalyst for transformation within the relationship and ultimately parents respond to children's developmental abilities rather than age alone (Bornstein et al., 2010; Karasik et al., 2015). During the first days and weeks of life, infants use looking and vocalizations such as cooing as a way to maintain their mother's proximity (Bowlby, 1969; Wendland-Carro et al., 2017). Children who can locomote maintain proximity by bringing toys to their parents or frequently returning to their parent after bouts of separation (Biringen et al., 2008). Children's interaction behaviors become more complex over the first years of life in response to advancing motor, cognitive, and language skills, and in turn parents are afforded opportunities to engage and foster development in new and more intricate ways (Biringen et al., 2008; Campos et al., 2000; Clearfield, 2011).

1.3 Synchrony of parent and child behaviors

Synchrony of the parent-child relationship predicts global developmental outcomes far and above individual parent or child factors or behaviors (Feldman, 2015; Landry et al., 2001; Smith et al., 2000). Synchrony of the relationship has been described as the ability of the dyad to match and share each other's affectual and behavioral states (Leclère et al., 2014; Treyvaud et al., 2009). While a synchronous relationship is considered optimal, this does not imply that a parent-child dyad must be perfect. In fact, a "just right" parent with adequate parenting behaviors has the skills to identify mismatches in synchrony and either correct their own behavior or scaffold the environment to allow the child the opportunity to change their state to match their parents (Beebe et al., 2008; Bornstein & Manian, 2013). Having a "just right" relationship allows the parent to pick and choose which bids to respond to and affords children multiple opportunities to advance self-regulatory and exploratory skills, thus fostering a balance of parent involvement and autonomy (Biringen et al., 2014; Biringen & Easterbrooks, 2012; Bornstein & Manian, 2013).

Emotional Availability (EA) is a relationship construct that considers the synchrony of the "just-right" parent and child within the context of their relationship. EA considers the capacity of the parent-child dyad to share an emotional connection and to enjoy a mutually fulfilling and healthy relationship (Biringen & Easterbrooks, 2012). Parent EA is described as sensitivity (congruent and positive responsiveness and affective exchanges), structuring (adequate provision and guidance during interaction, taking into account autonomy-fostering behaviors), non-intrusiveness (lack of controlling behaviors), and non-hostility (absence of covert or overt verbal or non-verbal hostile responses) (Biringen et al., 2014; Biringen & Easterbrooks, 2012). An emotionally available child is described as responsive to (eager to respond to bids while also demonstrating age-appropriate autonomy) and involving of (demonstrates initiative in involving behaviors) the adult (Biringen et al., 2014; Biringen & Easterbrooks, 2012).

EA is specific to two individuals and what is considered optimal can present very differently from one dyad to another when considering children's age or cultural context. Parent EA is generally stable over time and predictive of children's empathy, language skills, academic success and internalizing and externalizing behaviors (Célia et al., 2018; Moreno et al., 2008). Children's EA increases linearly from birth to three and is mediated by cognitive and developmental abilities (Célia et al., 2018). One proposed pathway between EA and child development is that children high in EA are more willing to pursue autonomous exploration, dyadic play, and affectively engage with new objects and people (Sorce & Emde, 1981). Parents high in EA are skilled in structuring opportunities that are challenging yet achievable and appropriate to the developmental needs and abilities of their children (Biringen et al., 2014; Sorce & Emde, 1981).

Additionally, parents aid in supporting children's self-regulation by sharing in their child's pleasure during positive experiences and comforting and reassuring them when faced with adversities (Sorce & Emde, 1981). Children apply their advancing developmental and regulatory skills to involve parents in new and more complex ways, thus enriching the interaction. This cyclical relationship between parent EA and children's development underscores the transactional nature of the dyad.

1.4 Impact of DD on the parent-child relationship

Consistent with the transactional model, DD impacts not only children but the entire family unit (Maccoby, 1992; Sameroff, 1975). Alterations in parents or children in the presence of DD threatens the synchrony of the relationship which may compound delays in development. Research on the relationship in children with DD is limited, especially when considering longitudinal associations between the quality of the relationship and children's global developmental outcomes. Most previous research has measured the short-term impact of unidirectional parenting behaviors (i.e., what the parent did or did not do) on concurrent child outcomes in small samples of young children (Bentenuto et al., 2020; de Galco et al., 2009; Van Ijzendoorn et al., 2007). For this paper, DD encompasses differentiated (cerebral palsy, autism spectrum disorder, Down syndrome, premature birth) and undifferentiated (delays in motor, language, socioemotional and/or language development of an unknown etiology) diagnoses.

1.5 Parents of children with developmental delays or disabilities

Parents of children with DD face numerous emotional stressors which may impact their mental health and potentially strain day to day interactions with their children. Parents of children with DD face higher rates of stress, depression, chronic grief, anxiety, and posttraumatic stress disorder (Forcada-Guex et al., 2011; Misund et al., 2013). Receiving a diagnosis of DD, uncertain prognosis, social isolation, relationship distress, and unmet expectations are just some of the factors that may impact the mental health of parents, specifically mothers of children with DD (Whittingham et al., 2013; Winter et al., 2018). Qualitative research including parents of children with DD express feeling less competent to meet their child's needs and overall view their role as parents to be more difficult (Whittingham et al., 2013). They also report having difficulty interpreting their child's affective and behavioral cues (Esposito & Venuti, 2010; Whittingham et al., 2013). However, despite potential strains on mental and physical health and/or lower levels of perceived competence, most studies identify that during observational assessment of discrete parenting behaviors, parents of children with DD engage in similar rates of sensitive and responsive caregiving as parents of children with typical development (Ku et al., 2019; Van Ijzendoorn et al., 2007).

Parents of children with DD have been described as tending to exert more controlling or intrusive behaviors during interactions, which could be related to multiple dyadic factors. Parents of children with DD may display overprotective behaviors due to their child's past or current medical history (Thomasgard & Metz, 1997). Parents may over-lead or over-stimulate as a way to support and guide their child. As mentioned previously in this paper, the context in which intrusive behaviors occur must be considered as this may change the effect they have on children. Previous researchers have hypothesized that parent's tendency for intrusive behaviors with "good intentions" may be of benefit to children with DD (Forcada-Guez et al., 2006; Kelly & Barnard, 2000). Venuti et al. (2008) proposed that “it is possible that maternal directiveness in this population may be appropriate or inappropriate depending on how much it sensitively fosters or disrupts child behaviors”. However, empirical support for this perspective has been mixed, highlighting the need for more longitudinal research on this topic to guide interventions and prevent parent stigma.

1.6 Children with developmental delays or disabilities

Challenges with social relationships are a common manifestation in children with DD. While DD in an umbrella term which encompasses numerous etiologies and impairments, in general, children with DD often have varying degrees of motor, language, cognitive, and socioemotional impairments. Motor development is often considered a control parameter for development in other developmental domains (Campos et al., 2000). For example, the motor milestone of walking brings euphoria to children’s affect, promotes a stronger sense of self, advances perceptual, spatial, and cognitive development, and transforms children’s social interactions (Biringen et al., 2014; Campos et al., 2000). Children who can walk initiate engagement, share objects, direct adult’s attention to objects of interest (joint attention), and seek information about novel situations from caregiver’s (social referencing) more often than children who are not walking (Biringen et al., 2014; Campos et al., 2000; Clearfield, 2011). In turn, parent’s set more limits and prohibitions, have higher expectations of compliance, provide more verbal commands, and spend more time interacting playfully with their child who is walking (Biringen et al., 2008; Biringen et al., 1995).

Due to limitations in motor, cognition, language, and/or socioemotional skills, children with DD may be more covert and less predictable during interaction potentially violating rules of social norms. Children with DD have been described as less active, persistent, or salient in attempts to engage parents, and spend more time in solitary exploration (Cress et al., 2007; Venuti et al., 2009). While it is possible that children with DD demonstrate fewer responsive or involving behaviors during interactions, the perception that children are passive may be inaccurate. Delayed or atypical responses to parents may be due to difficulties with processing input and organizing motor-based responses such as looking, reaching, or facial expressions rather than lack of interest in their parent. Delayed or atypical responses can disrupt the natural temporal sequencing of interactions and may contribute to a parent's tendency towards intrusive behaviors (Wilder et al., 2004). If children with DD were given ample time or more environmental support their interaction behaviors may mimic children with typical development.

Despite potential difficulties with interaction behaviors, children with DD perform better when their parents are involved in interactions, thus highlighting the protective role parents play in fostering their children's development. Sensitive parenting behaviors allow children with DD to elevate their play by engaging in more persistent exploration and allocating more attention to the current task (de Falco et al., 2010). Adequate structuring during play leads children to engage in more elaborative, symbolic play and demonstrate higher levels of mastery motivation (de Falco et al., 2010; Poehlmann & Fiese, 2001; Venuti et al., 2009). Sensitive parenting in response to difficulties with temperament advances self-regulation skills and decreases negative reactivity (Jaekel et al., 2015; Poehlmann & Fiese, 2001; Treyvaud et al., 2010).

1.7 Relationship Synchrony

Evidence regarding emotional availability in dyads with children with DD is emerging as most evidence has been published within the last few years. Stack et al. (2019) investigated the persistent effects of birth status on maternal and child EA in children born premature or very low birth weight birth. Birth status was identified to have a negative effect on children's EA but not rate of change. From 6 months to 4 years of age, children born preterm had similar rates of change in child EA compared to typically developing peers but scored lower across time. Birth status also moderated parental structuring as only the scores for parents of children born preterm decreased over time. Regardless of birth status, if a parent was higher in sensitivity and structuring at one timepoint, their child also performed higher than average in responsiveness and involvement at that same time point, supporting the protective role of parenting (Stack et al., 2019). Bentenuto et al. (2020) quantified EA in 3-4 year old children with autism spectrum disorder during a single play interaction. In contrast to typically developing populations, parent and child EA in this study were not correlated, and parents demonstrated "good enough" sensitivity, non-intrusiveness and non-hostility, but had difficulties with their ability to structure interactions. Parent EA was not influenced by severity of symptoms however child EA was. Overall, children scored lower in responsiveness and involvement, which was reflected as difficulty with their affective responses and engaging parents. These studies, although few, demonstrate the usefulness of a construct such as EA to provide an overall gestalt of the relationship quality while also providing insight into strengths and potential weaknesses of specific parent and child interaction behaviors that can be used to guide intervention.

In sum, evidence suggests that parents and children with DD are resilient in the face of adversity and continue to share in mutually enjoyable and synchronous interactions despite potential relationship stressors. Parents of children with DD face mental, physical, and behavioral adversities on a daily basis but continue to demonstrate similar parenting behaviors and qualities to parents of children with typical development. Positive parenting behaviors have the same beneficial effects for children with DD as described for children with typical development. Children with DD are often more dependent on their caregiving environment than their peers with typical development, highlighting the urgency to understand how delays in development impact dyadic emotional availability.

2. Parenting can buffer adverse effects of contextual risk factors

Parents and children's health and well-being are influenced by distal contextual factors or social determinants of health (Figure 1) (Bronfenbrenner, 1979). The World Health Organization refers to social determinants of health as a condition in which people are born, grow, live, work, and age. Parenting is a social determinant of health for children as most of children's interactions with their social environments are through their parents (Walker, 2021). Therefore, most of this section on contextual risk factors will focus on how social determinants of health or more specifically, inequalities in social determinants of health, impact children through potential alterations in parenting. As every individual and parent-child dyad represents a unique mix of risk and resilience, in addition to highlighting contextual risk, we will emphasize the role of healthy parent-child relationships in promoting dyadic resilience in the face of adversity.

2.1 Systemic Inequalities

Systemic inequalities based on race and/or socioeconomic status present barriers to education, adequate nutrition, safe and affordable housing, and health access and affordability, which may compound the complexity of the parenting experience for many families (Jones, 1997; Savell et al., 2019). Racism, the longstanding institutional and systemic prejudice, discrimination and oppression of people based on their ethnicity, skin color, or assumed biology, is “alive and sick” in the United States (Berry et al., 2021; Harrell et al., 2011; Jones, 1997). Racism cuts across many social determinants of health with effects in health and well-being across the lifespan, including prenatally (Geronimus et al., 2006; Trent 2019). Beginning in infancy, children may experience racism through implicit bias, racial disparities in health care access, and/or provider bias (Flores 2010; Marrast 2016; Witt et al., 2022). Children can also suffer indirect (or vicarious) effects of racism through the lived experiences of their parents (Berry et al., 2021; Heard-Garris et al., 2018). Family experiences of racism can affect caregiver well-being (toxic stress, depression) which can threaten the caregiving environment (Berry et al., 2021; Geronimus et al., 2006; Becares et al., 2015).

Women and infants of color have higher rates of maternal and infant mortality and morbidity, preterm birth, and low birth weight, with the disparities continuing to widen (Creanga et al., 2014; Martin et al., 2018; Xu et al., 2018). Racism, not racial group, is often linked to these disparities as factors such as maternal health behaviors or prenatal care, neighborhood poverty or unemployment do not completely explain these differences in birth related outcomes (Braveman et al, 2015; Goldenberg et al., 1996). Children of color with DD are up to 75% more likely than their peers to not receive the EI services they need (Khetani et al., 2017; McManus et al., 2020). In general, racial minorities have less access to care, experience less family centered care, and parent's concerns regarding their children's development are often met with skepticism and attributed to social rather than biological risk (Magnusson et al., 2016; McManus et al., 2020).

Socioeconomic status is another social determinant of health which is often associated with risks to parenting and children's adaptive development (Hanson et al., 2013; Luby et al., 2013; Nisbett et al., 2012). Consistent with current literature, SES is conceptualized as both income status and parental educational achievement (Elliot & Bachman, 2018). The disparities between development in children of differing household incomes begins in infancy as seen by differences in language and executive function abilities and extends all the way into adulthood, with adults living in low-income households being more prone to chronic diseases (Cartmill, 2016; Duncan et al., 2010). The mechanistic role of SES on children's development has been widely hypothesized (parenting stress or adversity, parental cognitions, inequalities in education, systems of prejudice) but conflicting findings have impeded the identification of a single pathway and rather it is likely the interaction of multiple factors.

Race/ethnicity (the mixture of physical, behavioral, or cultural attributes) and SES are often confounded in parenting and developmental sciences thus making interpretations of previous studies difficult (Kamii & Radin, 1967). Studies that have been successful in disentangling race/ethnicity from SES generally indicate that it is SES or racism, not race/ethnicity, that may present adversities which compound the relationship (Clarke-Stewart, 1973; Ispa et al., 2004; Kamii & Radin, 1967). Racial and SES injustices and inequalities must be advocated for on a national policy level.

Additionally, professionals working with families and young children with DD who may experience racism or inequalities in social determinants of health need to prioritize supporting parents and the parent-child relationship as a pathway to optimize children's health and development and familial well-being. Professionals also need to commit to understanding their own potential implicit biases in order to optimize care across diverse populations (Fitzgerald & Hurst, 2017). Parenting and the quality of the relationship is a strong predictor of children's outcomes across all social determinants of health and the relationship can moderate the adverse effects of many of these systemic injustices (Harris et al., 2014; Savell et al., 2019).

2.2 Culture

Culture impacts what parents expect of their children, which behaviors they emphasize and appreciate or discourage and influences the timing of developmental milestones (Bornstein, 2009; Karasik et al., 2015). Different cultural groups often demonstrate similarities in the types of parenting behaviors they perform, but display differences in the frequency in which they perform these behaviors (Bornstein, 2009; Ispa et al., 2004). The same parenting behaviors can have differing effects on children across different cultures depending on the context in which the behaviors occur (Ispa et al., 2004). Therefore, understanding the cultural context in which these behaviors occur as well as considering the dyadic relationship rather than discrete unidirectional parenting behaviors is essential to prevent stigmatizing different cultural groups. EA is a relationship construct that considers not just what parents do or don't do, but how behaviors influence children within the dyad's unique relationship (Biringen et al., 2014). When investigating EA across the three main cultural groups in the United States

(European Americans, African Americans, and Latino Americans) there were no differences between groups in EA suggesting “manifestations of EA in each race/ethnic subgroup are similar in the context of recorded play” (Derscheid et al., 2019). EA has been utilized internationally by researchers across different cultures, regions, languages, genders, age, and SES’s (Biringen et al., 2014; Biringren & Easterbrooks, 2012).

2.3 Gender

While most parenting research has been conducted on mothers it is only recently that literature emphasizes the unique impact fathers have on children’s development. Mothers and fathers physiologically respond to their infants similarly but display differences in their behavioral responses thus contributing to children’s development in similar but yet unique ways (Malmberg et al., 2016; Newton et al., 2014; Vertsberger & Knafo-Noam, 2019). During the first years of life mothers spend between 65-80% more time than fathers interacting with their young children which may allow mothers to learn infants nuanced communications bids leading to a more sensitive parenting style (Bornstein, 2012). Unique predictive qualities of mother- or father-child interaction is hypothesized to stem from the types of interactions each dyad frequently engages in. Mothers spend more time engaging in warm and sensitive caregiving routines which may explain their unique contribution to children’s development of prosocial behaviors (actions or tendencies intended to benefit others) (Brownell et al., 2013; Newton et al., 2014). Whereas fathers engage with their children mostly during play which may provide opportunities to promote exploration and limit setting thus predicting behavioral and cognitive outcomes (Malmberg et al., 2016).

There are differences in how parents (mothers or fathers) interact with their children (sons or daughters) and this may be attributed to existing gender based stereotypes. Daughters are generally raised to display higher levels of social interest that emphasize collaborative behaviors which may result in lower levels of autonomy but higher emotional availability and symbolic play (Lovas, 2005; Robinson & Biringen 1995). In contrast, sons are often raised to be autonomous, thus advancing self-exploration skills at the expense of emotionally involving their parent in their play (Lovas, 2005; Robinson & Biringen 1995). In studies on gender differences in emotional availability, girls generally perform the same or more optimal than boys due to higher scores in child responsiveness and involvement (Lovas, 2005). Differences within dyadic emotional availability based on children's gender are important considerations when designing and implementing early therapeutic interventions for children with DD as males are at a higher risk for preterm birth, adverse morbidity following preterm birth, and are more likely to be enrolled in EI services (Teoh et al., 2018; Townsel et al., 2017).

2.4 Adverse Childhood Experiences

Adverse childhood experiences (ACEs) can have long lasting impacts on adults psychological, behavioral, and physical well-being and can impact future generations (Felitti et al., 1998; Narayan et al., 2021). Approximately 50-60% of adults report having at least one ACE with 12.5% experiencing four or more (Centers for Disease Control and Prevention, 2021; Felitti et al., 1998; Madigan et al., 2019). There is a dose-response relationship between ACEs and risk to offspring in that as parents report more than 3 or 4 ACEs, the risk for difficulties with attachment, non-optimal EA, DD, or maladaptive internalizing and externalizing behaviors increases. (Cprek et al., 2019; Folger et al., 2018; Hughes et al., 2018; Lange et al., 2019; Rowell & Neal-Barnett, 2022). Alterations to parenting practices and the attachment relationship is a hypothesized pathway in which the adverse effects of early life experiences are transmitted to subsequent generations (Bowlby, 1951; Chung et al., 2009; Rowell & Neal-Barnett 2022; Widom et al., 2018). Mother's histories of maltreatment or household dysfunction are empirically linked to an increase in stress or depressive symptoms in adulthood as well as alterations in parenting cognitions or behaviors, all of which can impact parenting and the attachment relationship and subsequently children's development (Rowell & Neal-Barnett, 2022). Maternal depression is a potential mediator of the relationship between ACEs and EA or children's internalizing/externalizing behaviors (Banyard et al., 2003; Rowell & Neal-Barnett, 2022; Zvara et al., 2017). Parenting interventions which support adaptive parent-child relationships despite parent and/or child ACEs can have positive long-term effects on both parents and children (Sandler, 2011; Yamaoka & Bard, 2019). Measuring parental ACEs as part of routine intake may be a novel way to understand family adversity and promote familial resiliency.

2.5 Maternal Mental Health

The transition to motherhood can be a rewarding and fulfilling experience while also being a time of great stress and challenge (Nelson et al., 2014). The perinatal period represents a time of risk to maternal mental health for a multitude of reasons to all women, but especially to women with a history of adversity. Women exposed to chronic stressors such as inequities in social determinants of health, racism, or adverse childhood experiences often face higher rates of psychological distress during the transition to motherhood (Adynski et al., 2019; Bossick et al., 2022; Chung et al., 2009; Lyu & Ma, 2022; Nelson et al., 2014; Yim 2015). The short and long-term effects of perinatal depression on child development is well established leading to public health initiatives to identify and treat maternal depression as early as possible (Hoffman et al., 2017; Kingston & Tough, 2018). Difficulties with parenting behaviors and/or mother-infant bonding are hypothesized pathways for the adverse effect of parental mental health on development outcomes (Hoffman et al., 2017; Kingston & Tough, 2018). Therefore, to optimize familial well-being, in conjunction with treating maternal depression with pharmaceutical or interpersonal psychotherapy mediums, interventions which support parenting and the parent-child relationship are also critical in supporting maternal mental health and children's development (Forman et al., 2007; Holt et al., 2021; Kersten-Alvarez et al., 2011). Parents of children with DD face many acute and chronic stressors which may increase their susceptibility to adversities with mental health (Forcada-Guex et al., 2011; Misund et al., 2013; Whittingham et al., 2013). Early intervention providers can play a key role in supporting parents during the transition to parenthood. Promoting parent's self-efficacy, opportunities for optimal parent-infant bonding, and children's development may all be pathways in which early intervention professionals can positively impact maternal mental health (Adina et al., 2022; Holt et al., 2021; Potharst et. al., 2022; Waldrop et al., 2021).

2.6 Summary

Points key to this brief summary on contextual risk factors are that risk does not occur in isolation but rather it is the cumulative risk of these factors that compounds global development, parenting, and the parent-child relationship. In many situations, positive parenting behaviors or more optimal relationships can buffer the potential risk on development. Contextual factors can guide study design by influencing the selection of non-ethnocentric assessment tools and prioritizing diversity of participants recruited. EI professionals should feel empowered to support families within the families they see as well as advocating for broad social and policy changes in order to stop the cycle of poverty, social and health inequities, racism, etc, for children with DD and their families.

3. Early Intervention lacks rigor in assessing and treating the parent-child relationship

The efficacy of EI on motor and cognitive outcomes for children with DD has been mixed but most evidence points to promising short-term results (Novak & Honan, 2019; Orton et al., 2009; Morgan et al., 2016). However, longitudinal studies highlight that these short-term gains may not be maintained to school age (Spittle, 2015). One proposed mechanism of action on the lack of long-term efficacy of EI, is the continued sole focus on child level outcomes in designing and measuring success of intervention (Campbell & Sawyer, 2007; Peterson et al., 2007). Despite numerous calls for EI professionals to utilize a relationship-focused service model that measures and targets children's development within the context of the relationship in addition to executing child focused activities, EI professionals lack the skills, support, time, and tools to heed this call (Alexander et al., 2018; Bamm & Rosenbaum, 2008; Dusing et al., 2019; Guttentag et al., 2014; Mahoney et al., 1998). It is possible that current EI interventions affect parents and children's behavior at a specific developmental timepoint, but it does not impact their relationship thus any changes are transient and not sustained. To impart long lasting change, EI professionals need to promote the habitual relationship between parents and children, allowing for countless enjoyable, growth fostering interactions that persist across developmental contexts and time. We hypothesize that measuring and targeting the relationship during EI will optimize children's development and long term effectiveness of EI by directly supporting the quality of the relationship and indirectly by increasing parents' efficacy, engagement during EI, and adherence to parent-delivered intervention recommendations (Figure 2).

3.1 Parent efficacy, engagement, and adherence

Parent efficacy, engagement, and adherence are all pathways to better developmental outcomes and program effectiveness that hinge on the quality of the relationship (Figure 2) (D'Arrigo et al., 2017; Nix et al., 2018). Lack of focus on the relationship during EI can stress an already stressed dyad, thus proving the intervention to be ineffective and highlighting why the same intervention delivered to two different families can result in widely different outcomes. To optimize children's development and program effectiveness, the parent-child relationship must be at the forefront of family centered EI (Mahoney et al., 1998). Family centered care is mandated as part of EI and endorses shared decision making, facilitates family choice and control, and acknowledges that the parent is the expert on their child's needs (McManus et al., 2020). There is little evidence that relationship-focused intervention is delivered as part of family centered care, but rather parents are involved through methods of "parent education" or "parent coaching" (Morgan et al., 2016). In light of increasing waitlists and fewer family-therapist direct contact hours, therapists are dependent on parents to deliver intervention outside of therapy in order to achieve clinical dosage (Lord et al., 2018; Richardson et al., 2020). Therefore, a main priority for EI professionals is to equip parents with the knowledge, skills, and competence to implement parent-delivered intervention (McManus et al., 2020). While parents acknowledge appreciating learning these skills, they ultimately value and prioritize their role as a parent over therapist and would like more knowledge on opportunities to advance familial well-being (McManus et al., 2020; Novak, 2011). More than half of parents surveyed report some level of dissatisfaction with the family centeredness of EI (McManus et al., 2020).

Recent studies underscore that on average children are not receiving the recommended dosage needed for clinical change as parents report a fifty percent adherence rate to therapist recommendations for frequency of parent-delivered interventions (Lillo-Navarro et al., 2015; Sakzewski et al., 2009). Parents report they are less likely to adhere to therapists' recommendations when they felt the activities restricted their time for recreational activities, impacted the parent-child affective relationship, or if the activities were too challenging and burdensome for the child (Lillo-Navarro et al., 2015; Novak, 2011). Whereas they are most likely to adhere to recommendations if activities were enjoyable for both parents and children and if activities are designed as part of a parent-therapist collaboration (Lillo-Navarro et al., 2015; Novak, 2011).

A focus on training parents for parent-delivered intervention without focusing on the parent child relationship sets the stage for difficulties within the relationship, non-optimal developmental outcomes, inconsistent program effectiveness, as well as discourages parental efficacy, engagement, and adherence (Barfoot et al., 2017; Evans et al., 2014; Novak, 2011). Parent-delivered intervention within the context of an out-of-sync relationship, reinforces undesirable parenting behaviors, such as insensitivity to children's cues, hostility or intrusiveness, and can further inhibit children's active participation during interaction (Barfoot et al., 2017; Evans et al., 2014; Novak, 2011). Parents and children are less likely to engage with one another if interactions are unpleasant, thus children are provided fewer opportunities to advance development and parents feel less competent in their ability to guide their child. However, parent-delivered intervention within a synchronous relationship can reinforce dyadic emotional availability and lead to more enjoyable opportunities for parents to scaffold their child's learning of a wide array of developmental skills.

4. Focus of this dissertation

The central theme of this dissertation is to better understand the relationship between emotional availability and early delays in motor development (Chapter 2), children's global development (Chapter 3), and physical therapy interventions (Chapter 4) (Figure 3). Children's early learning and social interactions are driven by their gross motor abilities, putting children with delays in motor development at high risk for difficulties with EA. There is evidence to support this notion in that children with DD and their caregivers have been described as having behavioral difficulties within their interactions. However, there is lack of evidence on how alterations in individual behaviors impact the other member of the dyad within the context of their relationship. Relationship synchrony, rather than individual behaviors, gives insight into the reciprocal nature of the dyad and drives children's adaptive development. Given the importance of EA on children's healthy development and reciprocally the importance of children's development on optimal EA, any early alterations to EA need to be identified and treated as early as possible. Potential results from Chapter 2 and 3 will identify motor delay as a risk for optimal EA and subsequently identify nonoptimal EA as a risk to children's future development, both of which can guide service allocation and treatment delivery.

Prior to executing the analyses proposed in this dissertation, extensive training and consultation with the developer of the EA Scale was completed. The EA Scale quantifies EA in children aged 0-21 and their caregiver. The EA Scales have been applied to children of all developmental abilities and diagnoses similar to those included in this dissertation including children with Autism Spectrum Disorder, Down syndrome, Cerebral Palsy, and infants born preterm. EA training consisted of watching 10 hours of instructional videos followed by scoring a set of standardized reliability training videos until 90% reliability was achieved. At the end of training, the developer of the EA Scale met one on one to discuss applying the EA scales to children with motor delay. Prior to scoring the videos included in this dissertation, the coders involved in this project reviewed the EA Scales scoring protocol and added detail to definitions and criteria that may be relevant to ways in which children with motor delay expressed or responded to emotional signaling. Ten videos of children 7 to 20 months of age with varying levels of motor delay were scored prior to starting this project to ensure the coders could reliably score the EA Scales on the proposed population. The developer of the EA Scales reviewed these ten training videos to ensure valid application of the EA Scales to this novel population. To ensure reliable and valid application of the EA Scales throughout the duration of this project, the developer of the EA Scales scored 25 videos included in this dissertation.

Physical therapists often spend many hours with families of young children with DD during the first months and years of life, putting them in a great position to support EA in addition to children's development. Although many physical therapists implement a parent coaching model to achieve adequate dosage needed for clinical change, it is unknown how or if there is an effect on dyadic emotional availability. Results from Chapter 4 can guide our understanding of how early physical therapy interventions impact dyadic emotional availability in young children with motor delay. Identification of ingredients of interventions which aide or potentially hinder EA can guide future education models, outcome assessments, and service delivery models.

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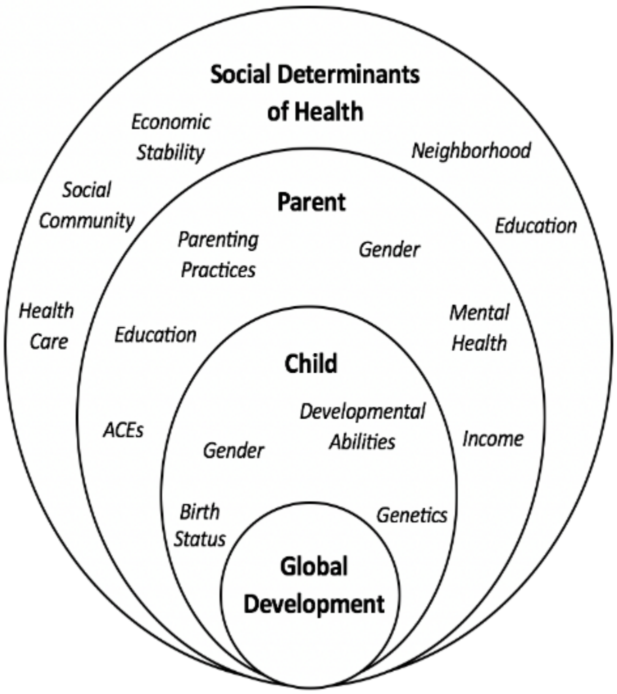


Figure 1. Theoretical representation of the embodiment of children's global development within child, parent, and social contextual factors

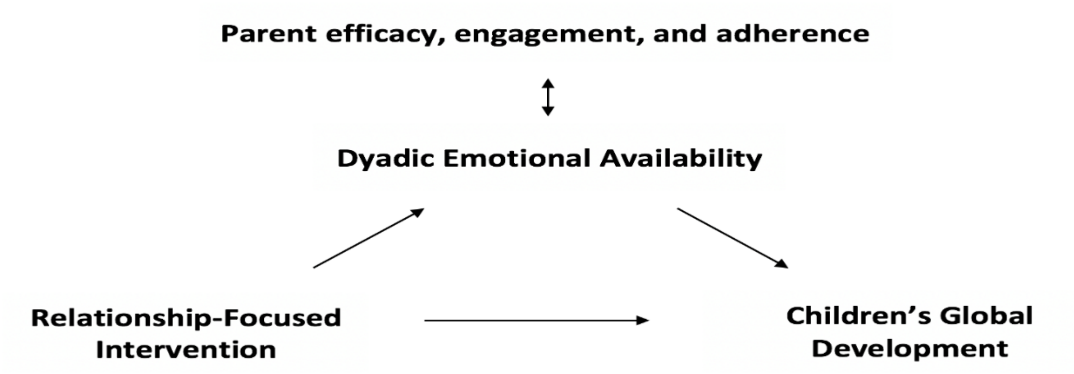
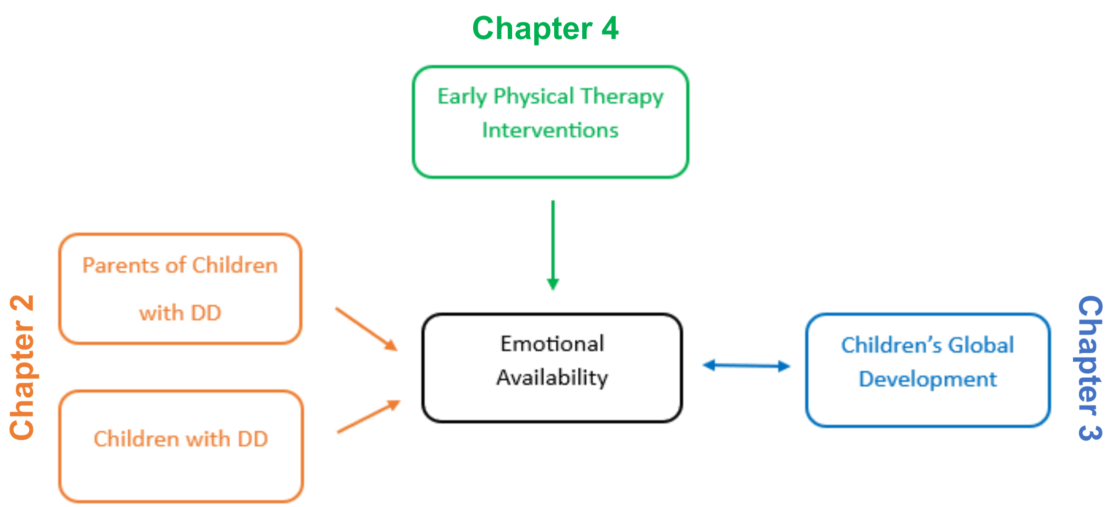


Figure 2. Theoretical model of the moderating role of dyadic Emotional Availability on optimizing the efficacy of relationship-focused early physical therapy interventions on children's global development

Figure 3. Conceptual model of the gaps in evidence on Emotional Availability in young children with motor delay and their caregivers.



DD=Developmental Delay or Disability. Orange boxes and arrows represent Chapter 2, blue box and arrow represent Chapter 3, and the Green box and arrow represent Chapter 4.

Chapter 2: Developmental Trajectories of Emotional Availability differ in Parents and Children with and without Motor Delays

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Abstract

Background. Dyads with children with motor delay may be at risk for alterations in Emotional Availability (EA) due to the grounding of children's early learning and social interactions in gross motor abilities. The purpose of this analysis was to compare developmental trajectories of EA in children with and without motor delay.

Methods. Data were drawn from 99 young children with and without motor delay (Mild motor delay, N=34, baseline age=9.26 months; Significant motor delay, N=30, baseline age=11.85 months; Typical motor development, N=35, baseline age=5.71 months). EA was scored from 5 minute videotaped parent-child interactions at baseline, 3-, 6-, and 12-months post baseline. EA trajectories were described and compared using multilevel growth modeling with unstructured variance and child level random effects. Pearson's correlations quantified the association between adult and child EA at the same visit and baseline to 3- or 12- month change.

Results. Trajectories of EA in children with mild motor delay differed from typical motor development in Child Involvement. Trajectories of EA in children with significant motor delay differed from typical motor development in Total EA, Sensitivity, Child EA, Child Responsiveness, and Child Involvement. There were no differences in trajectories between children with mild or significant motor delay. All groups had strong and significant correlations between Adult and Child EA at all visits and in change over time.

Conclusion. Severity of motor delay moderated the risk to EA in that dyads of children with more significant motor delay had difficulties with EA over time. Dyads with motor delay may benefit from early interventions which support child outcomes as well as the parent-child relationship.

Parent child relationships represent the earliest beginnings of life and have far reaching consequences across the lifespan (Belsky et al., 2015; Bornstein, 2014). While important at all ages, the parent child relationship from birth to three has been highlighted as a setting event for future development. Birth to three, referred to in this paper as early childhood, represents a window of time in which children are heavily dependent on caregivers for survival, socialization, and learning about the world (Bornstein, 2014; Holden & Miller, 1999; Maccoby, 1992). This time of great parental impact is also a sensitive period of children's experience dependent neurological development characterized by rapid synaptogenesis, pruning, and myelination of new neural pathways (Belsky et al., 2015; Bernier et al., 2016; Feldman, 2015). The opportunities that parents provide and facilitate as well as the relationship context in which they occur are shaping their children's brains (Belsky et al., 2015). Given the importance of the parent child relationship during early childhood it is imperative to identify processes that may pose a threat to the quality of the relationship as this could be a pathway to maladaptive developmental outcomes (Cicchetti & Toth, 2009). The purpose of this paper is to investigate the development of the quality of the parent child relationship, conceptualized as emotional availability, during early childhood and identify if delayed motor development serves as a risk factor to the relationship.

Emotional Availability (EA) is a multidimensional construct which provides insight into the quality of the parent-child relationship and is related to children's adaptive development (Biringen et al., 2014). The quality of the parent-child relationship is conceptualized as the "fit among the infants needs and capacities to respond, the mother's provision of necessary experiences, and the emotional tone of their interaction" (Bornstein et al., 2012). EA reflects the dyad's ability to share a healthy emotional relationship and has been coined the "connective tissue of healthy socioemotional development" (Easterbrooks & Biringen, 2000, p.123). Grounded in the transactional model of development, EA asserts that parents and children are equal partners and that their behaviors mutually influence one another (Biringen et al., 2014; Sameroff, 2009). Considering both parents and children as equally influential partners during day-to-day transactions guides our understanding of how adversity in parents, children or contextual factors can impact dyadic EA (Sameroff, 1975, 2009). Therefore, when investigating EA, the focus shifts from considering only the individual parent or child characteristics (an approach common to previous research), to focusing on how each individuals' behavior meet the needs of the other within the context of their unique relationship (Biringen et al., 2014). In typically developing populations adult and child EA are highly correlated so that a highly sensitive parent is one who nurtures a responsive and involving child, and vice versa (Biringen et al., 2014; Célia et al., 2018). During early childhood, Adult EA is generally stable and unchanging as children become older, but child EA increases linearly over time (Célia et al., 2018; Lovas, 2005; Ziv et al., 2000; Biringen et al., 2000). EA or the quality of the parent-child relationship have been found to predict developmental outcomes across childhood (ex: emotion regulation, empathy, and internalizing/externalizing behaviors) and can be protective against social and parent-level risk factors, such as maternal depression, fewer years of parental education, and adverse childhood experiences (Easterbrooks et al., 2000; Holt et al., 2021; Little & Carter, 2005; Moreno et al., 2008; Wurster et al., 2020).

Consistent with developmental cascades, EA in early childhood is hypothesized to be 80-90% nonverbal, meaning parents and children rely on gross and fine motor skills to emotionally signal, respond, and relate to one another (Biringen et al., 2012). Developmental cascades underscore that developmental milestones act as a catalyst for transformation within the relationship and ultimately parents respond to children's developmental abilities rather than age alone (Bornstein et al., 2010; Karasik et al., 2015). Motor skills which emerge in the first months and years of life such as tracking, pointing, sitting or walking influence how parents and children interact with one another (Bowlby, 1969; Campos et al., 2000; Wendland-Carro et al., 2017). In general, as children are able to do more motorically, they are able to interact with their parents in new and more complex ways, and in turn, parents are afforded new opportunities to take their child's development to the next level (Biringen et al., 1995; Campos et al., 2000; Clearfield, 2011). The increasing complexity of the relationship in response to motor development is hypothesized to be the catalyst to children's blossoming language skills that emerge after they start walking (Iverson, 2010). Most previous evidence on the associations between motor development and dyadic interactions has investigated discrete parent or child behaviors in response to the child learning a new motor skill (Biringen & Easterbrooks, 2008; Clearfield 2011; Iverson, 2010;). To our knowledge, there are no studies that have investigated how typical or atypical development of motor skills impact the emotional quality of the relationship. Emerging evidence highlights that the relationship between motor skills and multimodal development may differ between children with and without typical development (West et al., 2019).

Developmental Delay or Disability (DD) is a child level early life experience that may impact EA which in turn may compound global delays in development (Bell, 1968; Bronfrenner, 1979). For this paper, DD encompasses differentiated (cerebral palsy, autism spectrum disorder, Down syndrome, premature birth) and undifferentiated (delays in motor, language, socioemotional and/or language development of an unknown etiology) diagnoses. Delayed or atypical motor development during early childhood may interfere with children's responsive and involving behaviors during parent-child interactions. Children with DD may demonstrate a delayed, absent, or less salient response to their parents' bids for interaction (Cress et al, 2007; Crnic et al., 1983; Hwang et al., 2009; Venuti et al., 2009). Latent responses may be perceived as children being uninterested or unresponsive, but more likely they are often due to difficulties in motor control, strength, and/or processing speed (Cress et al., 2007; Wilder, 2004). Similarly, parents of children with DD face numerous stressors which may impact their mental and physical health in addition to experiencing potential difficulties with their parenting behaviors (Whittingham et al., 2031; Winter et al., 2018). Parents of children with DD report difficulty in interpreting their child's affective and behavioral cues as well as initiating and maintaining joint attention (Esposito & Venuti, 2010; Forcada-Guex et al., 2011; Wilder, 2004). Despite these potential difficulties, during observed dyadic interactions, parents of children with DD share similar behaviors to parents of children with typical development in both type and frequency (Ku et al., 2019; Van Ijzendoorn et al., 2007).

There is a paucity of studies that have examined the development of EA over time in children with biological risks. Most available studies include dyads of children with autism spectrum disorder or infants born preterm and utilize a cross sectional study design. Results generally suggest that child EA is moderated by severity of delay with children with more severe symptoms of autism or born more preterm having lower EA scores (Baptista et al., 2019; Bentenuto et al., 2020; Salvatori et al., 2016; Van Ijzendoorn et al., 2007). Findings for Adult EA is less clear as some studies report adults are less influenced by delay and continue to perform at more optimal EA levels whereas some studies identify difficulties with Adult EA (Barfoot et al., 2017; Bentenuto et al., 2020; Salvatori et al., 2016). Potential mismatches in Adult and Child EA may contribute to the lower correlations of adult and child EA also found in atypically developing populations (Bentenuto et al., 2020; Stack et al., 2019). Stack et al. (2019) described and compared EA from 6 months to 4 years of age in parent-child dyads in children born very low birth weight/preterm to term born children. The authors reported that parents of children born pre-term displayed similar EA to parents of children born term with some potential difficulties in their ability to structure interactions (Stack et al., 2019). Child EA increased linearly over time at similar rates for all participants, but children born very low birth weight/preterm scored significantly lower on child EA at all time points (Stack et al., 2019).

Taken together, the importance of the relationship quality on children's future development as well as the risk of DD on the quality or emotional availability of the parent child relationship, underscores the urgency to advance knowledge on this topic in children with DD. Optimizing EA may be a pathway to optimizing children's global development and familial health and well-being. From a transactional perspective, it is also possible that advancing children's gross motor skills may be a pathway to optimizing dyadic EA. Identifying early alterations in the parent child relationship can aid professionals working with young children and their families in service allocation and in designing individualized family centered care. Additionally, anticipated results can serve to support a paradigm shift in early therapeutic interventions to prioritize the parent-child relationship as a pillar of early intervention.

The primary objectives of this study are to explore the role of delayed motor skills on the development (Aim 1) and correlation (Aim 2) of adult and child emotional availability during the first and second years of life. Based on theoretical and empirical data we hypothesize that Adult EA dimensions (Sensitivity, Structuring, Non-Intrusiveness, and Non-Hostility) will remain stable over time while Child EA dimensions (Responsiveness and Involvement) will increase linearly in response to children's advancing development (Célia et al., 2018; Stack et al., 2014). We anticipate strong positive correlations between Adult and Child EA at the same point in time and in change over time. We hypothesize that severity of motor delay will moderate trajectories and correlations in that dyads with children with significant motor delay will demonstrate less optimal EA over time and have weaker correlations (Bentenuto et al., 2020; Salvatori et al., 2016; Stack et al., 2019).

Methods

Sample

The sample includes 99 young children who were enrolled at the developmental skill of learning to sit. The emergence of sitting was defined as the ability to sit propping on arms for support for at least three seconds, spontaneous movement of the arms, and inability to transition in and out of sitting (Harbourne et al., 2018, 2021). Sixty-seven of the participants had a known motor delay and were participating in the control group of the “Sitting Together and Reaching to Play (START-Play)” randomized and controlled clinical trial (NCT 02593825) and 37 participants had typical motor development (Harbourne et al., 2018, 2021; Marcinowski et al., 2019). The participants from START-Play all scored >1.0 SD below the mean on the gross motor subtest of the Bayley Scales of Infant and Toddler Development, Third Edition (Bayley) at baseline, were between 7-16 months corrected age at baseline, and were recruited from 5 sites across the United States (Virginia, Delaware, Pennsylvania, Nebraska, and Washington) on a rolling basis from 2016-2019 (Bayley, 2006; Harbourne et al., 2018). The typically developing participants were recruited in Virginia from 2016 to 2017, scored < 1.0 SD below the mean on the gross motor subtest of the Bayley at baseline, and were between 5-7 months at baseline (Marcinowski et al., 2019).

In addition to having a baseline motor delay, the inclusion criteria for the participants from START-Play included: neuromotor disorder such as cerebral palsy, increased risk for cerebral palsy due to prematurity or brain damage around birth, or motor delay of an unknown origin (Harbourne et al., 2018, 2021). Exclusion criteria common to all participants were: Medical complications limiting participant in assessments (e.g., severe visual disorder), a primary diagnosis of autism, Down syndrome, spinal cord injury, diagnosed uncontrolled seizure disorder, parent younger than 18, or a neurodegenerative disorder (Harbourne et al., 2018, 2021; Marcinowski et al., 2019).

Participants were recruited through social media, mailings, websites, as well as through medical centers and early intervention providers. Ethical approval was obtained from the Duquesne University and Virginia Commonwealth University Institutional Review Boards.

Procedures

For analysis purposes, the participants with motor delays were stratified into mild or significant motor delay groups based on baseline Bayley gross motor scores (mild delay > 1.0 to <2.5 SD below the mean and significant delay ≥ 2.5 SD below the mean) (Harbourne et al., 2021).

Parent-child dyads were assessed up to 5 times over 12 months (baseline, 1.5-, 3-, 6-, and 12-months post baseline) in the home, daycare setting, or a home like lab space, as dictated by the caregiver's choice. Assessors were trained to reliability standard and blinded to group assignment. All assessments were video recorded and stored for later scoring by researchers masked to group assignment. During each assessment a battery of tests were performed but only the Parent-Child Interaction and gross motor assessments are relevant to this analysis (for a full description of all assessments performed see Harbourne et al., 2018). At the first and last visits, parents completed a Health & Demographic Form regarding background information about the parent, child, and home environment.

Outcome Measures

Emotional Availability Scales. The 4th edition of the EA Scales was used to quantify EA from the five-minute videotaped parent child interactions collected at each assessment visit. During the parent-child interaction assessment parents were instructed to "interact with their child as they normally would" and to ignore the assessor and camera operator insofar as possible. During the assessment, the assessor resisted interacting with or even making eye contact with the parent or child during the filming to prevent distracting them. Parents were aware that the objective of the study was to investigate how children moved and learned (Harbourne et al., 2018). Parents were not restricted to the current play space and told they were free to move about the home. A standardized set of toys were provided to parents at the start of each assessment and parents were told that they could use these toys, along with any other toy in the home if they wanted to. The standardized set of toys were provided with the goal of providing all parents with access to toys regardless of SES or home environment (Harbourne et al., 2018). The toys provided were a phone rattler, interlocking rings, pull and go car, and ball.

The EA Scale was designed to assess EA through observations and ratings of age and context appropriate behaviors during parent-child interactions (Biringen et al., 2014). The EA Scale is composed of six dimensions, four focused on adult behavior and two focused on child behavior (Biringen et al., 2014). The four adult EA Scale dimensions are: (a) *sensitivity,* which includes affect, responsiveness, timing, flexibility, acceptance, amount of interaction, and managing conflict; (b) *structuring,* which includes provision and success of guidance, amount and types of structuring implemented, and setting and remaining firm in limit setting; (c) *non-intrusiveness,* which includes the ability to follow the child's lead, enter interaction without physically or verbally intruding, and talking and relating in a way that teaches rather than commands; and (d) *non-hostility,* which includes an overall lack of negativity in face or voice and overall the parent is composed, patient, pleasant, available to comfort and support the child (Biringen, 2008). The two child EA dimensions include: (a) *responsiveness*, which includes the child's balance between age-appropriate autonomous exploration and responding to parent's interaction bids, enjoyment of the interaction, and organized affect regulation; and (b) *involvement*, which includes the child's willingness to simply and elaboratively initiate interaction with their parent (Biringen, 2008). Each dimension contains seven scored items with a potential score range of 7-29 for each dimension with a higher score indicating more optimal emotionally available behaviors (Biringen, 2008). The first two items of each dimension were scored on a 7-point Likert scale from non-optimal (1) to optimal (7). The remaining five scored items of each dimension were scored on a 3-point Likert scale from non-optimal (1) to optimal (3). The child EA score includes the sum of the 7 scored items from the child EA dimensions for a potential score ranging from 14-58. The adult EA score includes the sum of the 7 scored items from the 4 adult EA dimensions for a potential score ranging from 28-116. Each item was scored in 0.5 point intervals. The adult EA and child EA scores are summed to get a total Score (range 42-174). Child EA, Adult EA, and Total EA scores give insight into the global relationship quality, while investigating the dimensions provides context into specific mechanisms of change in EA (Biringen, 2008).

Two trained and reliable coders, blinded to group assignment, scored all videos included in this analysis. Videos were assigned randomly and equally distributed across enrollment site, motor group, and assessment visit. Coders were assigned the same dyad across time to limit intra-individual variability in EA trajectories. Coders watched the parent-child interaction videos at least thrice, first to gather a gestalt conceptualization of the dyad, then to score the adult, and child during the remaining two passes. Twenty percent of all videos were scored twice to track inter- and intra-rater reliability. ICC’s for inter-rater reliability were: Adult EA = .88 Child EA = 91, Sensitivity = .80, Structuring = .86, Non-Intrusiveness = .82, Non-Hostility = .88, Child Responsiveness = .86, and Child Involvement = .91.

Bayley Scales of Infant and Toddler Development, Third Edition (Bayley). The Bayley is a well-known norm-referenced test designed to assess multiple developmental domains in infants of 3 to 42 months of age (Bayley, 2006). The motor scale is comprised of fine and gross motor subtests. The gross motor subtest consists of 72 items assessing the degree of body control, large muscle coordination, and dynamic movement (Bayley, 2006). The fine motor subtest consists of 66 items assessing prehension, perceptual-motor integration, motor planning and speed, object grasping and manipulation (Bayley, 2006). All items are scored as a 1 (able to perform the test item as described) or 0 (unable to perform the test item as described). Participants were positioned in a supportive chair or supported by the parent or assessor and items were administered according to the Bayley administration guidelines. The child’s age, adjusted for prematurity if needed, designates the starting point on the assessment. Once the basal was set (scoring 1 on 3 consecutive items), items were administered in a forward direction. The assessment of each domain was terminated when the child received a score of 0 for 5 consecutive items. The Bayley fine and gross motor subtests were scored from video by trained and reliable coders. The scores of each administered item were summed to get a raw score for fine and gross motor subtests. The raw scores in addition to the child’s age were used to get fine and gross motor scaled scores, which were then summed together to get a motor composite score. Reliability of the Bayley motor composite score for this study was, intra-rater 0.99-1.00 and inter-rater 0.99-1.00 (Harbourne et al., 2021).

Analysis plan

Univariate (mean, SD, median, range, percentage) analyses were performed to describe the baseline demographic characteristics of the sample and EA outcomes aggregating across the entire sample and stratifying by three baseline motor severity groups (typical motor development vs Mild motor delay vs. Significant motor delay).

Demographic variables considered important to parenting and EA (child race and gender, ethnicity, parent reported education, and household income) were entered into the multilevel growth model one at a time (Chaudhuri et al., 2009; Lovas, 2005; Wurster et al., 2020). Gender, race, and ethnicity were not significant and therefore removed from the model. Parent education and income were both significant, but multicollinearity was suspected and confirmed using a chi-square analysis (p=<.0001). Parents achieving a bachelor's degree or higher were also likely to report an income of > or equal to $60,000 in contrast parents not reporting a bachelor's degree at baseline were likely to report a lower household income. Parent education rather than income was chosen as a covariate as education was specific to the individual parent that participated in the study rather than income which was reported at the household level. And from a practical perspective, income had more missing data, thus decreasing the sample size. To achieve similar group sizes, dyads were divided into two groups based on parent reported baseline education: dyads with parents reporting at least a bachelor's degree (≥BA) or parents reporting less than a bachelor's degree (< BA).

To describe patterns of Adult EA, Child EA, and each EA dimension by time since baseline (Aim 1), we used multilevel growth modeling analyses with unstructured variance aggregated across all participants. Multilevel growth modeling was chosen given its ability to easily handle repeated measures of the same outcomes where time points may vary across participants (Grimm et al., 2017). Time since baseline was entered into the model as a continuous variable to account for differences in time between assessments across participants. All models examined both linear (TIME) and quadratic (TIME*TIME) effects with non-significant quadratic effects removed. To investigate if baseline EA scores or trajectories vary as a function of baseline motor severity (typical motor development, mild or significant motor delay), a categorical variable “GROUP” was added as an interaction term with linear or quadratic time.

All models controlled for baseline mean centered age and parent reported education level. As baseline mean centered age varied between the motor severity groups, the interaction between baseline mean centered age*GROUP was also included as a control variable. Random effects of intercept and time slope at the child level were included. When investigating EA trajectories aggregated across participants, an additional control variable was also entered into the model to account for differences in which sample the participants were recruited from. All participants were included in the model, even if they had missing data as missingness was assumed to be at random. Baseline demographic and EA data of participants who dropped vs completed the study were compared to identify differences (Supplemental table 1). When comparing dyads who dropped vs completed the study, there were differences at baseline in parent reported education and ethnicity, with dyads whose parent reported less than a

Bachelor’s degree at baseline or those identifying as Hispanic, being more likely to drop out. Additionally, dyads scoring lower in Sensitivity and Child Involvement were also more likely to drop out than to complete the study (Supplemental Table 1).

Significance was based on alpha=0.5. Cohens *d* describes the effect size for within group change for the results aggregated across all participants (Cohen, 1988). Hedges *g* with small sample correction will measure effect sizes or standardized differences between group means (Hedges, 1988; What Works Clearinghouse, 2017). Standardized differences of 0.20, 0.50, and 0.80 are interpreted as small, medium, and large effects, respectively (Cohen, 1988).

To examine correlation of Adult and Child EA (Aim 2), multivariate linear mixed modes were run. To investigate intercept and slope correlations aggregated across motor groups, Adult and Child EA scores were entered into the same model with linear and quadratic fixed effects with estimates of random intercepts and random linear slopes. To investigate the effect of baseline motor delay on intercept and slope correlations, group was added as an interaction variable to the model. There were issues with convergence with this model, therefore separate models were run for each group. Models converged for the mild or significant motor delay groups, but the Estimated G matrix was not positive definite when running the group with typical motor development. Therefore, simpler and separate models investigating Pearson’s correlations of between- and within-dyad Adult and Child EA were run for each motor group. Between-dyad correlations described the strength of the relationship between average Adult and Child EA across all visits. Within-dyad correlation removed between-dyad variability and investigated the association between residual Adult and Child EA at each visit. Residual Child EA at each visit were computed by subtracting a child's aggregated average EA from their EA score at a particular visit, with the same process repeated for Adult EA. Correlation of residual EA describes if a child performed high (or low) at a particular visit in relation to their average EA, would their caregiver also perform high (or low) in relation to their average EA at that same visit. Lastly, correlation of 3- or 12-month Adult and Child EA change scores was computed by subtracting baseline Adult or Child EA from the 3- or 12-month Adult or Child EA scores respectively.

Results

Descriptive statistics of the sample aggregated and stratified by severity of motor delay are listed in Table 1**.** Overall, the sample was mostly mothers (94%) and predominantly white (67%), non-Hispanic (87%), and had at least a Bachelors degree (65%). Children's average age at baseline was 8.79 months, with age differing between the three motor groups. Children with typical motor development entered the study on average at 5.71 months, mild motor delay at 9.26 months, and significant motor delay at 11.85 months. Groups did not differ in any EA outcome at baseline except for dyads with children with typical motor development scored significantly higher than dyads with significant motor delay in Child Responsiveness (EST=2.11, p=.03).

Describing EA trajectories aggregated across participant's

Estimates of linear change for time since baseline indicates estimated change within or between groups in EA for each month in the study. Cohens *d* and Hedges *g* effect sizes are based on estimated 12-month change in EA.

Aggregating across all participants, there were significant linear changes in Total EA (*p*=.04, *d*=.22), Child EA (*p*=.00, *d*=.42), and Child Involvement (*p*=<.00, *d*=72) (Supplemental Table 2; Supplemental Figure 1). Significant quadratic effects were seen in trajectories of Non-Intrusiveness (*p*=.02, *d*=.20) and Adult EA (*p*=.04, *d*=.06) with acceleration after the 3 and 6 month post baseline visit, respectively (Supplemental Table 2; Supplemental Figure 1).

Describing EA trajectories within each motor group

There were no significant quadratic time by group interactions, therefore quadratic terms were removed from the model and only linear changes are reported. Dyads with children with significant motor delay remained stable in all EA outcomes while dyads with children with mild motor delay had a significant linear increase in Child Involvement (*p*=.00, *d*=.62) (Table 2, Figure 4). Dyads with typical motor development had significant linear increases in Total EA (*p*=.00, *d*=.62), Sensitivity (*p*=.04, *d*=.46), Non-Intrusiveness (*p*=.04, *d*=.40), Child EA (*p*=.<.00, *d*=.95), and Child Involvement (*p*=.<.00, *d*=1.45) (Table 2, Figure 4).

Comparing EA trajectories between motor groups

When comparing trajectories of EA over time in dyads with children with mild motor delay and typical motor development, significant differences in trajectories were seen only in Child Involvement (*p*=.03, *g*=.63) (Table 3 and 4, Figure 4). For every month in the study, children with typical development were increasing in Child Involvement, on average, .24 points more than dyads with children with mild motor delay. Trajectories of EA in dyads with significant or mild motor delay did not differ in any EA outcome (Table 3 and 4, Figure 4). Change in EA over time in dyads with children with significant motor delay or typical motor development significantly differed in Total EA (p=.02, g=.66), Sensitivity (p=.03, g=.70), Child EA (p=.00, g=.94), Child Responsiveness (p=04, g=.59), and Child Involvement (p=.00, g=1.23) (Table 3 and 4, Figure 4).

Correlations

Between-dyad covariation of overall average Adult and Child EA were strong and significant for each motor group (Significant r=.67, Mild r=.80, Typical r=.91) (Table 5). For all motor groups, if a child had high (or low) EA on average across time, then their parent was also likely to have high (or low) EA on average across time (Table 5). Covariation of average Adult and Child EA was significantly stronger in children with typical motor development compared to mild motor delay (test statistic z=1.7, p=.04) and significant motor delay (test statistic z=2.74, p=.00).

Time specific within-dyad covariation of adult and child EA residuals at all visits indicate strong and significant positive correlations for all groups (Table 5). Positive correlations indicate that if a child scored high in EA at a particular visit relative to their average EA, then their parent was also likely to score higher relative to their average EA at that same visit. Covariations did not differ between motor groups at any visit, except between dyads with children with mild motor delay or typical motor development at 12 months post baseline (test statistic z=2.19, p=.01) (Supplemental table 3).

Lastly, covariation of 3 or 12 month change scores of Adult and Child EA reveal strong and significant positive correlations for all groups, with no differences in correlations between groups (Table 5, Supplemental table 3). On average, if an adult changed at a higher rate relative to other adults in the sample, then their child was also likely to change at a higher rate relative to other children in the sample.

Discussion

The purpose of this paper was to investigate the impact of delayed motor development on emotional availability during early childhood. Results suggest children with motor delay, significant more so than mild, changed differently in EA compared to children with typical motor development. Dyads entered the study with similar dyadic EA, but differences quickly emerged between dyads with children with typical motor development, mild motor delay, or significant motor delay. Results for children with mild motor delay are in line with previous evidence in that children's EA more so than adult's EA is moderated by the severity of children's delay in development. However, the effect of delayed motor development on EA in dyads with children with significant motor delay was seen at both the adult and child level.

Trajectories of EA over time: Aggregated

When considering the results of EA trajectories over time, it's important to recall that stability of EA can be just as desirable as increasing EA depending on baseline values. In the presence of optimal EA at baseline, it is likely that dyads will not increase over time as they are already demonstrating dyadic emotional availability and therefore remaining stable over time is desirable. If baseline values indicate inconsistent or nonoptimal EA then the desired trajectory over time is one that increases towards more optimal scores. A decrease in any EA dimension over time is never considered a desirable outcome. Clinical score guidelines for the EA dimensions include scores ≥ 26 are considered optimal EA, scores of 18-25 indicate inconsistent EA, and scores ≤ 17 are considered nonoptimal EA (McLean et al., 2022).

Aggregating across all participants, trajectories of Total EA, Child EA, and Child Involvement increased linearly over time and Adult EA and Non-Intrusiveness demonstrated quadratic change. These results align with previous results in that children’s EA is likely to increase in early childhood whereas adult’s EA is malleable but generally stable (Bentenuto et al., 2020; Célia et al., 2018; Stack et al., 2019). We anticipate that the change in total EA was likely a reflection of changes in the child more so than the adult and that quadratic change in Adult EA was a reflection of quadratic change in Non-Intrusiveness.

It is interesting that linear changes were seen in child-level EA outcomes, while quadratic changes were seen in adult-level EA outcomes. Linear change in child EA outcomes indicates children were undergoing consistent growth over 12 months, whereas quadratic change in adult outcomes indicates parents underwent more growth in the latter half of the study. By the final study visit, many of the children transitioned from immobile sitters to having some form of independent mobility (rolling, scotting, crawling, or walking). This change in mobility may have contributed to quadratic changes within Non-Intrusiveness. During early interactions in which children were immobile, parents may have assumed more responsibility for leading interactions, and this may have inadvertently presented as physical or verbal intrusions (i.e., hand over hand demonstrations or talking over the child). Additionally, as children may have needed more hands-on support for balance during sitting play, parents may have blurred the lines between physical support and physical intrusions. As parents were physically helping with sitting balance, they may have also provided to much support in other aspects of the interaction thus limiting children's autonomy. However, it is also possible that quadratic change in adult outcomes was due to a longer interval of time between the final visit (12 months post baseline) and the previous visit (6 months post baseline), with earlier visits separated by 3 months.

Trajectories of EA over time: stratified by motor group

The results for change in EA over time within each of the three motor groups suggested a different general trend for each group. Dyads with children with typical motor development increased in both adult and child EA dimensions, dyads with children with mild motor delay stayed stable in adult EA outcomes but increased in child involvement, and dyads with children with significant motor delay remained stable over time with decreasing predicted trajectories for seven out of the nine EA outcomes (Table 2). Decreasing trajectories during a time in which children are anticipated to be learning new developmental skills is the opposite of developmental cascades and is worrisome as this is a time in which the parent-child relationship yields long-term implications (Bernier et al., 2016; Bornstein, 2014).

Dyads with children with mild motor delay. Dyads with children with mild motor delay or typical motor development differed only in their trajectories of Child Involvement. Both groups had significant increases in Child Involvement over time but dyads with typical motor development had a steeper rate of change. By 12 months post baseline, children with typical motor development were scoring significantly higher than children with mild motor delay with an estimated difference of 2.88 points. Both groups started at similar levels of Child Involvement and were likely using similar involving strategies such as briefly looking towards their parent or attending to how their parent manipulated different toys. These early episodes of involvement may have revolved around children using parents as a means for physical or emotional support (i.e., seeking help with a toy or a hug if they were tired or hurt). In contrast, increasing involvement scores indicate that over time children transitioned from simple to complex involving strategies and spent more time initiating and reciprocating sustained bouts of joint attention. Complex involving strategies could behaviorally be seen as engaging in pretend play, following their parents commands, suggesting game play or even placing demands on their parent.

Although trajectories were non-significant, children with typical motor development were scoring higher than mild motor delay at the 6 and 12 months post baseline visits in Child EA and Child Responsiveness. Trajectories of Adult EA outcomes in children with typical motor development or mild motor delay did not differ, however adults with children with typical motor development were scoring significantly higher than those with children with mild motor delay at the 12 months post baseline visit in Sensitivity and Adult EA. Longer periods of follow up may have revealed differences in trajectories.

Dyads with children with significant motor delay. Trajectories of EA in dyads with children with significant motor delay differed from typical motor development in the dimensions of Total EA, Sensitivity, Child EA, Child Responsiveness, and Child Involvement. Children with significant motor delay scored significantly lower than children with typical motor development in 1 of 9 EA outcomes at the developmental skill of learning to sit (baseline) but by 12 months post baseline the groups differed in 8 of 9 outcomes. Learning to sit represents a setting event for both infant learning and caregiver provided learning opportunities (Kretch et al., 2022; Soska et al., 2010). Our results highlight that the emergence of sitting also represents an important developmental milestone that precedes a period of potential risk to the parent-child relationship for dyads with children with significant motor delay. Dyadic EA is malleable during this time making the onset of sitting a critical time to measure and treat EA in at-risk dyads.

Children with significant motor delay or typical motor development had opposite directions of change in Child Responsiveness resulting in significantly different trajectories. Children with typical motor development were increasing by .13 points per month (or 1.54 points over 12 months) while children with significant motor delay were decreasing by -.09 points per month (or -1.02 points over 12 months). Children with significant motor delay scored 2.11 points lower than children with typical motor development at baseline and by 12 months they scored 4.7 points lower. Optimal responsiveness is seen in children with robust affects and who can effectively self-regulate or seek support from parents to help regulate during challenging times (Biringen, 2008). In contrast, lower responsiveness scores may reflect children who are easily dysregulated and dependent on parents for regulation or children who may be more emotionally shut down and reliant mostly on themselves for regulation (Biringen, 2008). While more research is needed for specific mechanisms to understand decreasing scores in responsiveness, previous research supports that children with DD may have more difficulties with temperament and emotional regulation and may be more dependent on caregivers for regulation (Bornstein et al., 2015; Hwang et al., 2009; Norona & Baker, 2017).

Although child involvement scores (non-significantly) increased over time for children with significant motor delay, they could not match the rate of change compared to their peers with typical motor development. Children with significant motor delay had difficulties with Child involvement as seen by their scores at 12 months post baseline were lower than baseline scores for children with typical motor development or mild motor delay. Difference in scores and trajectories indicate that while children with typical motor development were engaging in longer bouts of reciprocal emotional and playful interactions, children with significant motor delay were likely engaging in shorter bouts of engagement and involving their parent for physical support or emotional regulation rather than playfully.

Sensitivity differed overtime between dyads with children with significant motor delay or typical motor development. As sensitivity scores are heavily influenced by affect and responsiveness, difficulties in one or both areas could explain differences in trajectories over time. Difficulties with sensitivity in adults of children with significant motor delay may be a reflection of “non habitual” use of therapeutic techniques (Barfoot et al., 2017; Biringen, 2008). It is expected that most if not all children with significant motor delay were receiving some form of therapeutic intervention(s) during this study. The physical and cognitive load of integrating therapy techniques into interactions may have impacted caregiver’s ability to engage emotionally with their child. Parents may have assumed a sterner or “business like” affect as opposed to one that was authentic and mirrored their child. And as parents may have had an agenda of what intervention activities they were going to implement they may have been less aware of children's cues or flexible to deviate from their pre-determined activities thus lowering responsiveness. These hypothesized mechanisms are similar to qualitative findings by Barfoot et al. (2017), who found that parents scoring lower in EA prioritized teaching over emotional connection. These findings underscore the importance of blending early therapeutic interventions with modeling or education on sensitivity and emotional availability.

Correlations

All groups had strong and significant correlations of Adult and Child EA at all visits indicating that at specific points in time if an adult was going to score high in comparison to their average EA then their child was also likely going to score high in comparison to their average EA. Although the strength of the correlations differed between groups, the differences were not significant. This indicates that at a particular point in time parents' and children's EA were influenced by one another similarly regardless of motor abilities.

Dyads with children with typical motor development had significantly stronger covariation in average Adult and Child EA means over time compared to dyads with children with mild or significant motor delay. Lower covariation of mean scores in children with motor delay may be explained by findings from Aim 1 as well as previous EA evidence in clinical populations (Bentenuto et al., 2020; Salvatori et al., 2016; Stack et al., 2019). In general, child EA is moderated by the severity of delay whereas adults continue to perform at levels similar to adults of children with typical development. While we did identify some difficulties in adult EA in our participants, the biggest impact of motor delay was seen at the child level. “Good enough” adult EA coupled with low child EA may explain lower correlations of overall mean scores in dyads with motor delay.

Limitations

Although other demographic variables such as household income, parent’s education level, ethnicity or race are often described as being associated with parenting or emotional availability (Chaudhuri et al., 2009; Huang et al., 2022; Ispa et al., 2004), due to lack of variability in sample characteristics we controlled for these variables rather than understanding their unique impact on EA. Future research should consider composite variables that gives insight into the multi-dimensional impact of family background on the parent-child relationship (Karlamangla et al., 2006). While the purpose of this paper was to investigate the impact of motor delay on EA, we did not consider development in other domains such as cognition or language, which may impact EA. As the severity of motor delay increases, the likelihood of cooccurring delays in other domains also increases, which could explain why dyads with significant motor delay differed in EA trajectories over time (Hollung et al., 2020). Similarly, children with typical motor development were recruited based on their motor scores but it is possible that their cognitive or language abilities did not fall into the typically developing range at baseline or at other times in the study.

Although all participants entered the study at the same developmental skill level, it is likely that soon after enrollment, the trajectories of motor abilities differed between the groups. Our analysis indicates how categorization of motor delay at baseline impacts EA but does not provide insight into how EA changes in response to advancing motor skills. Lastly, there were convergence concerns with covariation analysis and therefore a simpler model was run separately for each group. The simpler model was unable to handle missing data thus decreasing sample size as many dyads had some missed visits throughout the study.

Clinical relevance or conclusion

The results from this study indicate that during the first and second years of life the risk to non-optimal patterns of EA increases as the severity of motor delay increases. Given the importance of EA to familial well-being, early identification and treatment of EA in children with motor delay is essential. Many children with motor delay routinely receive early therapeutic interventions in efforts to optimize or maintain children's development and support family goals. Integrating EA into existing therapies is a clear pathway to optimizing both familial and children's health and well-being. Early therapeutic interventions could serve as a source of resilience and equip parents and children with the skills needed to promote dyadic EA.

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Table 1. Baseline child and family descriptive statistics

Variable	Total	Mild Motor Delay	Significant Motor Delay	Typical Motor Development
N	99	34	30	35
Gender				
Male	52	21	15	16
Female	47	13	15	19
Race				
Asian	4	3	1	0
Black or African American	12	1	7	4
Multiple	6	4	2	0
Other	3	1	0	2
White	66	23	18	25
Missing	8	2	2	4
Ethnicity				
Not Hispanic	86	27	27	32
Hispanic	10	5	2	3
Missing	3	2	1	0
Adult scored				
Father	5	2	1	2
Mother	93	32	28	33
Other	1	0	1	0
Parent Education*				
≥ Bachelor's degree	62	21	13	28
< Bachelor's Degree	33	11	16	6
Missing	4	2	1	1
Dropped				
Yes	15	28	23	33
No	84	6	7	2
Multiple caregivers				
Yes	16	29	24	30
No	83	5	6	5
Age in months*				
Baseline	8.79	9.26	11.85	5.71
3mo post baseline	11.88	12.58	15.15	8.66
6mo post baseline	14.89	15.61	18.26	11.69
12mo post baseline	20.92	21.60	24.39	17.73

*indicates significant differences between motor delay groups

Table 2: Predicted baseline and 12 months post baseline Emotional Availability (EA) in dyads of children with mild motor delay (Mild), significant motor delay (Significant) or typical motor development (Typical). Twelve-month change effect sizes (cohens *d*) and statistical significant within each motor group.

	Baseline	12mo	Estimated change over 12 months		
	Estimate (SE)	Estimate (SE)	Estimate (SE)	*p*	*d*
Total EA					
Mild	130.66 (3.11)	134.57 (3.78)	3.92 (3.93)	.32	.17
Significant	128.21 (3.38)	126.14 (4.11)	-2.08 (4.31)	.63	-.09
Typical	135.26 (3.11)	146.66 (3.63)	11.40 (3.78)	.00	.62
Adult EA					
Mild	90.48 (2.10)	91.06 (2.43)	.58 (2.50)	.82	.04
Significant	90.00 (2.28)	88.31 (2.64)	-1.69 (2.74)	.54	-.11
Typical	93.82 (2.10)	98.04 (2.33)	4.22 (2.41)	.08	.37
Sensitivity					
Mild	21.95 (.64)	22.05 (.73)	.10 (.76)	.90	.02
Significant	21.81 (.69)	20.86 (.79)	-.94 (.84)	.26	-.22
Typical	22.72 (.64)	24.28 (.70)	1.56 (.74)	.04	.46
Structuring					
Mild	22.19 (.64)	22.39 (.79)	.20 (.87)	.82	.04
Significant	22.02 (.70)	21.27 (.86)	-.75 (.95)	.44	-.18
Typical	22.87 (.65)	24.03 (.76)	1.16 (.84)	.17	.32
Non-Intrusiveness					
Mild	20.93 (.76)	22.14 (.85)	1.21 (.88)	.18	.22
Significant	20.84 (.83)	21.25 (.97)	.40 (.97)	.68	.08
Typical	22.27 (.76)	24.02 (.82)	1.75 (.85)	.04	.40
Non-Hostility					
Mild	25.41 (.39)	24.52 (.48)	-.89 (.54)	.11	-.31
Significant	25.30 (.43)	25.00 (.53)	-.29 (.60)	.62	-.09
Typical	25.95 (.39)	25.73 (.46)	-.21 (.52)	.68	-.14
Child EA					
Mild	40.18 (1.20)	43.52 (1.56)	3.34 (1.56)	.05	.39
Significant	38.22 (1.31)	37.85 (1.70)	-.37 (1.81)	.84	-.05
Typical	41.45 (1.21)	48.64 (1.49)	7.20 (1.59)	<.00	.95
Child Responsiveness					
Mild	21.60 (.64)	22.18 (.82)	.58 (.82)	.49	.13
Significant	20.89 (.69)	19.88 (.89)	-1.02 (.91)	.27	-.22
Typical	23.01 (.64)	24.54 (.78)	1.54 (.79)	.06	.39
Child Involvement					
Mild	18.58 (.63)	21.37 (.81)	2.79 (.93)	.00	.62
Significant	17.33 (.69)	18.00 (.89)	.68 (1.01)	.51	.17
Typical	18.44 (.63)	24.11 (.78)	5.66 (.89)	<.00	1.45

Table 3. Statistical Significance of predicted differences in change in Emotional Availability (EA) per month in the study between children with mild motor delay (MILD), significant motor delay (SIGNIFICANT) or typical motor development (TYPICAL).

	Predicted difference in change per month		
	EST	SE	*p*
TOTAL EA			
MILD-TYPICAL	.62	.45	.17
SIGNIFICANT-TYPICAL	1.12	.48	.02
MILD-SIGNIFICANT	.50	.49	.31
ADULTEA			
MILD-TYPICAL	.30	.29	.30
SIGNIFICANT-TYPICAL	.49	.30	.11
MILD-SIGNIFICANT	.10	.31	.54
SENSITIVITY			
MILD-TYPICAL	.12	.09	.17
SIGNIFICANT-TYPICAL	.21	.09	.03
MILD-SIGNIFICANT	.09	.09	.36
STRUCTURING			
MILD-TYPICAL	.08	.10	.43
SIGNIFICANT-TYPICAL	.16	.11	.14
MILD-SIGNIFICANT	.08	.11	.47
NON-INTRUSIVENESS			
MILD-TYPICAL	.05	.10	.66
SIGNIFICANT-TYPICAL	.11	.11	.30
MILD-SIGNIFICANT	.07	.11	.54
NON-HOSTILITY			
MILD-TYPICAL	.06	.07	.37
SIGNIFICANT-TYPICAL	.01	.07	.92
MILD-SIGNIFICANT	.05	.07	.46
CHILD EA			
MILD-TYPICAL	.32	.19	.10
SIGNIFICANT-TYPICAL	.63	.20	.00
MILD-SIGNIFICANT	.31	.20	.14
CHILD RESPONSIVENESS			
MILD-TYPICAL	.08	.10	.40
SIGNIFICANT-TYPICAL	.21	.10	.04
MILD-SIGNIFICANT	.13	.10	.20
CHILD INVOLVEMENT			
MILD-TYPICAL	.24	.11	.03
SIGNIFICANT-TYPICAL	.42	.11	.00
MILD-SIGNIFICANT	.18	.11	.13

Table 4. Baseline and 12-month change Effect Sizes and Statistical Significance between dyads of children with mild motor delay (MILD), significant motor delay (SIGNIFICANT) or typical motor development (TYPICAL).[a]

	MILD-TYPICAL		**SIGNIFICANT-TYPICAL**		**MILD-SIGNIFICANT**	
	Baseline	12-month change	Baseline	12-month change	Baseline	12-month change
Total EA	.24	.33	.36	.66*	.13	.23
Adult EA	.26	.24	.29	.45	.04	.13
Sensitivity	.21	.34	.23	.70*	.04	.20
Structuring	.17	.21	.21	.50	.04	.18
Non-Intrusiveness	.27	.11	.30	.28	.02	.14
Non-Hostility	.25	.23	.30	.03	.04	.16[c]
Child EA	.17	.44	.42	.94*	.27	.39
Child Responsiveness	.35	.21	.50*	.59*	.18	.31
Child Involvement	.04[b]	.63*	.29	1.23*	.34	.44

*p<.05

Results favor children with less motor delay unless otherwise indicated

[a] long term effects (baseline to 12 month post baseline. Effects favored dyads with children with less motor delay unless otherwise indicated.

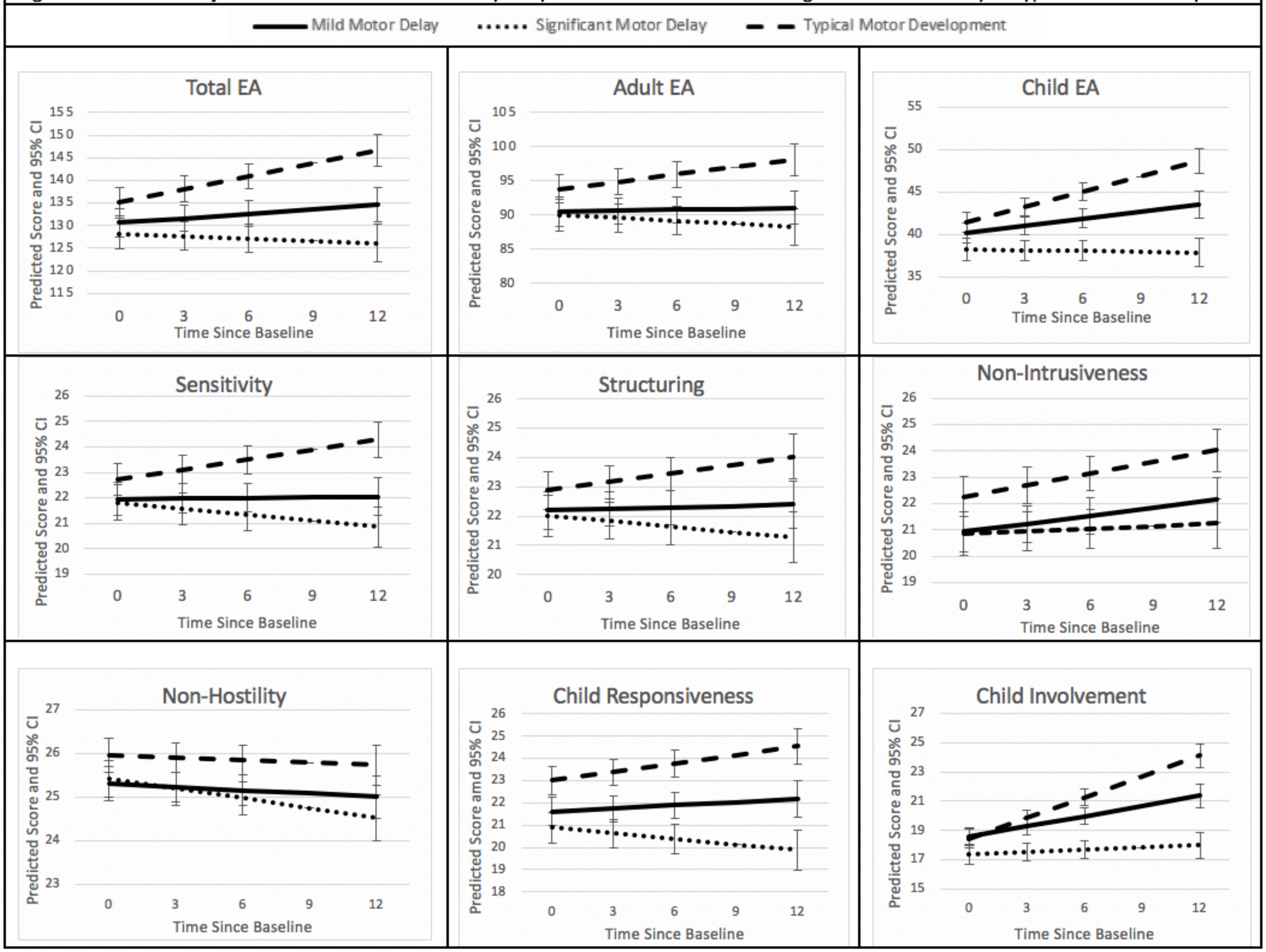
[b] results favor children with mild motor delay over typical motor development

[c] results favor children with significant motor delay over mild motor delay

Table 5. Adult and Child EA Pearsons' correlations (*r*) and statistical significant (*p*) aggregated and stratified by motor severity group

	r	*p*	N
Between-dyad covariation in group centered means			
Aggregated	.81	<.0001	99
Mild motor delay	.80	<.0001	34
Significant motor delay	.67	<.0001	30
Typical motor development	.91	<.0001	35
Within-dyad covariation in scores at specific visits			
Baseline			
Aggregated	.73	<.0001	91
Mild motor delay	.74	<.0001	34
Significant motor delay	.80	<.0001	27
Typical motor development	.63	.0002	30
3 months post baseline			
Aggregated	.80	<.0001	82
Mild motor delay	.81	<.0001	27
Significant motor delay	.85	<.0001	25
Typical motor development	.74	<.0001	30
6 months post baseline			
Aggregated	.78	<.0001	79
Mild motor delay	.68	<.0001	28
Significant motor delay	.87	<.0001	22
Typical motor development	.79	<.0001	29
12 months post baseline			
Aggregated	.78	<.0001	78
Mild motor delay	.85	<.0001	27
Significant motor delay	.80	<.0001	20
Typical motor development	.57	.00	31
Between-dyad covariation in 3 month change scores			
Aggregated	.63	<.0001	74
Mild motor delay	.75	<.0001	27
Significant motor delay	.52	.01	22
Typical motor development	.56	.00	25
Between-dyad covariation in 12 month change scores			
Aggregated	.77	<.0001	70
Mild motor delay	.82	<.0001	27
Significant motor delay	.82	<.0001	17
Typical motor development	.58	.002	26

Figure 4. Estimated trajectories of Emotional Availabiilty in dyads of children with mild or significant motor delay or typical motor development



Supplemental Table 1. Baseline characteristics of dyads who Dropped vs Completed the study

Variable	Completed	Dropped	*p*
N	84	15	
Gender			.23
Male	42	10	
Female	42	5	
Race			.27
Asian	4	0	
Black or AA	9	3	
Multiple	4	2	
Other	2	1	
White	59	7	
Ethnicity			.04*
Not Hispanic	76	10	
Hispanic	6	4	
Adult scored			
Father	4	1	.87
Mother	79	14	
Other	1	0	
Parent Education			.02*
≥ Bachelor's degree	57	9	
< Bachelor's Degree	24	5	
Motor delay			.13
Mild motor delay	28	6	
Significant motor delay	23	7	
Typical motor development	33	2	
Multiple caregiver			.28
Yes	69	14	
No	15	1	
Baseline Emotional Availability			
Sensitivity	22.5	20.13	.03*
Structuring	22.57	21.23	.23
Non-Intrusiveness	21.57	20.53	.60
Non-Hostility	25.78	24.87	.16
Child Responsiveness	21.95	20.3	.16
Child Involvement	18.23	15.67	.02*
Adult Emotional Availability	92.43	86.77	.13
Child Emotional Availability	40.18	35.97	.05

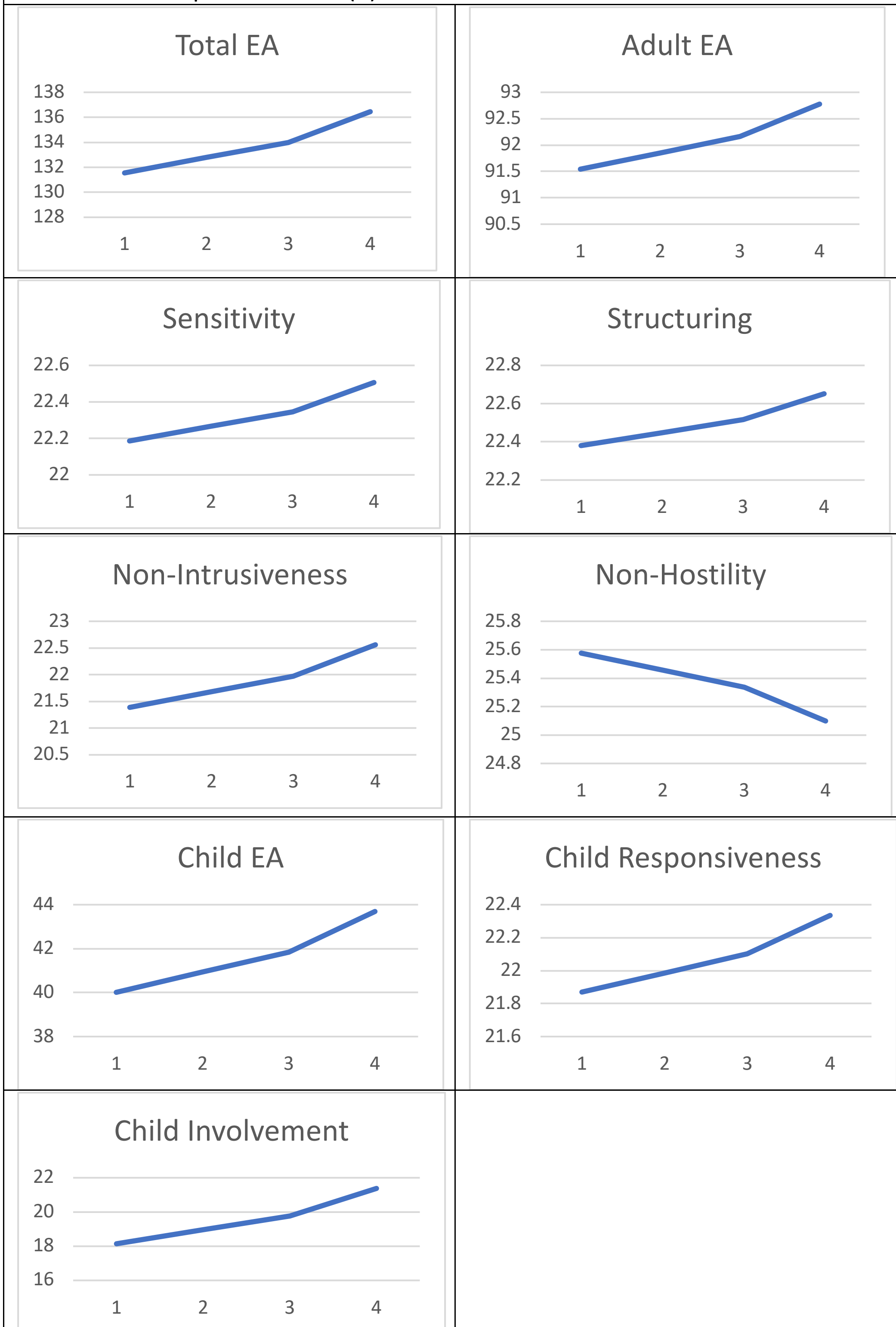
Supplemental Table 2. Linear and Quadratic Model results: Predicting EA by time aggregated across participants

	Linear effects (TIME)		Quadratic effects (TIME*TIME)	
	Est	*p*	Est	*p*
Total EA	.41	.04*	.04	.30
Adult EA	-0.58	.10	.06	.04*
Sensitivity	.03	.49	.01	.12
Structuring	.02	.60	.01	.38
Non-Intrusiveness	-.20	.13	.02	.02*
Non-Hostility	-.04	.13	.01	.08
Child EA	.31	.00*	-.01	.49
Child responsiveness	.04	.35	-.00	.97
Child involvement	.30	<.0001*	-.01	.23

Supplemental Table 3. Statistical significance of Adult and Child EA correlations between motor groups (MILD=Mild Motor Delay; SIGNIFICANT=Significant Motor Delay; TYPICAL=Typical Motor Development)

	Test statistic	p
Within-dyad covariation in group centered means		
MILD-SIGNIFICANT	1.09	.14
MILD-TYPICAL	1.7	.04
TYPICAL-SIGNIFICANT	2.74	.00
Within-dyad covariation in scores at specific visits		
Baseline		
MILD-SIGNIFICANT	.55	.29
MILD-TYPICAL	.79	.21
TYPICAL-SIGNIFICANT	1.27	.10
3 months post baseline		
MILD-SIGNIFICANT	.44	.33
MILD-TYPICAL	.63	.27
TYPICAL-SIGNIFICANT	1.06	.14
6 months post baseline		
MILD-SIGNIFICANT	1.66	.05
MILD-TYPICAL	.87	.19
TYPICAL-SIGNIFICANT	.87	.19
12 months post baseline		
MILD-SIGNIFICANT	.50	.31
MILD-TYPICAL	2.19	.01
TYPICAL-SIGNIFICANT	1.45	.07
Between-dyad covariation in 3 month change scores		
MILD-SIGNIFICANT	1.29	.10
MILD-TYPICAL	1.15	.13
TYPICAL-SIGNIFICANT	.18	.43
Between-dyad covariation in 12 month change scores		
MILD-SIGNIFICANT	0	.5
MILD-TYPICAL	1.19	.05
TYPICAL-SIGNIFICANT	1.46	.07

Supplemental Figure 1. Estimated trajectories of Emotional Availability (EA) aggregated across participants at baseline (1), 3 months- (2), 6 months- (3) and 12 months-post baseline (4)



Chapter 3: The Bidirectional Relationship Between Caregiver Emotional Availability and Global Development in Children with Motor Delay

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Abstract

Background. The purpose of this analysis was to investigate the transactional relationship between Adult emotional availability (EA) and children's development (gross motor or motor-based problem-solving skills).

Methods. Data were drawn from 67 children with motor delay, aged 10.47 months at baseline. Outcome measures were the Emotional Availability Scales, 4th edition; the Gross Motor Function Measure (GMFM-66); and the Assessment of Problem Solving in Play (APSP). Outcomes were collected at baseline, 3-, 6-, and 12-months post baseline. Cross-lagged panel model estimated autoregressive and cross-lagged paths between Adult EA and GMFM-66 or APSP. Pearson's correlations quantified strength of associations between Adult EA and GMFM-66 or APSP at each visit.

Results. Autoregressive paths were significant for all outcomes. Correlations of Adult EA and GMFM-66 or APSP at each visit were non-significant. There were no significant cross-lagged effects between Adult EA and child development at any timepoint, while controlling for all other effects

Conclusion. Caregivers and children are stable in rank order, highlighting the needs to treat difficulties with Adult EA or child outcomes es early as possible. Many enrolled participants were receiving community-based therapy services which may have changed how Adult EA and child outcomes related to one another. Future research needs to investigate the effect of therapies on the parent-child relationship.

Infancy and early childhood, although only a small portion of one's life, have longstanding impacts on health and well-being across the lifespan (Bornstein, 2014). The transactional model posits that when predicting children's developmental outcomes, to focus solely on the relationship between individual and binary characteristics of the parent (e.g. positive or negative affect) and its effect on the child (e.g. language development) would be misleading (Bell, 1968; Sameroff, 2009). The parent-child relationship and children's global development are dynamic and complex processes which are embedded within day-to-day reciprocal interactions between parents and children (dyad) (Bronfrenbrenner, 1979; Sameroff, 2009). Therefore, any processes that lead to adaptive or maladaptive development often reside not in individual traits or characteristics but within the dyadic relationship. An emotionally available relationship between parents and children is supported to provide an important context for nurturing healthy development in children (Biringen et al., 2014). Emotional availability (EA) is a relationship construct which captures the quality of the parent-child relationship and reflects a parent's ability to support and nurture an emotionally affective relationship with their child, and vice versa. Emotionally available parents use consistent emotional cues through their face, voice, and gestures to direct and maintain children's attention during interactions, scaffold children's play and learning through developmentally appropriate tasks, and affirm children's emotional signaling (Biringen & Easterbrooks, 2012; Robinson & Biringen, 1995). Given the importance of the quality of the parent-child relationship as a pathway to fostering children's adaptive development, any alterations or risks to the relationship must be identified as early as possible. Childhood developmental delay or disability (DD), one that impacts children's motor, cognitive, social and emotional development, is a chronic biological factor that can complicate dyadic EA (Bentenuto et al., 2020; Biringen & Easterbooks, 2012; Stack et al., 2019). Previous research has identified DD as impeding the clarity and complexity of children's interactive and emotional behaviors as well as impacting parent's psychosocial health and the ability to engage in positive parenting behaviors (Blacher et al., 2013; Feldman & Eidelman, 2006; Spittle et al., 2009). The purpose of this paper is to use a developmental psychopathology framework to investigate the interplay of biological (children's development) and social-contextual (EA) aspects of abnormal development across the first two years of life (Cicchetti & Tosh 2009) (Figure 5).

Developmental competence as well as positive parenting behaviors during early childhood are two empirically supported protective factors that promote adaptive development and academic success (Biringen et al., 2014; Bornstein, Hahn, & Suwalsky, 2013; Bornstein, 2014; Maccoby, 1992). Most research to support these constructs as protective factors is from studies which investigates children's development from a unidirectional perspective, meaning they investigate the effect of parenting on children's development or children's early development (often motor development) as a predictor of their own future development (Adolph & Hoch, 2019; Campos et al., 2000; Maccoby, 1992). Additionally, most of these studies have been conducted on primarily typically developing populations. This perspective, while insightful, may have contributed to stigmatizing parents and children with DD by applying standards for optimal parenting or developmental trajectories that were developed on a different population. More research is needed to investigate the unique transactional relationship between parenting practices and children's development in diverse, often understudied populations. Consistent with differential susceptibility, children with DD may benefit more than their peers with typical development from enriching parent-child relationships (Belsky, 1997, 2005; Jolicoeur-Martineau et al., 2019). Investigating the transaction between the parent-child relationship and children's global development will provide a more holistic representation of mechanisms of adaptive and maladaptive development (Biringen et al., 2005; Cicchetti & Toth, 2009).

Although very young infants are dependent on parents to meet their daily needs, this does not imply passivity. Within minutes of being born infants are able to focus and look at their parents as a way to engage and influence their parents (Bowlby, 1969). Day to day interactions are influenced reciprocally by parents, children, and the socio-cultural context in which the interaction occurs (Bell 1968; Bronfenbrenner, 1979; Sameroff, 1975, 2009;). Each member of the dyad brings distinctive traits and characteristics to each interaction and leaves each interaction as a changed individual (Sameroff 2009). The immense quantity of dyadic physical and emotional interactions forms the building blocks of the enduring parent-child relationship (Lollis & Kuczynski, 1997). The quality of current interactions is based in part on expectancies built on past interactions as well as the dyad's expectations of future interactions (Hinde & Stevenson-Hinde, 1987; Lollis & Kuczynski, 1997). Children's behavior during interaction is predictive of parenting quality, and the resultant quality of parenting will intensify children's prior behaviors (Sameroff 1975, 2009). A common and well-supported example of the transactional nature between children's development and parenting resides in the association between children's externalizing behaviors and harsh parenting. Children with tendencies to engage in externalizing behaviors are likely to be recipients of as well as predictors of a harsher parenting style (Belsky et al., 1998; Pinquart 2017).

Children born preterm provide one of the earliest examples of how children's biological status can hinder or highlight the protective role of the parent-child relationship. Child born premature often have difficulties with their regulation and communication skills (Clark et al., 2008; Harel-Gadassi et al., 2020; Spittle et al., 2009). These difficulties may influence their parent's ability to respond contingently and congruently to meet their needs, which in turn can exacerbate children's regulation and communication difficulties (Feldman & Eidelman, 2006, Forcada-Guex et al., 2011; Muller-Nix et al., 2004). Parent's perception of their inability to meet their child's needs may exacerbate feelings of poor self-efficacy and parental competence, which can contribute to their future responsiveness (Pennell et al., 2012). While parents and/or children's interaction behaviors may be altered by factors such as maternal feelings of stress or anxiety from receiving an unexpected and life changing diagnosis, or children's delayed development, the pathology resides within the relationship (Feldman & Eidelman, 2006; Winter et al., 2018). If parents and children maintain a relationship style rich in parental sensitivity and child responsiveness, they can often buffer the risks associated with prematurity or other developmental risks and provide the context for children's development to flourish (Poehlmann & Fiese, 2001; Treyvaud et al., 2016).

The parent-child relationship has been hypothesized as a mechanism to explain the variability in neurodevelopmental outcomes in children born preterm but currently there is a lack of research to support this claim (Poehlmann et al., 2012; Treyvaud et al., 2016). Investigating the variables which influence the parent-child relationship as well as the association between the parent-child relationship and children's development can guide the content of preventative and early intervention programs. Consistent with the transactional model and developmental psychopathology frameworks, it is likely no longer adequate to focus solely on children or parents during early intervention programs, but rather the key to fostering children's health and well-being relies on optimizing the intricate 'dance' between parents and children (Cichhetti & Toth, 2009; Sameroff 2009).

In the current study we examined the transactional relationship between children's global development and adult emotional availability in young children just learning to sit (Figure 5). The two aims of this study described the transactional relationship between adult EA and gross motor development (Aim 1) and motor based problem-solving (Aim 2) in children with motor delay. Within each Aim, three paths were estimated: symmetrical (Path 1), autoregressive (Path 2), and cross-lagged paths (Path 3). Symmetrical paths (Path 1) investigated correlations between residuals of Adult EA and child outcomes at the same time point after accounting for all other effects. As Adult EA is described as a catalyst to advancing children's development and child development is supported to advance the complexity of interactions, we hypothesized that there were would strong positive correlations at all visits (Biringen et al., 2014; Célia et al., 2018; Moreno et al., 2008; Sorce & Emde, 1981). Autoregressive paths (Path 2) described if previous rank order of Adult EA (or child outcome) is associated with future rank order of Adult EA (or child outcome). Given the abundance of evidence on stability of rank order in parenting and child development, we hypothesize that previous adult EA or child development will predict future adult EA or child development, respectively

(Bornstein, 2014). Lastly, cross-lagged paths (Path 3) will describe if previous rank order of Adult EA is associated with children's future rank order of child outcomes (gross motor or problem-solving), and reciprocally how rank order of child outcomes (gross motor or problem-solving) are associated with future rank order of Adult EA. We anticipated significant and positive cross lagged associations between Adult EA and child development, with adults (or children) who rank higher on EA (or child outcomes) will likely have children (or adults) who rank higher on child outcomes (or Adult EA) (Biringen et al., 2014; Biringen & Easterbrooks, 2012).

Methods

Participants

The sample included 67 young children with motor delay from the control group of the "Sitting Together and Reaching to Play (START-Play)" clinical trial. All participants were enrolled between 7-16 months corrected age when they were learning to sit which was defined as the ability to sit propping on arms for support for at least three seconds, spontaneous movement of the arms, and inability to transition in and out of sitting. Additional inclusion criteria included scoring >1.0 SD below the mean on the gross motor subtest of the Bayley Scales of Infant and Toddler Development, Third Edition, having a neuromotor disorder such as cerebral palsy, increased risk for cerebral palsy due to prematurity or brain damage around birth, or motor delay on an unknown origin (Harbourne et al., 2018). Exclusion criteria common to all participants were: Medical complications limiting participant in assessments (e.g. severe visual disorder), a primary diagnosis of autism, Down syndrome, spinal cord injury, or parents younger than 18 (Harbourne et al., 2018). Participants were recruited on a rolling basis from

2016-2019 and followed for one year (Harbourne et al., 2018). Participants were recruited through social media, mailings, websites, as well as through medical centers and early intervention providers from five sites across the United States (Duquesne University, University of Delaware, University of Washington, Virginia Commonwealth University). Ethical approval was obtained from the Duquesne University and Virginia Commonwealth University Institutional Review Boards.

Procedures

Parent-child dyads were assessed up to 5 times over 12 months in the home, daycare setting, or a home like lab space, as dictated by the caregiver's choice. At least one caregiver was present at each assessment visit. Assessors were trained to reliability standard and blinded to group assignment. All assessments were video recorded and stored for later scoring by researchers masked to group assignment. The assessment schedule was designed as part of the larger clinical trial to examine baseline performance, change during (1.5 months) and immediately following (3 months) a three-month intervention, and follow-up at 6 and 12 months from baseline (Harbourne et al., 2018). For a full description of the measures performed at each assessment visit, see Harbourne et al., 2018. This analysis includes measures of infant's gross motor skills (Gross Motor Function Measure, GMFM; Russel et al., 2013), motor-based problem-solving (Assessment of Problem Solving in Play, APSP; Molinini et al., 2020) and parent-child interaction (Emotional Availability Scale; Biringen, 2008). At the first and last visits, parents completed Health & Demographic forms reporting on information about the parent, child, and home environment.

Outcome Measures

Emotional Availability Scale. The 4th edition of the EA Scales was used to quantify the quality of the parent-child relationship on 5-minute videotaped videotaped parent child interaction assessments. Parents were instructed to “interact with their child as they normally would” and to ignore the assessor and camera operator insofar as possible. Filmers resisted interacting with or making eye contact with the parent or child to prevent distracting them. Parents were aware that the objective of the study was to investigate how children moved and learned (Harbourne et al., 2018). A standardized set of toys were provided to parents at the start of each assessment and parents were told that they could use these toys, along with any other toy in the home if they wanted to. Parents were not restricted to the current play space and told they were free to move about the home. The standardized set of toys included age-appropriate toys of phone rattler, interlocking rings, pull and go car, and ball.

The EA Scale was designed to assess EA through observations and ratings of age and context appropriate behaviors during parent-child interactions. The EA Scale is composed of six dimensions, four focused on adult behavior and two focused on child behavior. The four adult EA Scale dimensions are *sensitivity, structuring, non-intrusiveness, and non-hostility*. *Sensitivity* quantifies affect, responsiveness, timing, flexibility, acceptance, amount of interaction, and managing conflict. The *structuring* dimension which includes provision and success of guidance, amount and types of structuring implemented, and setting and remaining firm in limit setting. *Non-intrusiveness* includes the ability of the adult to follow the child’s lead, enter interaction without physically or verbally intruding, and talking and relating in a way that teaches rather than commands. Lastly, *non-hostility,* scores the adult’s overall lack of negativity in face or voice and overall the parent is composed, patient, pleasant, available to comfort and support the child. Each EA dimension consists of 7 scored items, with the first two items scored on a 7-point Likert and the remaining five items scored on a 3-point Likert scale. All items were scored on a 0.5 scale and a higher score indicates more optimal EA for all items and dimensions. The adult EA score includes the sum of the 4 adult EA dimensions for a potential score ranging from 28-116. The EA Scale also includes two child dimensions of responsiveness and involvement, which are not included in this analysis. Although the two child dimensions were not included, the EA scale is dyadic in that the child's engagement or response to the adult's behavior was considered when scoring the adult (Biringen et al., 2014).

Videos were assigned randomly and equally distributed across recruitment site, severity of motor delay group, and time point. Two coders scored all videos, and one coder was assigned the same dyad across time to limit intra-individual variability in EA across time. Coders were instructed to watch the video at least thrice, with the first pass capturing an overall gestalt of the dyad, following by scoring Adult EA during the second pass and scoring Child EA during the third pass. Twenty percent of all videos were scored twice for inter- and intra-rater reliability. Inter-rater ICC's for Adult EA were .88.

The EA Scales are supported by validity and reliability evidence for use in children of varying ages, including those included in this analysis. The EA Scales have good short-term test-retest reliability across ages and contexts (Bornstein et al., 2006a; Bornstein et al., 2006b). The EA Scales have good construct and convergent validity with attachment (as measured by the Strange Situation Procedure) and the Attachment Q-Sort (Biringen 2008, 2012; Ziv et al., 2000). The EA Scales have demonstrated valid and reliable use across many cultural, racial, socioeconomic, and regional groups (Bornstein et al., 2008; Chaudhuri et al., 2009; Derscheid et al., 2019; Lovas et al., 2005; Ziv et al., 2000;). The EA Scales are responsive to change and Adult EA may be moderated by the severity of children's delays in development (Baker et al., 2015; Stack et al., 2019).

Gross Motor Function Measure. The GMFM is considered the "gold standard" for measuring change over time in gross motor function in children with neuromotor delays (Russel et al., 2002; Russel et al., 2013). The skills scored in the GMFM represent those that can be completed by a typically developing child from birth to 5 years of age. The GMFM comprises five motor dimensions Lying and Rolling; Sitting; Crawling and Kneeling; Standing; Walking, Running and Jumping. The GMFM-66 scores demonstrate high reliability evidence (ICCs=.97-.99) and are responsive to change over time (Wang & Yang, 2006; Wei et al., 2006). Within each dimension, the items are organized from easiest to hardest. Each item is given a score of 0 (does not initiate), 1 (initiates movement), 2 (partially completes the activity), 3 (completed the activity), or NT (item not tested). The total GMFM-66 score is calculated via the Gross Motor Ability Estimator-3.

During the GMFM assessment, assessors would encourage the child to perform each item. The assessment ended when all of the items were administered, or the child became too fussy to continue. Parent report was accepted with assessor's observation to ensure that the observed scoring reflected the child's typical abilities as reported by the parent (Russell et al., 2013). Occasionally infants would perform a motor task off camera and the assessor would be unable to recreate this task on camera. In this situation, the assessor would describe the child's specific motor performance on this item on the GMFM score sheet for the coders. Twenty percent of all videotaped assessments were coded twice for ongoing tracking of inter- and intra-rater reliability (ICC=GMFM-SS intra-rater 0.99-1.00, inter-rater 0.97-0.99; GMFM-66-IS intra-rater 0.99-1.00, inter-rater 0.98-0.99).

Assessment of Problem-Solving in Play. The APSP is a play based observational measure developed and validated for use in children with motor delay 7-27 months adjusted age (Molinini et al., 2020). The APSP is adapted from the Early Problem-Solving Indicator, a subtest of the Infant and Toddler Individual Growth and Development Indicators (Greenwood et al., 2006). The APSP is responsive to change over time in children with motor delays and demonstrates strong concurrent validity evidence with the BSID-III cognitive subscale scores (Molinini et al., 2020).

The APSP assessment consists of a child interacting with a set of 3 toys (popup toy, nesting cups, tower with balls), each for 2 minutes. During the assessment, the assessor acts as a play partner to the child and provides postural support as needed to allow the child to maintain upright sitting and use his/her arms to interact with the toy. The assessor provides re-direction cues if needed but never provides insight on how to interact with or solve the toy. Using Datavyu v1.3.7, behavioral coders score the videotaped assessments by marking the frequency in which five problem-solving key skills occur. The five problem-solving key skills in order of difficulty include:

1. **Look.** A Look is scored when the child gazes at the toy for greater than 3 seconds.

2. **Simple Explore**. A Simple Explore is scored when the child manipulates the toy to gain knowledge about the object properties, such as mouthing, banging, or scratching.
3. **Complex Explore.** A Complex Explore is scored when the child attempts to execute a Function but is unsuccessful, such as attempting to nest a large cup inside a smaller cup.
4. **Function.** A Function is scored when the child completes one step of a toy's function. An example of a function is popping up one animal on the popup toy or nesting one small cup inside a larger cup.
5. **Solution.** A Solution is scored when the child completes all possible functions of the toy. An example of a Solution is popping up and pushing down all animals on the popup toy and nesting or stacking all cups in the correct order.

The problem-solving skills are mutually exclusive and hierarchical in that if they are performing two skills simultaneously, only the highest-level skill is recorded. The frequency count of each problem-solving key skill is entered into a weighted scoring model which appoints Look a weight of 1, Simple Explore a weight of 2, Complex Explore a weight of 5, Function a weight of 8, and a Solution has a weight of 16 points (Molinini et al., 2020). Lastly, the summed weighted score is then divided by the total assessment time to provide a problem-solving rate per minute score to accommodate for any shortened assessment period. Twenty percent of all videos were scored twice to track inter- and intra-rater reliability. Inter-rater reliability for each problem-solving key skill was ICC=0.82-0.98.

Data Analysis Plan

Univariate analyses were performed to describe the baseline demographic characteristics of the sample and the GMFM, APSP, and adult EA scores at each visit. Then, a series of crossed lag panel models (CLPMs) were used to uncover stability and reciprocal relationships between longitudinal observations of adult EA and children's gross motor development or motor based problem-solving in M*plus* Version 8 (Muthén & Muthén, 1998-2017). The CLPM was chosen given its ability to estimate multi-path relationships between variables after removing changes in score that are likely due to time (Grimm et al., 2021; Usami, 2021). Detrending of time allows the mean, variance, and lagged covariance structure of the data to be independent of time to prevent overestimating the cross-lagged effects (Grimm et al., 2021). For each variable three paths were estimated after detrending the time-series data including symmetrical correlations (Path 1), autoregressive (Path 2), and cross-lagged paths (Path 3). Symmetrical correlations investigated the relationship between residuals of Adult EA and the residuals of GMFM66 or APSP at the same time point (Path 1: green arrows, Y1X1, Y2X2 Y3X3, Y4X4 on Figure 5), while controlling for all other effects. Autoregressive paths estimated if a participant scored high (or low) on Adult EA (or APSP/GMFM66) at the previous time point, would they also score high (or low) on Adult EA (or APSP/GMFM66) at a later time point (Path 2: orange arrows, Y1Y2, Y2Y3 or Y3Y4 or X1X2, X2X3, or X3X4 on Figure 5), while controlling for all other effects. Lastly, cross-lagged paths investigated if an adult scored high (or low) on Adult EA at a previous time point, would their child score high (or low) on GMFM-66 or APSP at the next timepoint (Path 3: blue arrows, Y1X2, Y2X3, Y3X4 on Figure 5), and reciprocally if a child scored high (or low) on GMFM-66 or APSP at the previous time point, would their caregiver score high (or low) on Adult EA at the next time point (Path 3: X1Y2, X2Y3, X3Y4 on Figure 5), while controlling for all other effects.

Models controlled for baseline age adjusted for prematurity, baseline motor severity, and a blended variable of risk which considered parent's baseline education level and household income (SES/ED). Participants with motor delays were stratified into mild or significant motor delay categorical groups based on baseline Bayley Scales of Infant and Toddler Development, Third Edition gross motor scores (mild delay > 1.0 to <2.5 SD below the mean and significant delay ≥ 2.5 SD below the mean) (Harbourne et al., 2021). The blended SES/ED risk variable first categorized parent education as "some high school or less" (score of 0), "high school graduate" (score of 1), and anything above this (some college or beyond) received a score of 2. Secondly, the poverty income ratio was calculated as the ratio of household income to the poverty level based on the number of individuals living in the household. The poverty level was specified in the Department of Health and Human Services according to the year 2018. Blended education and income was considered "high" (education > or equal to 1 (high school graduate or above) and poverty income ration greater than or equal to 2) or "low" (education = 0 (some high school or less) and poverty income ration less than 2) (Karlamangla et al., 2010).

Full information maximum likelihood estimation was performed and therefore all participants were included in the analyses despite missed visits or if they dropped. Statistical significance was set at $\alpha = .05$ and practical significance was indicated by standardized path coefficients.

Results

Parent and child baseline characteristics are presented in Table 6. Means, standard deviations, minimum and maximum scores for Adult EA and child outcomes are presented in Table 7. Means of each variable indicate that Adult EA had a slight decrease from baseline (89.59) to 12 months post baseline (88.31), whereas both child developmental outcomes (GMFM-66 and APSP) had positive change over time. Means and standard deviations of the four adult dimensions which comprise Adult EA are presented in Table 8. Of the covariates entered into the model, only baseline motor delay had a significant effect on outcomes. Therefore, baseline age adjusted for prematurity and SES/ED were removed from the model.

The CLPM for Adult EA and children's gross motor skills exhibited adequate model fit. Chi square test of model fit for the baseline model, 452.35, degrees of freedom = 36, p=.00, Standardized root mean square residual = .08, comparative fit index of .99, Tucker Lewis Index of .98 and root mean square error of approximation was .07 (90% CI 0.00-0.14).

The CLPM for Adult EA and child motor-based problem-solving skills also exhibited adequate model fit. Chi square test of model fit for the baseline model, 292.75, degrees of freedom = 36, p=.00, Standardized root mean square residual = .08, comparative fit index of .90, Tucker Lewis Index of .80 and root mean square error of approximation was .15 (90% CI 0.10 - .21).

Path 1. Symmetrical correlations between residuals of Adult EA and residuals of each child outcome (GMFM-66 and APSP) were small and non-significant at all visits (Figures 6 and 7).

Path 2. Autoregressive paths were significant for all variables. Adult EA was predictive of future Adult EA (Y1Y2 Est=.89, $p<.05$; Y2Y3 Est=.60, $p<.05$; Y3Y4 Est=.86, $p<.05$), while controlling for all other effects. GMFM-66 was predictive of future GMFM-66 (X1X2 Est=.93, $p<.05$; X2X3 Est=1.01, $p<.05$; X3X4 Est=.91, $p<.05$, Figure 6), while controlling for all other effects. APSP was predictive of future APSP (X1X2 Est=.67, $p<.05$; X2X3 Est=.84, $p<.05$; X3X4 Est=.54, $p<.05$; Figure 7).

Path 3. There were no significant cross-lagged effects between Adult EA and child development at any timepoint, while controlling for all other effects (Figures 6 and 7).

Discussion

Given the importance of an emotionally available caregiving environment on children's adaptive development, the current study examined the bidirectional relationship between adult's emotional availability and children's gross motor and problem-solving development during the first years of life. Consistent with the transactional model of development (Sameroff, 1975, 2009), our hypotheses were three-fold, adult EA or child development would predict future adult EA or child development, respectively, Adult EA and child development would be correlated at the same time points, and that Adult EA at one time point would predict future child development, and vice versa. Overall, the results support our hypothesis of stability in development and caregiving practices. However, lack of significant correlational or cross-lagged findings do not support that Adult EA and child development were influenced by one another.

Although novel, our findings of significant autoregressive relationships are supported by previous research. Despite early childhood being a time of great developmental change, it is also a period that is characterized by stability. For this discussion, stability is considered as maintenance in the ranks of individuals in a group, i.e. individuals who perform high (or low) at one time point will likely perform high (or low) in the future (Bornstein et al., 2014). Stability of rank order allows for current performance to inform or predict future performance. Development across domains such as language, cognition, and social development is supported as being both stable and predictive such that infants who know more words at 1 year tend to know more words at 2 years (Marchman & Fernald 2008), IQ at 3 years predicts academic achievement at 17 years (McCall 1977), or emotional distress to novel situations at 4 months predicts social wariness at 7 and 14 years of age (Meili-Dworetzki & Meili 1972).

Changing performance in developmental abilities can also shape children's caregiving environment, which in turn can reinforce children's development. Previous theoretical and empirical evidence supports that as children are able to do more developmentally, parents change their interactions and expectations and in turn foster children to new heights of development. As children achieve independent sitting caregivers provide more opportunities for learning (Kretch et al., 2022) or as children begin walking caregivers respond with co-occurring language or gestural input regarding action or object knowledge (Schneider & Iverson, 2022). However, our results did not support this transactional relationship as changes in children's gross motor or problem-solving skills were not associated with concurrent or change in Adult EA.

Overall, in this sample of young children with motor delay and their caregivers, as child developmental outcomes were increasing, Adult EA was minimally decreasing. We will now discuss hypothesized pathways for the lack of association between children and caregivers as well as potential future research directions.

Previous evidence on children's development influencing parenting behavior has often studied the achievement of discrete motor milestones (sitting or walking) as the catalyst for parents' change in behavior. These types of analyses are often one-way (child to parent) and often support associations but not causation. The parenting behaviors described are often dichotomous as they describe what the parent does or does not do. Adult EA is a blend of discrete parenting behaviors (Structuring and Non-Intrusiveness) with affectual and emotional signaling and regulation (Sensitivity & Non-Hostility) in consideration to the child's engagement and response (Biringen et al., 2014). While the strength of Adult EA is that it captures all of these important components of the interaction, it is possible that subtle nuances in how parents responded to or encouraged children's development were missed. Studies investigating behaviors that mimic the EA dimensions have found significant bidirectional relationships with parenting and children's adaptive development. For example, maternal overactivity (relates to Non-Intrusiveness) and warmth (relates to Sensitivity) are associated with conduct disorder and maternal scaffolding (relates to Structuring) is associated with emotional regulation in preschool aged children (Klein et al., 2018; Norona & Baker 2014; Rolon-Arroyo et al., 2018). Future research investigating the relationship between child development and the four individual dimensions that comprise Adult EA is warranted.

Evidence on the transactional relationship is often conducted over longer periods of time and span multiple developmental stages and includes assessment of adults and children's socio-emotional health and well-being. In contrast, our study included children in early childhood with only 1 year of follow-up with developmental assessments spaced 3 or 6 months apart. While the outcomes included in this study were novel, there were many other determinants of parenting and child development that were not included that may have impacted the results. Measuring variables known to impact child development such as parent stress (Berry & Njoroge 2021), mental health (Kingston & Tough, 2018; Hoffman et al., 2017) or adverse childhood experiences (Rowell & Neal-Barnett, 2022) may reveal more insight into how adult EA and child development do or do not relate to one another. Other factors to consider include birth order or if the child has siblings or not (Bornstein et al., 2019; Belsky et al., 1984; Bornstein et al., 2016). Considering these variables as covariates or investigating their unique impact on the relationship are all avenues for future research.

A final point to consider was the effect of early therapeutic interventions on parents and children. Many, if not most, of the children included in this study were receiving some form of early therapeutic interventions due to having a motor delay at baseline. The effect of intervention may have had contrasting effects on the parent and child depending on the type of intervention delivered. Early interventions aim to optimize children's development and support parents and familial well-being through the administration of family-centered care (Individuals with Disabilities Education Act, 2004; McManus et al., 2020). In reality, early interventions are variable in delivery with most still focusing solely on the child (Barfoot et al., 2022). The effect of early interventions on the relationship is largely unknown as the behavioral qualities of the relationship are often not measured. Recent evidence highlights that the effect of intervention on EA may depend on the type of intervention (Paper 3). Future research considering the type or frequency of intervention may provide insight into if or how early therapeutic interventions influence the transactional relationship between Adult EA and children's development.

Limitations & Future Research

Several limitations must be considered when interpreting the results of this study. The included sample lacked variability in adult emotional availability. On average, the adults included in this study were scoring relatively low in Adult EA and fell into the inconsistent range on each EA dimension that comprises Adult EA (Tables 7 and 8). EA is considered optimal when scoring >=26 in each of the four adult EA dimensions, and scoring 18-25 is considered inconsistent (McLean et al., 2022). In this study, the average EA score for caregivers was 88.5, whereas a score indicating a more optimal EA (scoring ≥26 in each dimensions) would be 104 or above (Table 7). Adults of children with DD may face more behavioral and mental health stressors on a daily basis that can compound the complexity of parenting. Additionally, the young children included in this study faced developmental limitations which may have impacted their own EA and as the scale is dyadic had a reciprocal effect on adult EA (Biringen & Easterbrooks 2012). It's possible that the relationship between EA and child development lies in the optimal and non-optimal ranges of EA, therefore lack of variability in Adult EA may have contributed to lack of significant findings.

Although all children entered the study at the same developmental skill level, there was great variability in development in future visits. Aggregating all participants into one group may have confounded results in that the bi-directional relationship may have differed between children with mild or significant motor delay. Severity of delay moderates EA and may also moderate the transactional relationship between EA and development (Stack et al., 2019). Additionally, as the severity of motor delay increases the likelihood for co-occurring difficulties in other developmental domains or medical complications also increases (Hollung et al., 2020). Future research should consider investigating if the relationship between parenting and child development differs as a function of motor severity as well as considering the effect of multi-dimensional development delay or other medical conditions.

Ninety-four percent of the parents that participated in this study were mothers. Mothers and fathers behaviorally respond to their children differently, potentially contributing to their child’s development in unique ways (Malmberg et al., 2016; Vertsberger & Knafo-Noam, 2019). A recent study on the transactional relationship between sensitivity and children’s external behaviors were reciprocally related in fathers but not mothers (Zvara et al., 2018). Differences in the contribution each parent or primary caregiver makes to children’s development underscores the importance of further investigating other parents. Recruitment strategies to enhance paternal participation in research are needed to understand the mechanism of the entire family unit on children’s development.

The parent-child assessment included in this study provided only a brief (5 minute) snapshot into the dyads daily life. The presence of the researcher in the home may represent a kind of novelty that evokes atypical responses or socially desirable behaviors. Capturing longer periods of interaction may reflect more “typical” interactions or asking parents for qualitative feedback on how they feel the videotaped interaction reflects daily interactions can contribute to confidence of results. The assessment included in this study was one of low-stress in that parents and children were instructed to interact as they normally would. A study by Dolev at al., (2009) found parents of children with autism performed better when given a task and lower in free play with toys. In contrast, parents of children with typical development often perform highest in EA during free play with toys and lowest in challenging task oriented contexts such as the introduction of a puzzle or problem-solving task (Blacher 2013; Dittrich et al., 2017; Kwon 2013). Giving parents a task with or without time constraints or performance demands may add stress to the dyad and elicit more typical day to day parenting styles.

Lastly, increasing economic, cultural, and racial diversity during recruitment will contribute to a more holistic understanding of how parents and children influence one another and enhance the generalizability of results. The sample included in this study was predominantly white, non-Hispanic, had at least a Bachelor’s degree and lived in high income homes. The lived experiences of families identifying as members of different racial and ethnic minority groups need to be captured (qualitatively or quantitatively) to explain potential differences. Past experiences of being parented, adverse childhood experiences, and ongoing exposures to structural and personally mediated racism all impact parenting and in turn child development (Berry & Njoroge 2021; Rowell & Neal-Barnett, 2022). Considering these variables as important social determinants of health rather than control variables in analytical models can shape our understanding of the unique pathways families take on the road to children's adaptive development.

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Table 6. Baseline child and family characteristics

Variable	N (%)
N	64
Baseline pre-maturity adjusted age in months (SD)	10.47 (2.76)
Baseline motor delay	
Mild	34
Significant	30
Gender	
Male	36
Female	28
Race	
Asian	4
Black or AA	8
Multiple	6
Other	1
White	41
Ethnicity	
Not Hispanic	54
Hispanic	7
Adult scored	
Father	3
Mother	60
Other	1
SES/ED	
High	36
Low	21
Dropped	
No	51
Yes	13
Multiple caregiver	
Yes	11
No	53

Table 7. Descriptive statistics for longitudinal variables

	Adult Emotional Availability				Assessment of Problem-Solving in Play				Gross Motor Function Measure-66			
	Mean	Std Dev	MIN	MAX	Mean	Std Dev	MIN	MAX	Mean	Std Dev	MIN	MAX
Baseline	89.59	13.09	64.5	113	49.84	26.05	0.67	100.50	30.55	5.42	18.40	39.80
3mo post baseline	87.26	14.79	60	115	57.25	29.79	0.50	152.50	38.29	8.82	21.10	55.80
6mo post baseline	88.49	14.71	58	113.5	73.58	39.55	5.33	152.17	43.40	11.86	17.20	60.80
12mo post baseline	88.31	15.57	51.5	113	79.98	43.28	5.00	167.67	49.29	14.13	17.30	68.70

Table 8. Means and standard deviations (SD) of the four adult dimensions which comprise Adult EA

	Baseline		3 months post baseline		6 months post baseline		12 months post baseline	
Adult EA dimension	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Sensitivity	21.64	3.74	21.07	4.45	21.27	4.38	21.19	4.98
Structuring	22.01	3.88	21.42	4.41	21.59	4.59	21.38	5.17
Non-Intrusiveness	20.66	4.94	20.05	5.16	20.90	5.00	21.34	5.79
Non-Hostility	25.29	2.57	24.72	2.98	24.73	2.96	24.39	3.71

Figure 5. Theoretical and Analytical Model. Green arrows represent symmetrical correlations. Orange arrows represent Autoregressive associations. Blue arrows represent cross-lagged associations.

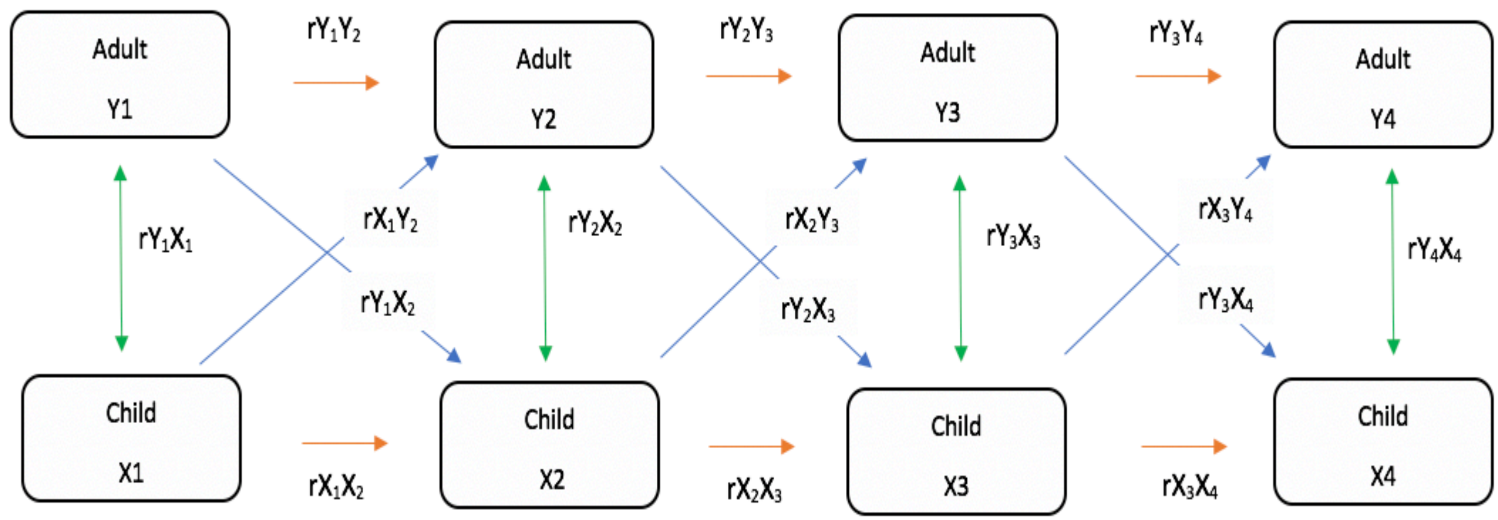


Figure 6. Cross lagged panel model results for Adult Emotional Availability (EA) and children's gross motor skills (Gross Motor Function Measure, GMFM-66).

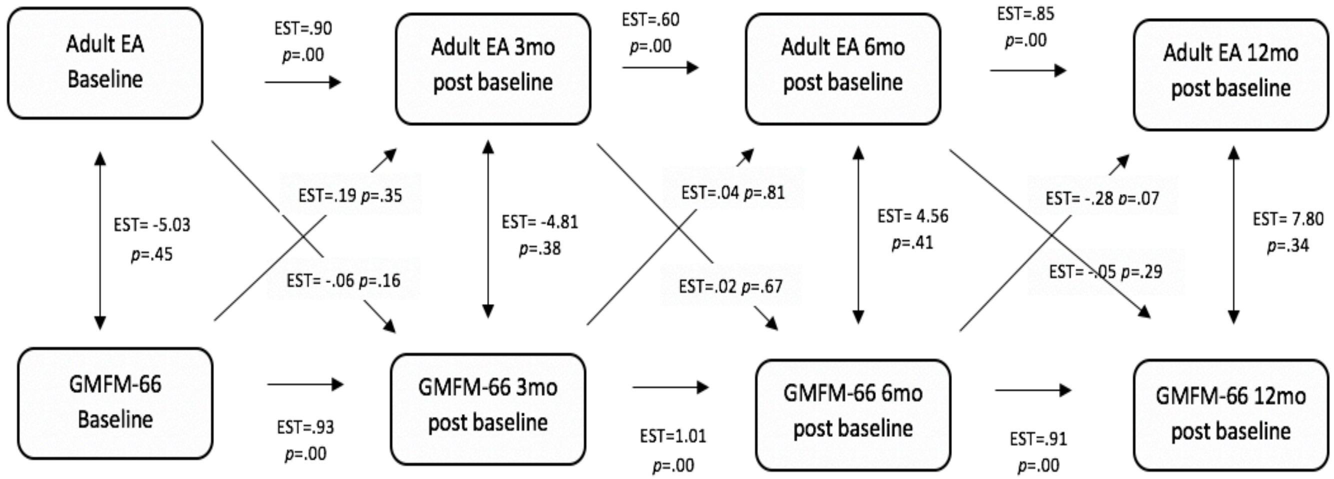
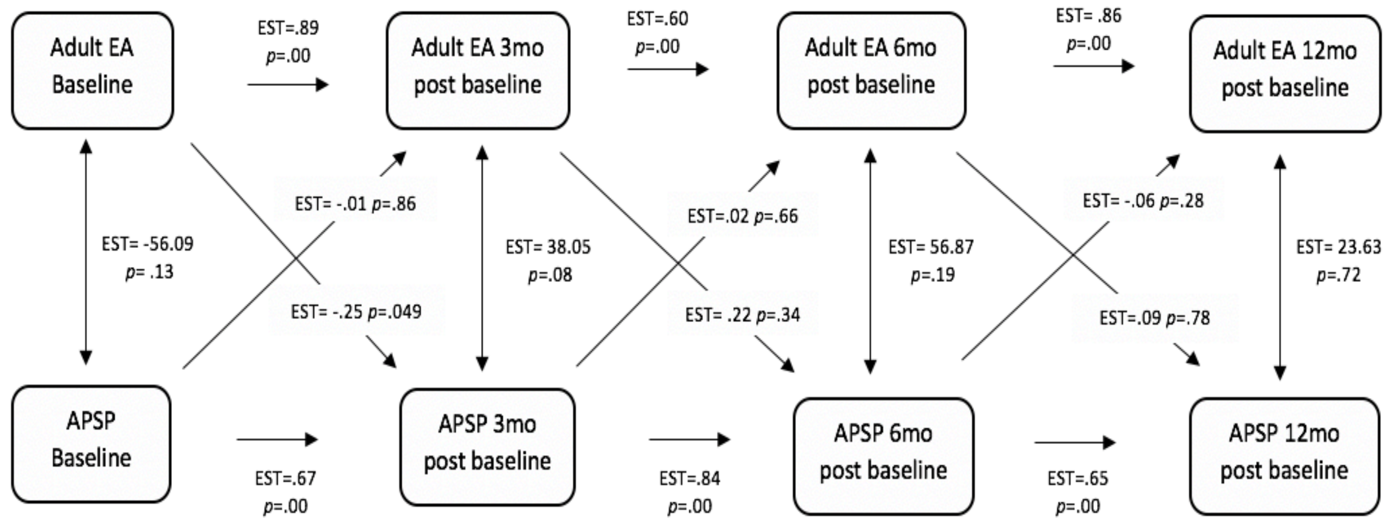


Figure 7. Cross lagged panel model results for Adult Emotional Availability (EA) and children's motor based problem-solving (Assessment of Problem-Solving, APSP).



Chapter 4: Impact of START-Play on Emotional Availability in Caregivers and Young Children with Neuromotor Delay

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Abstract

Background. Emotional Availability (EA) describes caregiver-child emotional responsiveness and attunement and is critical to fostering adaptive development. This analysis compares EA over time between and within dyads in Sitting Together and Reaching to Play (START-Play) vs Usual Care-Early Intervention (UC-EI).

Methods. Data were drawn from 104 children with neuromotor delay who were 7-16 months of age at baseline (Mean = 10.5 months) and their caregiver (91% Mothers). The EA Scale, 4th edition was scored from 5-minute videotaped interactions collected at baseline, 3-, 6-, and 12-months post baseline. Piecewise multi-level modeling with group x time interaction was performed controlling for baseline age and motor delay with random effects of time at the child level.

Results. When comparing EA between groups, there were significant positive short- and long-term effects of START-Play on *Adult EA* (*p*'s<.02, *g's*>0.38), *Sensitivity* (*p*'s<.04, *g's*>.26), *Structuring* (*p's*<.02, *g's*>.43), and *Non-intrusiveness* (*p*'s<.03, *g's*>.36). There were no differences in child-level treatment effects between groups.

Conclusions/Significance. Results highlight clinical implications for the positive effect of START-Play on EA. Lack of baseline differences in adult EA and similar child-level treatment effects highlight that the key difference between START-Play and UC-EI may lie in the way adults adapt to children's changing developmental and relationship abilities.

Emotionally available parent-child relationships provide the context in which children learn about themselves, their culture, and the world around them (Bronfenbrenner, 1979; Sameroff, 1975, 2009). Emotional availability (EA) is considered the "connective tissue" of healthy parent-child relationships and is conceptualized as the capacity of a dyad to engage emotionally and partake in congruent and mutually enjoyable relationships (Biringen & Easterbooks, 2012; Biringen et al., 2014; Easterbrooks & Biringen, 2000, p.123,). An emotionally available relationship can broadly be described as one in which parents are skilled in identifying and responding contingently to children's cues (sensitivity), scaffolding challenging but attainable learning opportunities (structuring), and allowing children the space and autonomy to lead (lack of intrusiveness) (Biringen et al., 2014). Children play an equally active role in EA by responding to their parents' efforts, involving parents in their play, and clearly communicating their wants and needs. When children and parents are part of an emotionally available relationship, each member feels loved, needed, and appreciated (Putnam et al., 2002). For parents, EA can reinforce parenting competence and mental health, and for children, EA can support self-efficacy, secure attachment, and autonomy (Ainsworth, 1971; Emde & Buchsbaum, 1990; Harel-Gadassi, 2020).

EA in the parent-child relationship predicts children's long-term adaptive development (Easterbrooks et al., 2009; Pastorelli et al., 2016), buffers adverse effects associated with biological and social risk factors (Hambrick 2019; Reck et al., 2016; Treyvaud et al., 2016), facilitates the development of self-regulation (Bernier, 2010), and influences the success of childhood interventions (Nix, 2018). The importance of the relationship to both parental and children's well-being underscores the urgent responsibility of professionals working with children and families to identify and treat any risks to the relationship as early as possible. Experiencing racism (Savell et al., 2019), fewer years of maternal education (Bornstein et al., 2011), adversities associated with mental health (Chorbadjian 2020, Lyons-Ruth, 2000), as well as prior experiences of being parented are all variables with the capacity to influence parenting and in turn children's long-term development. Developmental delay or disability (DD) is a child-level biological risk factor that impacts children, parents, and EA (Biringen et al., 2005; Stack). The direct pathway linking DD to EA is not clear. Proposed mechanisms highlight that difficulties in EA lie in the transactional nature of the relationship and are not the result of one member alone (Biringen et al., 2005; Sameroff, 2009). Previous studies investigating parenting or child behaviors from a unidirectional perspective found that parents of children with DD tend to demonstrate intrusive behaviors while children with DD tend to be more passive during interactions (Ku, 2019; Blacher et al., 2013; Cress et al., 2007; Venuti et al., 2009). If we only consider these findings, then we may inadvertently stigmatize parents or children for their role in the relationship. In contrast to this viewpoint, EA is aligned with the transactional model which views parents and children as equal contributors to the relationship in that each member is constantly influencing and being influenced by the other (Sameroff, 2009). Therefore, a parent's tendency toward intrusive behaviors may be the result of their benign intention of being a good interaction partner to their child who they perceive as passive. And as children perceive their parents as supporting or leading too much, they may assume more passivity during interactions.

The importance of fostering an emotionally available parent-child relationship in children with DD cannot be overstated as evidence supports that children with DD are influenced by their early caregiving environments even more so than their peers with typical development (Fenning & Baker, 2012). In some cases, parenting attributes such as parenting style and maternal mental health are greater predictors of neurodevelopmental outcomes than the disease process itself (Berliner et al., 2020; Golfenshtein et al., 2020; Vilaseca et al., 2019). There is growing evidence which supports that the effectiveness of intervention for children with DD may be more related to parenting and relationship quality rather than the amount or intensity of therapy (Atkins-Burnett & Allen-Meares, 2000; Evans, 2014; Mahoney et al., 1998; Ruane & Carr, 2019). Fields such as psychology, nursing, and social work have successfully targeted the relationship as a pathway to improving both child and parent outcomes in children with cerebral palsy, autism, or prematurity (Ruane 2019; Whittingham et al., 2013).

Most mother-child dyads score into adequately functioning ranges on the EA Scales (Bornstein et al., 2011). Adult EA in adults of children with typical development is moderately stable and unchanging, whereas Child EA increases linearly over early childhood in response to advancing developmental abilities (Célia et al., 2018; Stack et al., 2019). Adult and child EA are highly correlated and predictive of one another at the same time and over time (Biringen et al., 2014; Célia et al., 2018). Adult EA of children with DD is similar to adults of children with typical development with some potential difficulties in structuring (Gul 2016; Stack et al., 2019; van Ijzendoorn et al., 2007). Child EA in children with DD is generally lower but the rate of change over time is similar to children with typical development (Gul 2016; Stack et al., 2019, van Ijzendoorn et al., 2007). *Child EA* is generally moderated by children's level of functioning whereas *Adult EA* is moderated by the interaction between age and children's level of functioning with more difficulties being noted with older age (> 3 years old) and more severe delays (Bentenuto et al., 2020; Salvatori et al., 2016). Maternal age, education, and knowledge of children's development and parenting all have associations with Adult and Child EA (Biringen et al., 2014; Bornstein et al., 2011).

Despite evidence from other fields, such as developmental psychology or social work, the integral role of the parent-child relationship on program success is often overlooked as a qualifier or outcome of early therapeutic intervention targeting children with DD (Guttentag et al., 2014; Landry et al., 2006; Morgan et al., 2016, Novak & Honan, 2019; Thomas et al., 2017). Early Intervention (EI), conceptualized for this paper as therapeutic intervention delivered to children with DD from birth to three by physical, occupational, or speech therapist in the home, day-care, or clinic settings, continues to measure program success mostly by child level outcomes or frequency of parent-delivered interventions (IDEIA part C, McManus 2020; Morgan et al., 2016, Novak & Honan, 2019). Family centered care is considered the "lynchpin" of EI, but EI professionals lack the tools needed to measure and track the quality of the parent-child relationship, therefore it is unknown if EI professionals impact the relationship, and if so, to what degree or in what direction (D'Arrgio et al., 2018; Family engagement and school readiness, 2013).

Sitting Together and Reaching to Play (START-Play) is an example of an early physical therapy intervention that may have a positive impact on the parent-child relationship (Harbourne et al., 2018). In contrast to usual-care EI (UC-EI), START-Play aims to impact not only children's motor development but also cognition through exploration and social support from caregivers (Harbourne et al., 2018). START-Play was successful in impacting short term (baseline to 3 months) cognition, fine motor and problem-solving abilities and long term (baseline to 12 months) reaching and fine motor skills in children with significant motor delay as well as long term receptive language skills in children with mild motor delays (Harbourne et al., 2021). The key ingredients of START-Play include embedding opportunities to learn about cognitive constructs during motor activities and brainstorming with parents to identify and structure the "just-right" level of challenge to advance motor/cognitive skills (Harbourne et al., 2018). START-Play also encourages parents to support children in performing a variety of self-initiated movements in socially and cognitively rich environments (Harbourne et al., 2018).

Parents' ability to incorporate these key ingredients, which align with the EA tenants of *Structuring* and *Non-Intrusiveness* into daily interactions may have impacted EA even though the START-Play intervention did not specifically aim to target EA. As parents executed START-Play ingredients they encouraged children's self-initiated movements and autonomy while also being physically and emotionally available to support and guide their child as needed. Through support from their parent and in response to their own developmental changes, children in START-Play were able to advance the complexity in which they engaged their parent. Initial simple involving strategies may have presented as short bouts of looking or vocalizing. Whereas more complex involving strategies consisted of long periods of back and forth physical, emotional, or verbal interactions in which children shared toys, mimicked their parents affectual expressions or behaviors, or provided suggestions for what they wanted their parent to do next.

The purpose of this paper is to compare the impact of START-Play + Usual Care-Early Intervention (UC-EI) and UC-EI on EA in young children with neuromotor disorders and their caregivers. The first aim was to determine whether there were differences in short- (baseline to 3-month) or long-term (baseline to 12 months) changes of EA relative to group (START-Play + UC-EI vs UC-EI only). In addition to comparing trajectories between groups, we described change within each group to give context to how groups changed over time. We hypothesize that the START-Play + UC-EI supports short- and long-term effects on *Adult EA* through changes in the EA dimensions of *Structuring and Non-Intrusiveness*. We anticipate dyads in START-Play + UC-EI will have increases in *Structuring* and *Non-Intrusiveness* while dyads in UC-EI remain stable. The EA dimension of *Sensitivity* has been hypothesized to be a static or stable relationship construct (Biringen et al., 2014; Bornstein & Manian, 2013). Therefore, we hypothesize *Sensitivity* is beyond the scope of the current interventions and do not anticipate any group differences in this dimension. Research has shown increases in *Child EA, Child Responsiveness*, and *Child Involvement* over time in young children of similar ages to those included in this study (Stack et al., 2019; Célia et al., 2018). Consequently, we hypothesized increases in these dimensions over time in all participants, with children in START-Play having steeper changes in *Child Involvement* as this dimension reflects more complex relationship skills. The second aim was to investigate how child- and adult-centered variables impacted intervention effectiveness. We anticipate that treatment effects will vary as a function of baseline motor delay (Aim

2a) or parent-reported education (Aim 2b). In general, fewer years of parent education or more severe delays in development are associated with higher-risk to EA (Bentenuto et al., 2020; Gul et al., 2016; Wurster et al., 2020). In line with differential susceptibility, which posits that dyads with the most risk may benefit the most from intervention, we anticipated that dyads in START-Play with higher-risks to EA will have more optimal EA over time than UC-EI (Belsky, 2005; Landry et al., 2006). In contrast, we anticipated that dyads with less risk to EA (more years of education and mild motor delay) may not differ in EA trajectories between groups as dyads were likely starting at more optimal levels.

Methods

This study is a secondary data analysis of the START-Play clinical trial. Specifically, the 5-minute videotaped parent-child interactions are used to quantify Emotional Availability. Details of the START-Play methods can be found in the trial protocol (Harbourne et al., 2018)

Participants

One-hundred and twelve parent-child dyads were included in the primary outcomes analysis for START-Play (Harbourne et al., 2021). Children with neuromotor delay were recruited when they were corrected ages 7 to 16 months on a rolling basis between 2016 and 2019 and followed up to one year (Harbourne et al., 2018, 2021). All participants were recruited when they were learning to sit which included an ability to sit propped up on the arms for at least 3 seconds and an inability to transition in and out of sitting (Harbourne et al., 2018, 2021). Additional inclusion criteria were a score of >1.0 SD below the mean on the Bayley Scales of Infant and Toddler Development, Third Edition (Bayley; Bayley, 2006) gross motor subtest (Harbourne et al., 2018, 2021).

Exclusion criteria were medical complications limiting participation (e. g., severe visual disorder), a primary diagnosis of autism, Down syndrome, or spinal cord injury, a reported uncontrolled seizure disorder; or a neurodegenerative disorder (Harbourne et al., 2018, 2021).

Following the baseline assessment, blocked randomization was completed with stratification into START-Play plus UC-EI or UC-EI only (Harbourne et al., 2018, 2021). To achieve equivalent groups, participants were stratified by clinical site (Newark, DE; Omaha, NE; Pittsburgh, PA; Richmond, VA; Seattle, WA) and baseline movement ability (mild, moderate, or severe) (Harbourne et al., 2018, 2021). Baseline movement ability was based on a rubric developed by the study investigators that considered the child's scores on the Gross Motor Function Classification System and Manual Ability Classification System, along with information about the child's distribution of motor impairment and level of active movement (Harbourne et al., 2018)

To complete the proposed secondary data analysis, the sample was further refined based on two conditions, the adult present and the language spoken in the videotaped interaction. As EA is a relationship construct that is specific to two individuals, only visits in which the same adult caregiver was present were included (Biringen, 2008). If a child participant had their mother present at some assessments and father present at others, we identified the parent present at most visits and included those in this analysis. As verbal communication is important to quantifying EA, if a dyad primarily spoke a language other than English then they were excluded as a complete conceptualization of EA was not possible.

To answer aim 2, participants were stratified by motor severity and parent education groups based on baseline data. Severity of baseline motor delay was determined by performance on baseline Bayley motor composite scores, with children scoring <2.5 SD below the mean being grouped as having a mild delay and children scoring ≥ 2.5 SDs below the mean being grouped as having a significant delay (Harbourne et al., 2021). Parent education level of the caregiver included in the study was determined by reviewing baseline parent questionnaires and matching the education level to the parent present at the assessment. To achieve equal group size, parents were grouped by those who reported earning a Bachelor's degree or higher (≥BA) and those who reported earning less than a Bachelor's degree (<BA).

Procedure

Assessments and interventions took place at children's homes, childcare settings, family-friendly lab spaces or clinical settings, per caregiver preference. Children were assessed at baseline, 1.5, 3, 6, and 12 months post baseline (Harbourne et al., 2018, 2021). Assessors had physical or occupational therapy or child development backgrounds, were blinded to group assignment, and were continuously monitored for reliability (Harbourne et al., 2018, 2021). Interventionists and parents were not blinded to group assignment and all participating parents knew they were part of a clinical trial investigating a physical therapy intervention (Harbourne et al., 2018, 2021). All assessments were videotaped for later scoring by coders blinded to group assignment.

A five minute, unstructured, parent-child interaction was videotaped at each assessment. Parents were instructed to "interact with their child as they normally would" and were provided with the same set of toys at each assessment to standardize access to toys. Parents were not encouraged or discouraged from using other toys or moving around the home with their child. The filmer captured the faces of both the parent and child and if one member left the frame, then the filmer was instructed to follow the child. Assessors and filmers did not interfere with the dyad during the five minutes in any way including watching the dyad, making eye contact with parent or child, talking to the parent/child, retrieving toys for the dyad, or otherwise reacting to or engaging with the dyad. If siblings were present, researchers engaged with the sibling in a different location to limit distractions to the dyad. If both parents were present, one or both could be in the filmed interaction depending on parent preference.

Intervention

The START-Play intervention consisted of 2 sessions per week (average of 51.5 minutes, SD =4.4 minutes) for 3 months (mean = 21 visits), in addition to their UC-EI sessions. Licensed physical therapists delivered the intervention in collaboration with at least 1 parent/caregiver within the child's natural environment (Harbourne et al., 2018, 2021). UC-EI was performed by the child's usual interventionist (physical, occupational, or speech therapist) at their prescribed frequency (Harbourne et al., 2018, 2021). As part of the study protocol, differentiation of START-Play and UC-EI interventions was evaluated. Videotaped intervention sessions for both groups were scored and key statistical differences were noted. START-Play interventionists were required to maintain a priori set levels of adherence to intervention key principles resulting in significant differences from UC-EI in cognitive opportunities, encouraging self-initiated movements, and brainstorming with caregivers. Interventionists in UC-EI often provided greater motor assistance than needed, maintained rigid adherence to moving with "normal patterns", and performed intervention activities not START-Play related (An et al., 2021). While some of the therapists in UC-EI demonstrated START-Play behaviors, such as encouraging parent led activities, they occurred at lower rates than with the START-Play therapists (An et al., 2021).

Measures

Five-minute parent-child interaction videos were scored using the Emotional Availability Scales, 4th edition (Biringen, 2008). The EA Scale is composed of six dimensions, four focused on the adult and two focused on the child (Biringen 2008; Biringen et al., 2014). Although each member of the dyad has individually scored EA dimensions, the EA Scale is considered dyadic in that the child's response to the adult's actions are considered when formulating the adult score (Biringen 2008; Biringen et al., 2014). Therefore, it is possible that two adults may provide similar qualities but receive different scores based on their child response. The four adult EA Scale dimensions are: (a) *Sensitivity,* which includes affect, responsiveness, timing, flexibility, acceptance, amount of interaction, and managing conflict; (b) *Structuring,* which includes provision and success of guidance, amount and types of structuring implemented, setting and remaining firm in limit setting; (c) *Non-intrusiveness,* which describes the adults ability to follow the child's lead, enter interaction without physically or verbally intruding, and talking and relating in a way that teaches rather than commands; and (d) *Non-hostility,* which includes the absence of negativity in face or voice and overall the parent is composed, patient, pleasant, and available to comfort and support the child. The two child EA dimensions include: (a) *Responsiveness*, which describes the child's balance between age-appropriate autonomous exploration and responding to parent's interaction bids, enjoyment of the interaction, and organized affect regulation; and (b) *Involvement*, which includes the child's willingness to simply and elaboratively initiate interaction with their parent (Biringen 2008; Biringen et al., 2014).

Each of the six EA dimensions contains seven scored items, with higher scores indicating more optimal EA behaviors. The first two items of each dimension are scored on a 7-point Likert scale from non-optimal (1) to optimal (7). The remaining five scored items of each dimension are scored on a 3-point Likert scale from non-optimal (1) to optimal (3). The potential score range for each dimension is 7-29. The two child dimensions of *Responsiveness* and *Involvement* are added together to form a *Child EA* score with a potential score ranging from 14-58. The four adult dimensions of *Sensitivity, Structuring, Non-Intrusiveness,* and *Non-Hostility* are summed to produce an *Adult EA* with a potential score ranging from 28-116. Clinical cutoffs for the 6 EA dimensions have been reported as scores greater than 26 considered optimal EA, scores of 18-25 as inconsistent EA, and scores less than 17 as nonoptimal EA (McLean 2022).

The EA Scales were designed for use in children aged 0-21 years and their caregivers over time and across different contexts (Biringen et al., 2014). Specific to this analysis, EA is valid and reliable during infancy and toddlerhood, across different assessment contexts, including home and lab settings, across different racial, socioeconomic, and gender groups and across similar assessment intervals (Biringen et al., 2014, Bornstein et al., 2006a; Bornstein et al., 2006b; Bornstein et al., 2008; Chaudhuri et al., 2009; Derscheid et al., 2019; Lovas et al., 2005; Ziv et al., 2000;).

Reported ICC's for inter-rater reliability for each EA dimension of previous editions of the EA Scales were in the range of .76-.96 (Biringen et al., 2014). Each EA dimension has demonstrated the capacity to change in response to intervention and the EA Scales have been used as an outcome measure in interventions including participants as young as 2 months with intervention frequencies and durations similar to START-Play (Baker et al., 2015; Biringen et al., 2012; Perzolli et al., 2020; Porreca et al., 2017).

One coder scored the same dyad overtime to prevent inter-coder variability. Videos were assigned randomly by enrollment site and motor delay group. To prevent bias of previous scores influencing future scores, coders were assigned visits in random order and waited 10 days before scoring videos from the same dyad. Coders were instructed to watch the video at least thrice, conceptualizing an overall gestalt of the relationship on the first pass, followed by scoring *Adult EA* on the second pass and lastly scoring *Child EA* dimensions on the third pass. Unlimited viewings were permitted, with the video watched partially or as a whole to determine details of the EA Scale. If both parents were in the five-minute video, the coders watched the video in full to identify which parent was the main interactor and then identified if the other parent had enough interaction with the child to be scored. In total, there were 6 visits in which both parents were scorable, but for this study only data from one caregiver was included. In addition to scoring the EA scale, coders kept track of any assessor or sibling interference, which parent was in the video, and if other family members were also in the video including siblings, other caregiver, grandparents, nurses, or a nanny.

Twenty percent of all visits were scored twice for inter- and intra-rater reliability. In the presence of differences in reliability (less than 80% agreement), coders met and reviewed the video, discussed differences, and came to a consensus as per the developer's recommendations. If disagreements still existed, then the developer of the EA Scales served as a third party in resolving any disagreements between coders. Percent agreement was used to track reliability for the items scored on a 7-point Likert scale and yes/no logic agreement was used to track if the items scored on a 3-point Likert scale were within 1 point of each other. ICC's for inter-rater reliability were: Adult EA = .88 Child EA = 91, Sensitivity = .80, Structuring = .86, Non-Intrusiveness = .82, Non-Hostility = .88, Child Responsiveness = .86, and Child Involvement = .91.

Statistical Analysis

Analyses were performed in SAS. To investigate group differences in EA trajectories, intervention group x slope interaction terms were added to the model. Piecewise modeling was used to allow for separate slopes to be estimated during intervention (baseline to 3 months post baseline) and post-intervention (3mo post baseline to 12 months post baseline). Long-term change (baseline to 12 months post baseline) is considered the sum of the treatment effect during and post-intervention. Time since baseline was labeled as a continuous variable to account for variation of assessment timepoints across participants. To investigate the effect of child- or adult-level variables on EA over time, three way interaction terms were added to the model (Aim 2a = intervention group x slope x baseline motor delay; Aim 2b = intervention group x slope x parent education) to stratify treatment effects by baseline motor delay and parent education, respectively.

All models controlled for intercept level differences by baseline adjusted age and recruitment site as well as intercept- and slope-level differences by baseline motor delay. Baseline motor delay but not age was included as a slope-level variable as developmental skill, not age, is supported as the catalyst for increasing Child EA over time. Intercept and slope (during intervention and post intervention) random effects at the child level were included in all models to account for child level variation and covariation (Biringen et al., 1995; Kim et al., 2017; Stack et al., 2019).

Using an intention to treat framework, all participants, regardless of dropout or missed visits, were included in the analysis (Fisher et al., 1990). Missing data was assumed to be missing at random. To meet this assumption, baseline differences in demographic and outcome variables were compared between dyads that completed the final study assessment (N=85) and dyads that dropped (N=19). There were no significant differences in baseline demographics or scores in EA dimensions between dyads who completed vs dropped (Supplemental Table 4), therefore all participants were included in the analysis.

Significance was based on alpha = .05. The magnitude of short- and long-term treatment effects or Hedges *g* was calculated as the group difference in model-predicted change divided by the pooled standard deviation. Small sample size correction was used to produce unbiased estimates of the population effect size (What Works Clearinghouse, 2020). Hedges *g* of 0.20, 0.50, and 0.80 were interpreted as small, medium, or large effects, respectively (Cohen, J, 1998).

Results

Of the 112 participants included in the primary outcomes of START-Play, 104 were included in this analysis. Seven dyads were excluded based on primarily speaking a language other than English during the filmed interaction and one family declined to participate in the filmed parent-child interaction assessment. Seventeen dyads included different caregivers over time (e.g., father present at baseline and mother present at remaining visits); only the visits with one selected caregiver were included. There were no baseline EA differences between dyads with and without the same caregiver present at all visits (Supplemental Table 5). Descriptive statistics for demographic and other descriptive variables are presented in Table 9.

Baseline Comparisons

When aggregating across baseline motor delay or parent education level, there were significant differences in *Child Involvement* at baseline favoring the dyads in START-Play (Estimate=0.51, *p*=.033, *g*=.43) (Table 10). There were no baseline differences in any EA dimension when stratifying by baseline motor delay or for dyads whose parent reported less than a BA. Dyads in START-Play whose parent reported a BA or higher scored significantly higher at baseline than dyads in UC-EI in *Child EA* (EST=4.24, *p*=.038, *g*=.56) and *Child Involvement* (EST=2.35, *p*=.021, *g*=.62) (Table 10).

Treatment effects (Table 10, Figure 8)

Aggregating across severity and parent education levels, there were significant positive short- and long-term effects of the START-Play intervention on *Adult EA* (Short-term EST=5.69, *p*=.015, *g*=0.38; Long-term EST=7.83, *p*=.012, *g*=.49), *Sensitivity* (Short-term EST=1.38, *p*=.039, *g*=.33; Long-term EST=2.26, *p*=.013, *g*=.26), *Structuring* (Short-term EST=1.79, *p*=.017, *g*=.43; Long-term EST=2.20, *p*=.024, *g*=.46), and *Non-intrusiveness* (Short-term EST=1.98, *p*=.025, *g*=.36; Long-term EST=2.33, *p*=.031, *g*=.41).

To understand how the trajectories differed between groups, change *within* each intervention group was investigated. Dyads in START-Play had significant positive change in *Adult EA* (Short-Term EST=3.48, *p*=.031; Long-Term EST=4.38, *p*=.045), *Sensitivity* (Short-Term EST=0.97, *p*=.036; Long-Term EST=1.36, *p*=.034), *Non-Intrusiveness* (Short-Term EST= 1.55, *p*=.011; Long-Term EST=2.22, *p*=.004), *Child EA* (Long-Term EST=2.78, *p*=.033), and *Child Involvement* (Long-Term EST=1.94, *p*=.005). Dyads in UC-EI had significant negative change in *Structuring* (Long-Term EST= -1.340, *p*=.049) and *Non-hostility* (Long-Term EST= -1.047, *p*=.038) and positive change in *Child Involvement* (Long-Term EST=1.60, *p*=.020).

Treatment effects stratified by baseline motor severity (Table 10, Figure 9)

Among infants with mild motor delay, START-Play had significant positive effects on *Adult EA* (Short-Term EST=6.27, *p*=.049, *g*=.44; Long-Term EST=8.71, *p*=.041, *g*=.51) and *Non-hostility* (Long-Term EST=2.67, *p*=.006, *g*=.83) compared to UC-EI. When investigating change over time *within* the START-Play group, dyads with mild delay had significant positive short-term change in *Non-intrusiveness* (EST=1.72, *p*=.042), indicating more optimal EA. Change over time *within* dyads in UC-EI with mild delay revealed significant negative long-term change in *Non-Hostility* (EST=-1.66, *p*=.011) and a positive long-term change in *Child Involvement* (EST=1.95, *p*=.031).

When comparing trajectories *between* infants with significant motor delay in START-Play or UC-EI there were significant positive long-term effects on *Sensitivity* (EST=2.75, *p*=.039, *g*=.64) which favored START-Play. Trajectories of EA *within* dyads in START-Play with significant motor delay included significant long term positive change in *Sensitivity* (EST=1.78, *p*=.047), *Non-Intrusiveness* (EST=2.53, *p*=.019), and

Child Involvement (EST=2.18, *p*=.025), whereas dyads in UC-EI with significant motor delay stayed stable over time in all EA dimensions

Treatment effects stratified by baseline parent reported education level (Table 10, Figure 10)

Among infants whose parent reported a BA or higher, there were no significant differences in treatment effects *between* START-Play and UC-EI. Trajectories of EA *within* dyads in START-Play included a significant positive long-term change in *Non-intrusiveness* (EST=1.91, *p*=.045) while dyads in UC-EI had significant long-term positive change in *Child Involvement* (EST=2.21, *p*=.0243).

Among infants whose parent reported less than a BA at baseline, there were significant short-term intervention effects for *Non-intrusiveness* (EST=2.79, *p*=.042, *g*=.59) and long-term effects for *Adult EA* (EST=9.91, *p*=.029, *g*=.65) and *Sensitivity* (EST=3.22, *p*=.021, *g*=.70), favoring START-Play. Dyads *within* START-Play had significant positive change in *Non-intrusiveness* (Short-Term EST=2.15, *p*=.033; Long-Term EST=2.65, *p*=.031) and *Child Involvement* (Long-Term EST=2.35, *p*=.039) over time whereas dyads *within* UC-EI remained stable over time in all EA dimensions.

Discussion

The purpose of this paper was to address a gap in knowledge on the effect of early therapeutic interventions on parent-child EA in children with neuromotor delay. This study was a secondary data analysis of the START-Play clinical trial, which was supported to be an effective intervention for improving global development, specifically in children with significant motor delay (Harbourne et al., 2021). Results from the current study highlight important clinical implications for the positive effects of START-Play on

EA. In contrast, the same effect on EA was not observed in UC-EI. It is possible that UC-EI had unintended consequences on EA or was unable to buffer dyads from the adverse effects of time on EA in children with motor delay (Paper 1). However, as both groups received UC-EI it is not possible to determine the impact of UC-EI or START-Play alone. Future research, including the ongoing clinical trial comparing START-Play to UC-EI using a dose matched comparative effectiveness model will shed more light on these findings (Dusing et al., 2022).

Aim 1. Investigate Treatment Effects on EA in START-Play v UC-EI

START-Play had significant positive short- and long-term effects on *Adult EA*, *Sensitivity*, *Structuring*, and *Non-Intrusiveness* (Table 10). In addition to the hypothesized intervention effects on *Structuring* and *Non-Intrusiveness,* START-Play also had short- and long-term effects on *Sensitivity. Sensitivity* was not included in the original theoretical model as it was not clear if physical therapists untrained in EA and delivering an intervention that was not designed to impact EA, could in fact change this more global and potentially static parenting construct. Although, in retrospect it is hard to imagine adults changing in *Structuring* and *Non-Intrusiveness* without also changing in *Sensitivity*. In fact, supporting *Sensitivity* may be a precursor to changes in other EA dimensions. Qualities of *Sensitivity* such as warm, positive, and authentic affect, the ability to recognize and adjust one’s own behavior based on a child’s interests, and flexibility and acceptance of children’s emotional and physical needs all contribute to parent’s ability to structure non-intrusive interactions.

When investigating short- and long-term changes within each group, opposite trends between START-Play and UC-EI were found. In the EA dimensions in which dyads in START-Play increased (*Adult EA*, *Sensitivity & Non-Intrusiveness*), dyads in UC-EI stayed stable; and in the dimensions in which START-Play stayed stable, UC-EI decreased (*Structuring & Non-Hostility*). These differences in how the groups changed underscore inherent differences in intervention delivery or principles or how differently parents responded to the interventions. With consideration of the program differentiation results from An et al., 2021, we will hypothesize mechanisms of these contrasting results below.

Parents in START-Play spent most of the time in intervention sessions collaborating with therapists on promoting children's self-initiated and active movements and thinking, identifying small but meaningful challenges and changes, and allowing children to move the way that optimized their independence (An et al., 2021). Parents' actively practiced these constructs during intervention and observed therapists performing these same behaviors when working with their child. As parents were able to balance motor and cognitive tasks, children were likely able to allocate their attentional resources to parent's bids of joint attention (look at what their parent was pointing to) or initiate joint attention (use gestures or eye contact to direct parent's attention) (Berger et al., 2018; Mundy & Newell, 2007). Joint attention paves the way for richer infant-caregiver interactions that fosters development in language, play, affect, and social interactions (Mundy & Newell, 2007; Whalen et al., 2006).

As parents in START-Play likely became more flexible and patient in allowing their child the time and autonomy to move, act, and think on their own, they were making strides in *Sensitivity* & *Non-Intrusiveness*. And as they problem-solved with the therapists on how to provide and recognize small but meaningful motor and cognitive challenges and changes, they likely became more accepting and willing to meet their child where they were at, contributing to increases in *Sensitivity & Structuring*. As children with motor delays often need physical support during interactions, the finding of more optimal *Non-Intrusiveness* in START-Play is important as it implies that parents were able allow their child opportunities to lead interactions while likely still providing varying levels of physical support.

There were no group differences in short- or long-term trajectories in any Child dimension. *Child Responsiveness* was stable over time while *Child Involvement* increased significantly over twelve months for all participants. Dyads in START-Play scored significantly higher than UC-EI in *Child Responsiveness* at 6- and 12-months post baseline and at all visits for *Child Involvement*. Lack of significant findings does not support our hypothesis and this analysis was unable to disentangle the effect of intervention vs the natural course of development and time on *Child EA*. Similar child-level intervention effects, highlights that the potential key difference between START-Play and UC-EI may lie in the way in which adults adapt to their child's changing developmental and relationship abilities. However, it is also possible that children's higher involvement abilities in START-Play which preceded intervention, may have also had an effect on adults. Children who involved more may have provoked parents to be less intrusive and provide more learning opportunities over time, for example.

In START-Play both parents and children increased in their EA, highlighting that the dyads were changing in synchrony with one another. Whereas in UC-EI, dyads were moving out of sync over the course of the study as children were increasing and adults remained stable or decreased. As parent and child EA is generally highly correlated, it would be interesting to follow these dyads in UC-EI for longer periods to observe if they eventually achieved a synchronous state and if so, did parents eventually catch up to the levels of their children, or did children have regressions in EA.

Our findings of positive intervention effects on EA are in line with previous findings on dyads with adult-level risks. Studies on a variety of modes of intervention (video, virtual, or attachment based), have found positive effects on EA in diverse populations of families including mothers living in rural, low-income homes in Colombia (Barone et al., 2021), adoptive families (Baker et al., 2015), and mothers at outpatient community mental health clinic (Ziv et al., 2016). More relevant to our study population, Perzolli et al., (2020) used a single group, pre-post design to investigate the effect of parental based Interventions on EA in mother-child dyads with Autism Spectrum Disorder. The researchers found increasing scores in Adult Sensitivity, Structuring, Non-Intrusiveness, and Child Responsiveness and Involvement following intervention (Perzolli et al., 2020). Whittingham et al., (2022), used a wait-list controlled design to study the effectiveness of an online education intervention developed by psychologists in families of children with CP (aged 2-10). Study results found increases in non-intrusiveness and child involvement (Whittingham et al., 2022).

Aims 2a & b: Investigating child- and parent-level variables effects on trajectories between and within intervention groups

In general, the results from aims 2a and b, support the protective role of START-Play on EA in dyads with elevated child- or adult-level risk factors. The dyads with higher-risk to EA in START-Play (significant motor delay or fewer years of parent-reported education) significantly increased EA in many dimensions, whereas dyads in

UC-EI had no significant short- or long-term changes within any dimension with mostly decreasing estimates of change. These findings are in line with the theory of differential susceptibility which posits that dyads with the most risk often benefit the most from supportive environments (Belsky, 2005). As the field of pediatric physical therapy moves towards precision medicine, families with higher child- and/or adult-level risk factors may benefit from an intervention like START-Play above and beyond dyads with lower risk factors.

For dyads with children with mild motor delay (lower risks to EA), there were significant positive treatment effects in *Adult EA* (short- and long-term) and *Non-Hostility* (long-term) in favor of START-Play. There were no significant treatment effects on EA in dyads whose parent reported at least a BA or higher. Parent education level is often associated with SES, access to services, and/or foundational knowledge on parenting or child development, all of which can contribute to EA (Berger & Font, 2015; Davis-Kean et al., 2019). No difference in treatment effects for parents reporting at least a BA may be the result of these parents having the access, support, or skills to promote an emotionally available relationship with or without specialized intervention training. In contrast, dyads whose parent reported fewer years of education may not have had the same support or starting point and therefore benefited more from what START-Play offered.

Limitations

As indicated in Table 9, the included sample was lacking in children of varying races and ethnicity. Due to the lingual limitations of the researchers quantifying EA, dyads speaking languages other than English were excluded from this study. Lack of representation from multi-cultural families, specifically from families identifying as Hispanic, limited the generalizability of results. Future research needs to focus on including researchers of diverse backgrounds as well as implementing recruitment strategies that embrace diversity in children and families.

Although it was important to investigate the effect of motor delay and parent education level on treatment effects, as we stratified participants into these subsamples, the sample size of each group decreased. Additionally, dropout and post-hoc exclusion of children who were originally randomized into START-Play but later developed symptoms or diagnoses that fell into exclusion criteria, limited sample size and may have underpowered the study.

The two groups compared in this study were not dose matched as dyads in START-Play were receiving two forms of therapeutic interventions, START-Play as well as usual care early-intervention. Therefore, it is possible that the changes seen in EA could be attributed to an increase in therapy dosage rather than being attributed to START-Play.

Although EA is a useful tool for both research and clinical populations, there is no published minimal detectable change or minimal clinically importance difference. Therefore, although intervention effects were seen in this study, it is not clear how results reflect an important change for these families.

Future research

Future research is needed to investigate physical therapist-child EA during early interventions. Parents often try to emulate their child’s physical therapist during their interactions with their children, highlighting the importance of PT’s not only coaching parents about motor development but also modeling EA during their interventions. The results from this paper describe the effect of intervention on EA, but it unknown how the change in EA relates to child development. EA relates to many aspects of affective development, but future research needs to investigate if change in EA impacts the short- or long-term efficacy of early therapeutic interventions in children with neuromotor delay. Lastly, to support dissemination and translation of EA to practice, more research is needed to provide a qualitative description of what EA behaviors look like within the context of early physical therapy interventions and parent-child interactions. More concrete descriptions of EA behaviors can allow clinicians to model behaviors and support parents in implementing these behaviors during interactions.

There were no significant short-term changes within or between groups, indicating that dyads with children with significant motor delay may need more time to make changes within their relationship. Longer durations of intervention or follow-up may be warranted to allow potential differences within or between groups to reach a threshold of significance.

Conclusion/Clinical Implications

Clinical implications from this analysis indicate that an intervention like START-Play, delivered by physical therapists, can impact EA in dyads with neuromotor delay in addition to advancing children's global development (Harbourne et al., 2021). More research is needed to uncover the effects of UC-EI as results indicate less optimal EA trajectories in dyads receiving only this type of intervention. The effectiveness of START-Play on many aspects of EA is encouraging as it is possible that PT's untrained in EA and without the intention of targeting EA, can in fact impact EA. Physical therapists should consider incorporating ways to support the relationship into activities which support child development. Supporting and enhancing dyadic EA during early therapeutic interventions can nurture mutually enjoyable and growth-fostering interactions in which parents and children willfully engage in during and long after intervention has ended.

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Table 9. Baseline sample characteristics aggregated and stratified by baseline motor delay (Mild or Significant motor delay) and baseline parent reported education (≥ Bachelor's degree or < Bachelor's degree).

Variable	All participants	Stratified by treatment group		Stratified by baseline motor delay				Stratified by baseline parent reported education			
				Significant Motor Delay		Mild Motor Delay		< Bachelor's degree		≥ Bachelor's degree	
		UC-EI	START-Play	UC-EI	START-Play	UC-EI	START-Play	UC-EI	START-Play	UC-EI	START-Play
N	104	52	52	23	23	29	29	23	17	26	32
Baseline age in months (SD)	10.50 (2.58)	10.62 (2.58)	10.82 (2.60)	11.87 (2.59)	11.86 (2.86)	9.63 (2.14)	10.0 (2.08)	11.01 (2.85)	10.53 (3.16)	10.42 (2.45)	10.87 (2.39)
Sex											
Female	45 (43.27 %)	24 (46.15%)	21 (0.38 %)	13 (56.52%)	7 (30.43%)	11 (37.93%)	14 (48.28%)	11 (47.83%)	5 (29.41%)	11 (42.31%)	15 (46.88%)
Male	59 (56.73 %)	28 (53.85%)	31 (59.62%)	10 (43.48%)	16 (69.57%)	18 (62.07%)	15 (51.17%)	12 (52.17%)	12 (70.59%)	15 (57.69%)	17 (53.13%)
Race											
White	71 (71.71 %)	34 (70.83%)	37 (72.55%)	14 (66.68%)	18 (78.26%)	20 (74.07%)	19 (67.86%)	13 (59.09%)	13 (76.47%)	21 (80.77%)	23 (71.88%)
Black	10 (10.10 %)	5 (10.42%)	5 (9.80 %)	5 (23.81%)	1 (4.35 %)	-	4 (14.29%)	5 (22.73%)	3 (17.65%)	-	2 (6.25 %)
Other	18 (18.18 %)	9 (18.75%)	9 (17.65%)	2 (9.52 %)	4 (17.39%)	7 (25.93%)	5 (17.85%)	4 (18.18%)	1 (5.88 %)	5 (19.23%)	7 (21.88%)
Ethnicity											
Hispanic	13 (13.00 %)	6 (12.24%)	7 (13.73%)	2 (9.09 %)	3 (13.04%)	4 (14.82%)	4 (14.29%)	5 (21.74%)	5 (29.41%)	1 (3.85 %)	2 (6.25 %)
Not Hispanic	87 (87.00 %)	43 (87.76)	44 (86.27%)	20 (90.91%)	20 (86.96%)	23 (85.19%)	24 (85.71%)	18 (78.26%)	12 (70.59%)	25 (96.15%)	30 (93.75%)
Caregiver Included in the Study											
Mother	96 (92.31 %)	47 (90.38)	49 (94.23%)	21 (91.30%)	20 (86.96%)	26 (89.66%)	29 (100 %)	20 (86.96%)	16 (94.12%)	24 (92.31%)	31 (96.88%)
Father	6 (5.77%)	3 (5.77 %)	3 (5.77 %)	1 (4.35 %)	3 (13.04%)	2 (6.9%)	-	1 (4.35 %)	1 (5.88 %)	2 (7.69 %)	1 (3.13 %)

Grandmother	1 (1.62%)	1 (1.92%)	-	1 (4.35%	-	-	-	1 (4.35%)	-	-	-
Legal Guardian	1 (1.62%)	1 (1.92%)	-	-	-	1 (3.45%)	-	1 (4.35%)	-	-	-
Self Reported Education Level of Study Caregiver											
Hasn’t graduated high school	1 (1.01%)	1 (2.04%)	-	-	-	1 (3.70)	-	1 (4.35%)	-	-	-
High School Diploma / GED	16 (16.16%)	9 (18.37%)	7 (14%)	5 (22.73%)	6 (27.27%)	4 (14.82%)	1 (3.57%)	9 (39.13%)	7 (41.18%)	-	-
Some college	14 (14.14%)	6 (12.24%)	8 (16%)	4 (18.18%)	1 (4.54%)	2 (7.41%)	7 (25.00%)	6 (26.09%)	8 (47.06%)	-	-
Associate Degree or Training Certificate	10 (10.10%)	7 (14.29%)	3 (6%)	3 (13.64%)	2 (9.09%)	4 (14.82%)	1 (3.57%)	7 (30.44%)	2 (11.77%)	-	-
Bachelors	27 (27.27%)	11 (22.45%)	16 (32%)	8 (36.36%)	10 (45.46%)	3 (11.11%)	6 (21.43%)	-	-	11 (42.31%)	16 (50%)
Masters	22 (22.22%)	12 (24.49%)	10 (20.00%)	2 (9.09%)	1 (4.54%)	10 (37.04%)	9 (21.14%)	-	-	12 (46.15%)	10 (31.25%)
Doctorate	7 (7.07%)	2 (4.08%	5 (10.00%)	-	2 (9.09%)	2 (7.41%)	3 (10.71%)	-	-	2 (7.69%)	5 (15.63%)
Other type of post graduate degree	2 (2.02%)	1 (2.04%)	1 (2.00%)	-	-	1 (3.70%)	1 (3.57%)	-	-	1 (3.85%)	1 (3.13%)
Gestational age at birth, wk											
>= 37 weeks	66 (63.46%)	29 (55.77%)	37 (71.15%)	9 (39.13%)	19 (82.61%)	20 (68.97%)	18 (62.07%)	14 (60.87%)	12 (70.59%)	13 (50%)	24 (75%)
34-36 weeks	8 (7.69%)	3 (5.77%)	5 (9.62%)	-	1 (4.35%)	3 (10.35%)	4 (13.79%)	1 (4.35%)	3 (17.65%)	2 (7.69%)	2 (6.25%)

32-33 weeks	7 (6.73%)	6 (11.54%)	1 (1.92%)	4 (17.39%)	-	2 (6.89%)	1 (3.45%)	1 (4.35%)	-	5 (19.23%)	1 (3.13%)
25-31 weeks	14 (13.46%)	7 (13.46%)	7 (13.46%)	5 (21.74%)	3 (13.04%)	2 (6.89%)	4 (13.79%)	2 (8.69%)	2 (11.77%)	5 (19.23%)	4 (12.5%)
<25 weeks	9 (8.65%)	7 (13.46%)	2 (3.85%)	5 (21.74%	-	2 (6.89%)	2 (6.89%)	5 (21.74%)	-	1 (3.85%)	1 (3.13%)

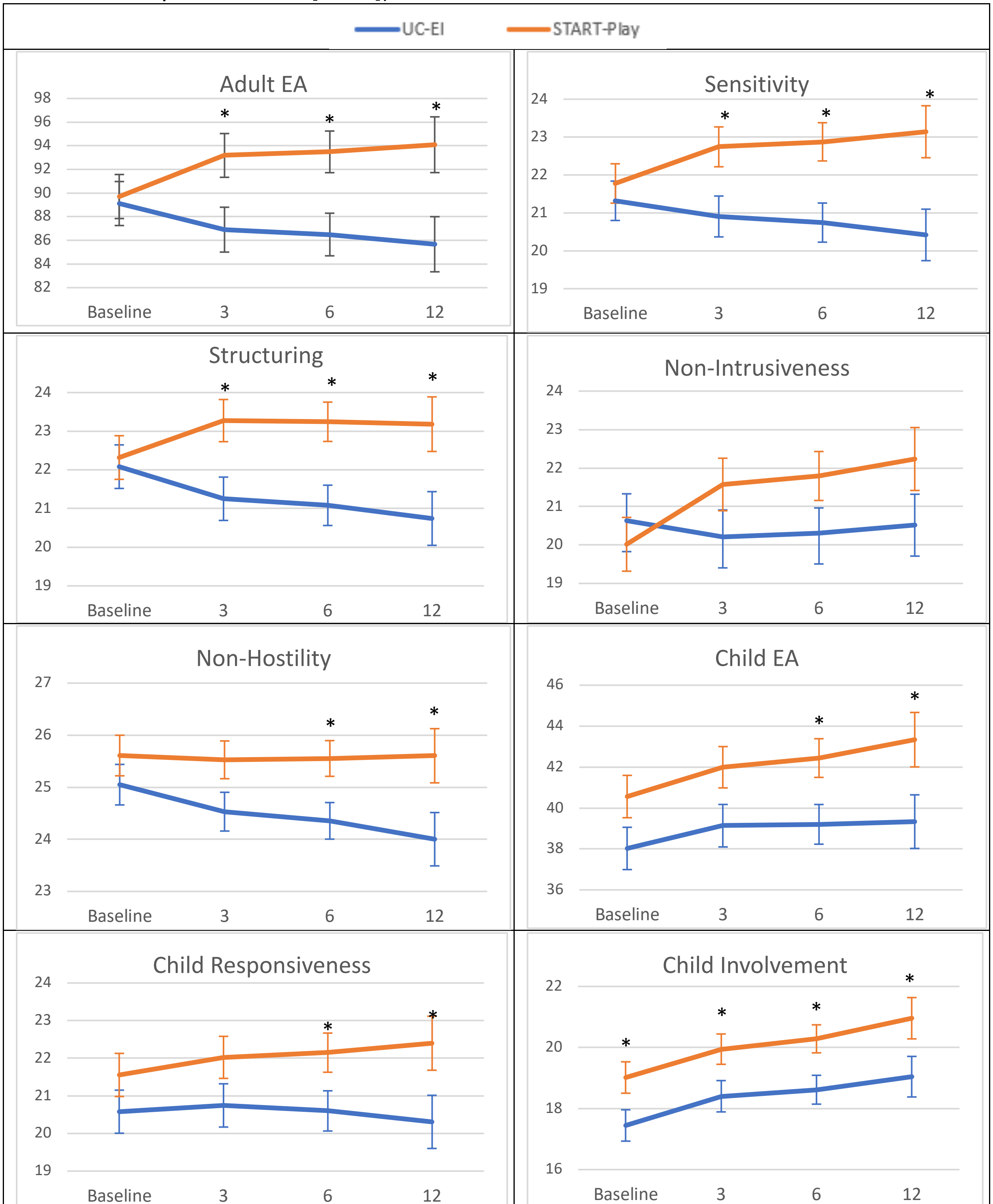
Table 10. Estimated Baseline, Short-, and Long-Term Intervention effect sizes (Hedges g) and Statistical significance

	Aggregated			Mild Motor Delay			Severe Motor Delay			≥ Bachelor's Degree			< Bachelor's Degree		
	Baseline	Short-Term	Long-Term	Baseline	Short-Term	Long-Term	Baseline	Short-Term	Long-Term	Baseline	Short-Term	Long-Term	Baseline	Short-Term	Long-Term
Adult EA	0.045	0.380*	0.486*	.159	.435*	.509*	-.034	.315	.438	.148	.256	.243	-.135	.484	.651*
Sensitivity	0.007	0.325*	0.256*	.292	.322	.376	-.08	.329	.642*	.281	.216	.214	-.096	.381	.704*
Structuring	0.027	0.425*	0.459*	.1	.467	.355	.009	.384	.593	.248	.312	.256	-.127	.422	.527
Non-Intrusiveness	-0.123	0.363*	0.405*	.004	.407	.414	-.280	.304	.383	-.072	.238	.225	-.039	.589*	.535
Non-Hostility	0.204	0.148	0.321	-.002	.296	.825*	.489	-.014	-.242	.149	.079	.068	.343	.111	.459
Child EA	0.354	0.0371	0.163	.436	-.018	.049	.248	.098	.292	.559*	-.147	-.039	.186	.214	.280
Child Responsiveness	0.248	0.064	0.229	.339	-.068	.153	.124	.199	.303	.453	-.072	.069	.078	.166	.249
Child Involvement	0.426*	-0.006	0.077	.587	.019	-.059	.347	-.029	.066	.623*	-.225	-.160	.260	.233	.256

Short-Term (baseline to 3mo after the start of intervention) and Long-Term (Baseline to 12mo after the start of intervention).

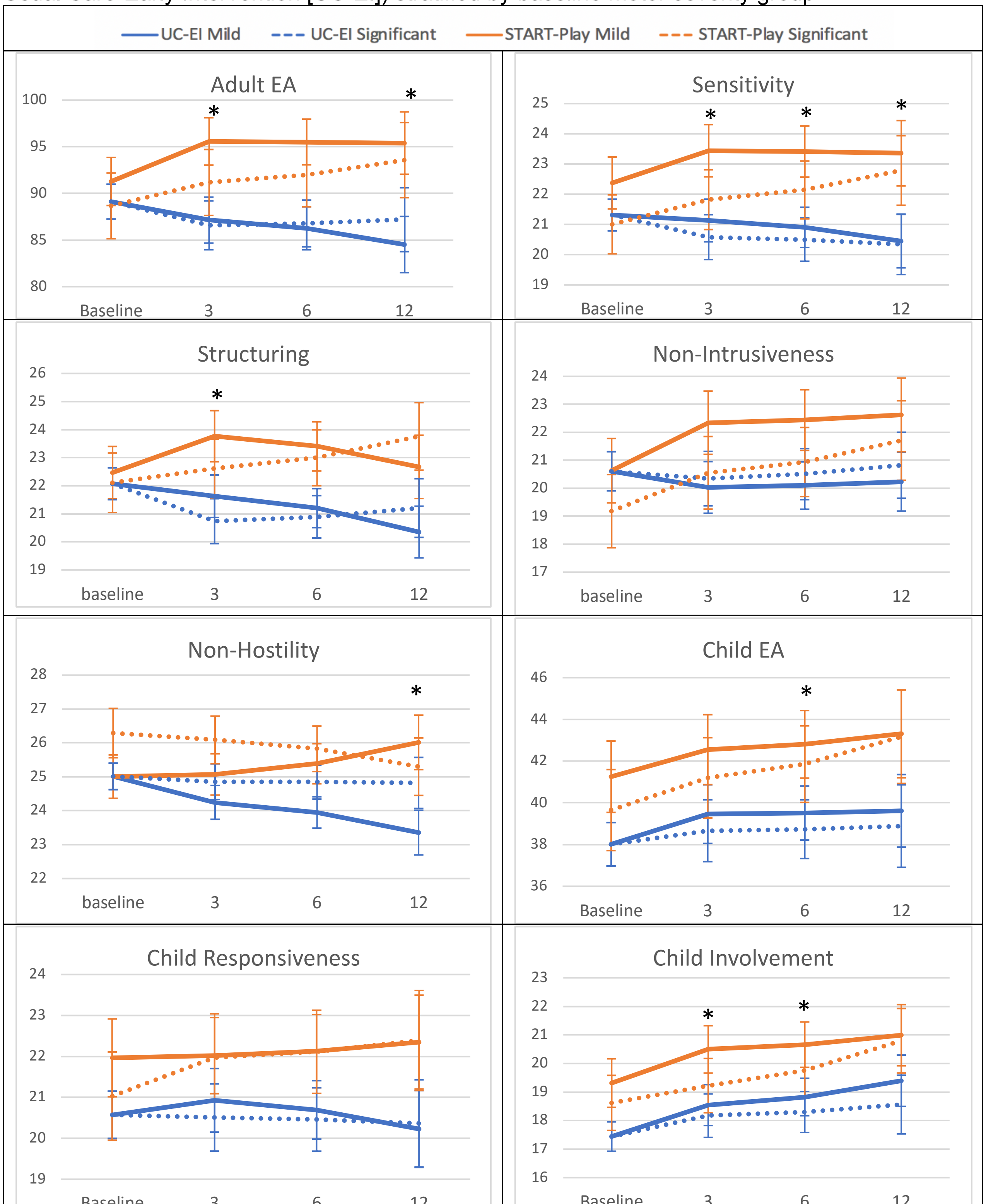
* =The effect was statistically significant ($p < .05$) in favor of the START-Play group.

Figure 8. Estimated trajectories and visit level estimate differences by time since baseline of Emotional Availability (EA) by group (Sitting Together and Reaching to Play [START-Play] vs Usual Care-Early Intervention [UC-EI])



*Indicates a significant difference in scores at that visit in favor of dyads in START-Play
Error bars represent +/- 1 standard error

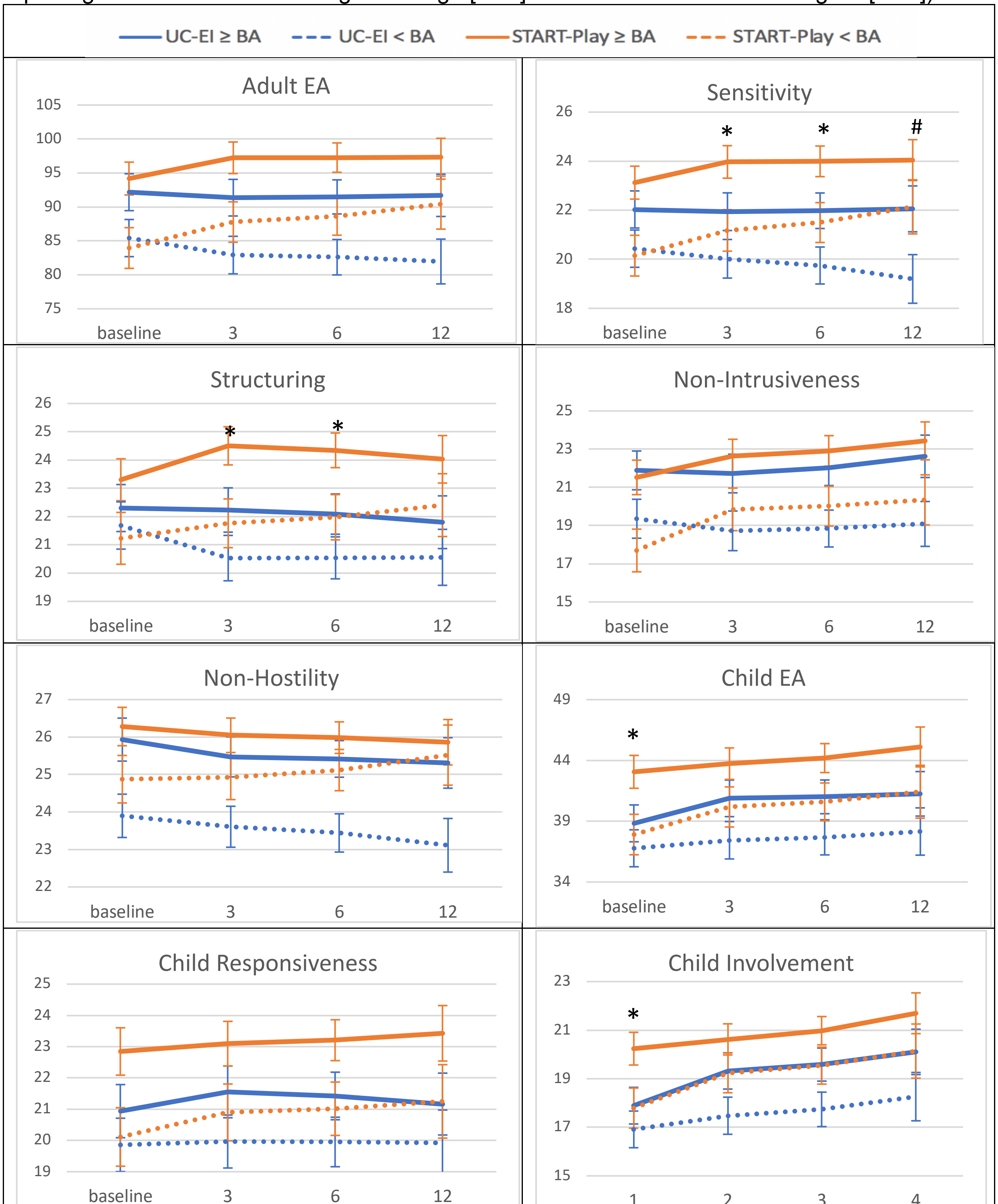
Figure 9. Estimated trajectories and visit level estimate differences by time since baseline of Emotional Availability (EA) by group (Sitting Together and Reaching to Play [START-Play] vs Usual Care-Early Intervention [UC-EI]) stratified by baseline motor severity group



*Indicates a significant difference in scores at that visit in favor of dyads in START-Play with mild motor delay

Error bars represent +/- 1 standard error

Figure 10. Estimated trajectories and visit level estimate differences by time since baseline of Emotional Availability (EA) by group (Sitting Together and Reaching to Play [START-Play] vs Usual Care-Early Intervention [UC-EI]) stratified by baseline parent reported education (parents reporting at least a Bachelors degree or high [≥BA] or less than a Bachelors degree [<BA])



* indicates a significant difference in scores at that timepoint in favor of dyads in START-Play whose caregiver reported earning at least a Bachelor's degree at baseline

# indicates a significant difference in scores at that timepoint in favor of dyads in START-Play whose caregiver reported earning less than a Bachelor’s degree at baseline
Error bars represent +/- 1 standard error

Supplemental Table 4. Baseline characteristics of dyads who dropped vs. completed the study.

Variable	Aggregated Across Participants	
	Dropped	Completed
N	19	85
Intervention Group		
UC-EI	12 (63.16%)	40 (47.06%)
START-Play	7 (36.84%)	45 (52.94%)
Baseline motor severity		
Mild	13 (68.42%)	45 (52.94%)
Severe	6 (31.58%)	40 (47.06%)
Baseline age months (Std Dev)	10.05 (2.46)	10.87 (2.59)
Sex		
Girls	8 (42.11%)	37 (43.53%)
Boys	11 (57.89%)	48 (56.47%)
Race		
White	8 (50.00%)	63 (75.90%)
Black	5 (31.25%)	5 (6.02%)
Other	3 (19%)	15 (18%)
Missing	2 (11%)	2 (2%)
Ethnicity		
Hispanic	6 (35.29%)	7 (8.43%)
Not Hispanic	11 (64.71%)	76 (91.57%)
Missing	2 (11%)	2 (2%)
Participating Caregiver		
Mother	18 (94.74%)	78 (91.77%)
Father	1 (5.26%)	5 (5.88%)
Grandmother	-	1 (1.18%)
Legal Guardian	-	1 (1.18%)
Education of Participating Caregiver		
≥ Bachelor’s Degree	7 (37%)	51 (60%)
< Bachelor’s Degree	10 (53%	29 (34%)
Missing	2 (11%)	5 (6%)
Household SES		
Low to middle SES (< Some college &/or PIR < 2)	10 (62.50%)	25 (31.25%)
High SES (>= Some college & PIR >= 2)	6 (37.50%)	55 (68.75%)

Missing	3 (16%)	5 (6%)
Gestational age at birth		
>= 37 weeks	12 (63.16%)	54 (63.53%)
34-36 weeks	3 (15.79%)	5 (5.88%)
32-33 weeks	1 (5.26%)	6 (7.06%)
25-31 weeks	-	14 (16.47%)
<25 weeks	3 (15.79%)	6 (7.06%)

Supplemental Table 5. Comparison of baseline family characteristics of dyads who had the same caregiver present at all visits vs. dyads in which the caregiver differed between visits. There were no significant differences between groups.

	Different caregivers	Same caregiver
Sex		
Male	17	42
Female	8	37
Race		
Asian	4	4
Black or African American	1	9
Multiple	1	7
White	19	52
Other	0	2
Ethnicity		
Hispanic	2	11
Not Hispanic	23	64
SESed		
0	2	33
1	21	40
Parent ed		
< Bachelor's degree	6	36
≥Bachelor's degree	18	39
Baseline Emotional Availability		
Sensitivity	22.53	21.11
Structuring	21.59	22.20
Non-intrusiveness	21.79	19.77
Non-Hostility	25.65	25.16
Child responsiveness	21.79	20.77
Child Involvement	18.62	17.99
Total EA	131.97	126.89
Adult EA	91.56	88.14
Child EA	40.41	38.75
Severity of baseline motor delay		
Mild	11	47
Significant	14	32
Intervention group		

UC-EI	9	43
START-Play	16	36
Baseline age in months	11.26	10.55

Supplemental Table 6: Observed and Estimates for each visit aggregated across participants

	UC-EI				START-Play			
	Mean	Std Dev	Estimate	SE	Mean	Std Dev	Estimate	SE
Adult EA								
Baseline	88.38	13.25	89.12	1.86	89.12	12.87	89.71	1.86
3	86.19	14.98	86.91	1.90	93.50	14.69	93.18	1.85
6	87.26	14.79	86.49	1.80	92.50	14.05	93.49	1.76
12	85.82	17.92	85.67	2.33	95.26	13.56	94.09	2.36
Sensitivity								
Baseline	21.09	3.60	21.32	0.52	21.63	3.70	21.78	0.52
3	20.74	4.42	20.91	0.54	22.69	4.00	22.74	0.53
6	20.89	4.30	20.74	0.52	22.65	4.04	22.88	0.50
12	20.47	4.99	20.42	0.68	23.39	3.95	23.14	0.69
Structuring								
Baseline	21.89	3.79	22.08	0.56	22.14	3.97	22.32	0.56
3	21.11	4.37	21.25	0.56	23.44	3.97	23.28	0.55
6	21.32	4.79	21.08	0.52	22.96	4.23	23.24	0.51
12	20.79	5.44	20.74	0.69	23.79	3.91	23.18	0.71
Non-Intrusiveness								
Baseline	20.44	5.13	20.63	0.70	19.92	4.80	20.02	0.70
3	19.94	5.34	20.21	0.70	21.89	5.46	21.57	0.68
6	20.60	5.10	20.31	0.65	21.36	5.14	21.79	0.64
12	20.58	5.86	20.52	0.81	22.35	5.52	22.24	0.82
NonHostility								
Baseline	24.96	2.68	25.05	0.39	25.53	2.76	25.61	0.39
3	24.40	3.13	24.53	0.37	25.49	2.71	25.53	0.36
6	24.45	3.15	24.36	0.35	25.53	2.29	25.55	0.34
12	23.97	3.88	24.00	0.51	25.74	2.29	25.61	0.52
Child EA								
Baseline	37.93	6.63	38.03	1.03	40.17	7.56	40.56	1.03
3	38.79	8.12	39.14	1.04	42.20	8.97	41.99	1.01
6	40.09	8.19	39.20	0.97	41.76	7.82	42.44	0.95
12	39.74	9.27	39.33	1.31	43.68	8.48	43.34	1.33
Child Responsiveness								
Baseline	20.52	3.75	20.58	0.57	21.38	4.05	21.56	0.57
3	20.52	4.40	20.75	0.58	21.96	4.83	22.02	0.56
6	20.96	4.36	20.60	0.53	21.94	4.30	22.15	0.52
12	20.46	5.07	20.31	0.71	22.54	4.50	22.40	0.72
Child Involvement								
Baseline	17.41	3.41	17.45	0.51	18.79	3.89	19.02	0.51

3	18.27	4.07	18.40	0.51	20.24	4.43	19.95	0.50
6	19.13	4.20	18.62	0.47	19.83	3.92	20.28	0.46
12	19.28	4.60	19.04	0.66	21.14	4.21	20.96	0.68

Supplemental Table 7: Observed and Estimates for each visit stratified by baseline motor severity

	Mild Motor Delay							
	UC-EI				START-Play			
	Mean	Std Dev	Estimate	SE	Mean	Std Dev	Estimate	SE
Adult EA								
Baseline	89.61	12.18	89.12	1.86	89.71	14.62	91.28	2.58
3	86.39	12.53	87.14	2.46	95.00	15.59	95.58	2.54
6	87.43	14.21	86.27	2.30	95.04	14.12	95.52	2.45
12	83.73	17.96	84.52	3.01	95.76	15.05	95.40	3.34
Sensitivity								
Baseline	21.41	3.20	21.32	0.52	22.08	3.94	22.38	0.86
3	20.95	3.53	21.13	0.71	23.25	4.11	23.44	0.86
6	21.04	4.08	20.91	0.67	23.48	3.75	23.41	0.85
12	20.20	5.23	20.45	0.88	23.47	4.39	23.36	1.08
Structuring								
Baseline	22.13	3.43	22.07	0.57	22.23	4.36	22.47	0.93
3	21.66	3.49	21.63	0.76	23.88	3.82	23.77	0.91
6	21.48	4.40	21.20	0.70	23.54	3.97	23.40	0.88
12	20.34	5.82	20.35	0.92	23.35	4.55	22.67	1.13
Non-Intrusiveness								
Baseline	20.80	5.09	20.61	0.70	20.35	4.91	20.63	1.15
3	19.55	5.28	20.03	0.92	22.63	5.76	22.34	1.13
6	20.57	4.77	20.10	0.85	22.22	5.47	22.44	1.09
12	19.86	5.59	20.23	1.05	22.76	5.62	22.62	1.32
Non-Hostility								
Baseline	25.27	2.53	25.01	0.39	25.06	3.08	25.01	0.64
3	24.23	2.56	24.25	0.50	25.23	2.96	25.07	0.61
6	24.35	3.02	23.95	0.46	25.80	1.95	25.39	0.59
12	23.32	3.84	23.35	0.66	26.18	1.96	26.01	0.80
Child EA								
Baseline	39.30	6.29	38.01	1.04	41.83	8.30	41.25	1.71
3	40.50	6.50	39.46	1.40	43.75	9.19	42.55	1.68
6	41.28	8.65	39.51	1.30	43.24	7.59	42.81	1.62
12	40.82	9.54	39.62	1.74	45.09	8.21	43.32	2.11
Child Responsiveness								
Baseline	21.16	3.46	20.57	0.58	22.19	4.59	21.96	0.95
3	21.36	3.37	20.93	0.78	22.40	4.98	22.02	0.93

6	21.26	4.55	20.69	0.71	22.50	4.05	22.13	0.89
12	20.73	4.91	20.23	0.94	22.94	4.33	22.35	1.15
Child Involvement								
Baseline	18.14	3.37	17.44	0.52	19.63	4.12	19.31	0.85
3	19.14	3.58	18.54	0.72	21.35	4.40	20.49	0.83
6	20.02	4.38	18.83	0.66	20.74	3.86	20.66	0.79
12	20.09	4.95	19.39	0.90	22.15	4.05	20.99	1.07

Significant Motor Delay

	UC-EI				START-Play			
	Observed	Std Dev	Estimate	SE	Observed	Std Dev	Estimate	SE
Adult EA								
Baseline	86.65	14.76	89.12	1.86	88.41	10.74	88.67	3.53
3	85.98	17.51	86.58	2.61	91.55	13.57	91.18	3.53
6	87.00	16.06	86.78	2.51	89.06	13.60	91.98	3.41
12	88.69	18.03	87.19	3.42	94.82	12.48	93.57	4.03
Sensitivity								
Baseline	20.65	4.14	21.32	0.52	21.09	3.40	21.01	0.98
3	20.52	5.27	20.58	0.74	21.95	3.82	21.82	0.99
6	20.66	4.73	20.50	0.72	21.53	4.25	22.15	0.96
12	20.84	4.78	20.35	1.00	23.32	3.63	22.79	1.15
Structuring								
Baseline	21.55	4.33	22.07	0.57	22.02	3.35	22.11	1.06
3	20.52	5.15	20.74	0.80	22.85	4.19	22.62	1.04
6	21.09	5.45	20.90	0.75	22.18	4.56	23.00	0.99
12	21.41	4.97	21.21	1.05	24.18	3.30	23.76	1.20
Non-Intrusiveness								
Baseline	19.93	5.28	20.61	0.70	19.20	4.69	19.18	1.31
3	20.36	5.51	20.35	0.97	20.93	5.00	20.55	1.30
6	20.66	5.71	20.50	0.91	20.21	4.57	20.94	1.24
12	21.56	6.26	20.82	1.18	21.97	5.58	21.71	1.42
Non-Hostility								
Baseline	24.53	2.89	25.01	0.39	26.09	2.26	26.29	0.73
3	24.57	3.69	24.86	0.53	25.83	2.37	26.09	0.70
6	24.59	3.41	24.85	0.50	25.15	2.70	25.83	0.67
12	24.88	3.88	24.82	0.75	25.34	2.54	25.30	0.85
Child EA								

Baseline	36.00	6.77	38.01	1.04	38.20	6.19	39.65	1.94
3	37.00	9.36	38.66	1.48	40.18	8.48	41.20	1.92
6	38.38	7.42	38.74	1.41	39.76	7.91	41.86	1.84
12	38.25	8.98	38.89	1.98	42.42	8.74	43.17	2.24
Child Responsiveness								
Baseline	19.63	4.04	20.57	0.58	20.41	3.15	21.03	1.08
3	19.64	5.21	20.51	0.82	21.38	4.69	21.97	1.07
6	20.53	4.19	20.46	0.77	21.18	4.62	22.11	1.01
12	20.09	5.42	20.36	1.06	22.18	4.74	22.39	1.22
Child Involvement								
Baseline	16.38	3.26	17.44	0.52	17.80	3.42	18.62	0.96
3	17.36	4.42	18.17	0.76	18.80	4.14	19.22	0.95
6	17.84	3.68	18.30	0.72	18.59	3.76	19.75	0.90
12	18.16	3.94	18.56	1.03	20.24	4.25	20.80	1.13

Chapter 5: Conclusions, Clinical Implications, and Future Research

The overall goal of this dissertation was to understand the relationship between emotional availability (EA), children's development, and early physical therapy interventions in young children with motor delays. Specifically, we were addressing gaps in knowledge on the relationship between early motor delays and the developmental change in EA (Chapter 2), the bidirectional relationship between adult EA and children's gross motor and problem-solving development (Chapter 3), and the effect of early physical therapy interventions on EA in young children with motor delays and their caregivers (Chapter 4). Our findings suggest that motor delay serves as a risk factor to the development of EA but importantly, we also found that pediatric physical therapists without training in EA or without the intention of changing EA, were able to enhance EA through the delivery of START-Play.

Trajectories of EA differ in dyads of children with significant motor delay

The results from Chapter 2 support that motor delay serves as a risk to dyadic emotional availability. In summary, parents and children with motor delay had lower scores, less steep, or different directions of change compared to dyads with children typical motor development. Similar to previous studies of EA in children with autism spectrum disorder or infants born preterm, severity of motor delay moderated EA with children being more affected than adults (Bentenuto et al., 2020; Salvatori et al., 2016; Stack et al., 2019). Trajectories of EA in adults of children with mild motor delay did not differ from adults of children with typical motor development. Children with mild motor delay only differed from children with typical motor development in Child Involvement, with children with typical motor development having greater change over time. However, trajectories of EA in dyads with children with significant motor delay differed from typically developing dyads in both adult and child EA outcomes. On average, dyads with typical motor development had greater positive change in Sensitivity, Child EA, Child Responsiveness, and Child Involvement compared to dyads with children with significant motor delay.

Results suggest that the emergence of sitting may represent a sensitive period in which EA is malleable to change. The groups were similar in both motor skill and EA at baseline which coincided with the developmental skill of learning to sit but soon differed in EA scores and trajectories. As dyads with typical motor development were increasing in EA outcomes, dyads with mild or significant motor delay were remaining stable in most EA outcomes. Given the importance of EA on familial well-being, decreasing EA is worrisome and needs to be addressed. Children with motor delay commonly receive pediatric physical therapy services to advance developmental skills. Integrating strategies to support the parent-child relationship into early physical therapy services as early as possible may buffer dyads from the adverse effects of time found in this study.

Lack of bidirectional relationship between Adult EA and children's development

Despite evidence from other fields highlighting the transactional relationship between parenting and children's adaptive development, results from Chapter 3 did not support cross lagged associations between Adult EA and children's problem-solving or gross motor development. In contrast to a lack of cross lagged findings, our results suggest that Adult EA at one time point is predictive of future Adult EA and that children's problem-solving or gross motor scores at one time point are predictive of future performance. Stability of rank in Adult EA or children's developmental outcomes supports the urgency to identify dyads at risk for alterations in EA as early as possible as adults who score low in EA at one time point are likely to score low in EA at later timepoints and the same for children.

An important consideration for this study is that lack of findings does not signify lack of importance. Limitations in study design, such as small sample size, may have confounded potential concurrent and cross-lagged associations between Adult EA and children's development. Future research should consider implementation of multi-dimensional outcome measures that quantify developmental as well as socio-emotional well-being of the child. Additionally, capturing psychosocial functioning of the parent will also give more insight into the complex process of parenting. When conducting research on young children with or at high risk for developmental delays who may be receiving early therapeutic interventions, it is important to consider how these interventions are impacting the relationship between adult EA and child development. Results from Chapter 4 suggest that the impact of interventions on EA vary as a function of the type of intervention delivered.

START-Play enhances optimal Emotional Availability

Chapter 4 highlights that the START-Play intervention had positive effects on many dimensions of EA compared to UC-EI. Dyads in START-Play remained stable or increased whereas dyads in UC-EI either remained stable or decreased in EA outcomes. It is unclear if UC-EI influenced the decreases in EA or if UC-EI was unable to buffer dyads from the adverse effects of time. When stratifying treatment effects by children's baseline motor severity or parent reported education, differences emerged in how the two interventions supported EA in dyads with higher vs lower risk of difficulties in EA. START-Play had significant positive treatment effects on dyads with high risk to EA (significant motor delay or fewer years of parent reported education), with trajectories of EA remaining stable or increasing overtime. In contrast, dyads with high risk to EA in UC-EI either remained stable or deceased in EA outcomes. There were no differences in treatment effects for dyads with lower risk to EA suggesting these dyads may have already been functioning at a higher level of EA or had other supports in place to protect EA. Results overall suggest that START-Play supports dyadic EA in all participants and that dyads with the most risk to EA may benefit the most from START-Play.

Future studies

Future research needs to be dedicated to understanding the mechanism of potential difficulties with EA in dyads with young children with motor delay. Results from this dissertation found that dyads with motor delay differed quantitatively compared to dyads with typical motor development. For further clinical application of these results, providing qualitative descriptions of what these changes look like in real-time as well as capturing the dyads lived experience of their unique relationship will give more clinical context to the current findings.

We will use current limitations in study design to guide future studies. To enhance generalizability of findings, we will implement targeted recruitment strategies to enhance representation of families across diverse economic, racial, and cultural groups. In addition to developmental assessments, we will include assessments of socio-emotional or adaptive development as well as understanding parent level factors known to compound parenting such as stress, efficacy, or beliefs.

In addition to measuring biological, psychological, and social constructs within the family, a shift in how these constructs are conceptualized also needs to occur. Federally funded research mandates the inclusion and reporting of racial and ethnic minorities in research. While this may mandate had the intention of enhancing representation of historically marginalized groups, an unexpected co-occurrence was the increase in race-based comparisons (Corbie-Smith et al., 2008). Comparing outcomes by race without understanding the effect of systemic inequalities and racism on individuals opens the door for unwarranted stigma and blame and suppresses our ability to understand root causes of racial disparities (Corbie-Smith et al., 2008; Jones, 2001). Future research needs to theoretically conceptualize race as a contextual variable that is complex and rooted in our society's longstanding institutionalized, personally mediated, and internalized racism (Jones, 2001).

Results from Chapter 4 support a positive effect of START-Play. Future research needs to investigate item level differences of EA to understand the mechanism of START-Play on EA. Additionally, videotaped intervention sessions from START-Play and UC-EI can be reviewed to quantify how therapists were supporting EA through education or modeling of their own behaviors. It's possible that parents were just as influenced by what the therapists did or did not do vs what they said or did not say.

Challenges with relationship focused assessment and intervention

Translating relationship-focused assessment and intervention to clinical practice requires overcoming numerous barriers and imparting a paradigm shift in current EI practice models. Most physical, occupational, and speech therapy graduate school curriculums still follow the medical model therefore to advance relationship-focused skills, many practicing EI professionals will require post qualification training. Additionally, there are a lack of measures accessible to EI professionals that assess synchrony of the dyad and a lack of empirical findings to support the translation of relationship-focused intervention into clinical practice (D'Arrigo et al., 2018; Dusing et al., 2019; Gridley et al., 2019; Novak & Honan, 2019).

Historically, measurement of the parent's role during EI has mainly revolved around binary measures of discrete behaviors, i.e., they did or did not perform parent-delivered interventions or attend therapies. While quantifying these behaviors may be valuable, they do not provide insight into the moderating role of the parent-child relationship on children's development. Additionally, considering only parent's discrete behaviors, neglects the role of the child in influencing parenting choices or behaviors. A recent systematic review appraising the clinometric properties of measurements of family engagement for use in pediatric rehabilitation found no suitable measures that captured parents affective, behavioral, and cognitive engagement (D'Arrgio et al., 2018). Additionally, a second systematic review critiquing dyadic relationship outcome measures used as part of parenting interventions from birth-five, were unable to confidently recommend any of the five identified measurement tools as all had low-quality psychometric evidence due to issues with reliability, validity, lengthy training, and limited clinical utility (Gridley et al., 2019). Most measures of the parent-child relationship used in empirical studies, rely on high-tech and high-resource methods thus limiting clinical usefulness (Gridley et al., 2019). Overall, if EI professionals are unable to objectively measure synchrony of the relationship prior to EI, then it is unlikely they can or will prioritize the relationship during intervention.

There is a scarcity of high-quality evidence on relationship-focused interventions delivered by EI professionals to families of children with DD. Most support for the effectiveness of relationship-focused intervention comes from theory as well as clinical trials in the fields of nursing and developmental sciences on typically developing children with behavioral difficulties or those exposed to adverse social risk factors (Guttentag et al., 2014; Landry et al., 2006; Thomas et al., 2017; Thomas & Zimmer-Gembeck, 2007). More recently, these other fields are applying interventions proven effective in typically developing children to parents and children born premature or with DD (Ruane & Carr, 2019; Whittingham et al., 2013). These interventions have been effective in advancing motor and cognitive development with mixed results on improving behavioral outcomes. However, the interventions are implemented by professionals with psychology degrees and are often times paired with parental cognitive behavioral therapies (Whittingham et al., 2013).

While these results show promise, it is unknown if EI professionals can execute similar interventions with the same results. To our knowledge, there are no available rigorous relationship-focused intervention studies that are implemented by EI professionals, that uses a comparison group, and measures quality of the bi-directional relationship as a primary outcome measure. For example, the “Supporting Play Exploration and Early Developmental Intervention” is delivered to infants born very preterm by a physical therapist, uses a control group, and has a blended focus on supporting parenting behaviors with infant’s developmental skills (Dusing et al., 2015; Dusing et al., 2018). Participating parents qualitatively report benefitting from the intervention and theoretically the intervention should positively impact the dyad, the quality of the relationship was not measured or published therefore the quantitative effect of intervention is unknown (Dusing et al., 2015; Dusing et al., 2018). Excitingly, there are randomized controlled trials currently underway that address these gaps and will provide high-quality evidence on the effect of relationship-centered EI delivered by EI professionals on the parent-child relationship (Baraldi et al., 2020; Benfer et al., 2018; Dusing et al., 2020).

Clinical Bottom Line

This dissertation highlights the usefulness and urgency of quantifying the quality of the parent-child relationship in dyads of children with motor delay. Pediatric physical therapists are in a unique position to identify and treat early difficulties in EA as they often spend many hours and months working with families in their home from the ages of birth to three. The onset of sitting represents a time of risk and resilience with the parent-child relationship. Dyads with motor delay had difficulty maintaining optimal EA levels after the emergence of sitting, but with support from START-Play dyads were able to increase in EA over time.

Quantifying the parent-child relationship should be considered a vital sign in families seeking early therapeutic services. Measuring the parent-child relationship to determine services should be just as important as quantifying delays in developmental domains. Alterations in the relationship can compound development and may inhibit the effectiveness of early therapeutic interventions. Autoregressive results from chapter 3 indicate that rank order of Adult EA is stable, meaning without intervention it is likely that adults with difficulties in EA at one time point, will likely continue to have these same difficulties at future time points. By measuring EA at baseline, professionals can spend time reinforcing dyadic strengths while teaching or modeling optimal EA to address weaknesses.

In addition to the opportunities for future research indicated above, identifying clinically applicable measures of the parent-child relationship needs to be at the forefront of future studies (D'Arrigo et al., 2018; Dusing et al., 2019; Gridley et al., 2019). Clinicians need tools without high tech, time, or training demands in order to measure the relationship before and during intervention. Applying tools used across other disciplines may be an avenue forward or possibly designing or modifying current measures may be needed to meet the unique needs of physical therapists and other early intervention professionals. Supporting the parent-child relationship as part of routine services, early intervention professionals will truly be practicing family centered care and optimizing familial health and well-being.

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APPENDIX A: Children's global development depends on type of intervention and caregiver's Emotional Availability

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The parent-child relationship during early childhood is supported to have longstanding implications on children's adaptive development (Bernier et al., 2016; Bornstein, 2014; Holden, 1997; Maccoby, 1992). Emotional availability (EA) is conceptualized as the capacity of the parent-child dyad to share an emotional connection and to enjoy a mutually fulfilling and healthy relationship (Biringen et al., 2014; Easterbrooks & Biringen, 2000). Emotionally available relationships foster children's adaptive development by supporting secure-base behavior (Biringen et al., 2014; Emde, 2012; Source & Emde, 1981). Through previous exchanges children learn that their caregivers are a safe haven and can protect or comfort them during times of distress. This confidence or security in parents physical and emotional availability encourages children's exploration and learning away from their parent (Source & Emde, 2981). Positive parenting behaviors and EA serve as sources of resilience and can buffer risks to children's development commonly associated with biological or social risks (Poehlmann & Fiese, 2001; Treyvaud et al., 2016). Children with delays in development are part of an emotionally available dyad, they are more persistent in their exploration, engage in more complex play, and make strides in their self-regulatory abilities (de Falco et al., 2010; Poehlmann & Fiese, 2001; Venuti et al., 2009).

Given the importance of EA in fostering development, the efficacy of early physical therapy interventinons may depend on the quality of the parent-child relationship just as much as the dosage or type of intervention (Atkins-Burnett & Allen-Meares, 2000; Karaaslan et al., 2013). EI is supported to have promising short-term but uncertain long-term effects on motor and cognition for children with developmental delay (Morgan et al., 2016; Novak & Honan, 2019; Orton et al., 2009; Spittle, 2015). One proposed mechanism of the lack of long-term efficacy of EI, is the continued sole focus on child level outcomes when designing and measuring success of intervention (Campbell & Sawyer, 2007; Peterson et al., 2007). Despite the mandates of family centered care, many EI providers lack the training, time, or tools to go beyond parent coaching and therefore are unable to treat and enhance the dyadic relationship (Alexander et al., 2018; Bamm & Rosenbaum, 2008; Dusing et al., 2019; Guttentag et al., 2014; Mahoney et al., 1998).

From a practical perspective, EI professionals often utilize parents as a pathway to delivering the adequate dosage needed for clinical change (Richardson, 2020). However, if the home-based intervention is delivered in a way that does not promote the relationship, it’s possible that our perceived pathway to success is hindering rather than promoting the relationship and therefore impeding program success. While EI professionals rely on parents to deliver intervention, there is evidence to support that on average, parents only adhere to 50% of therapists’ recommendation for parent-delivered intervention (Lillo-Navarro et al., 2015; Sakzewski et al., 2009). Parents report one barrier to implementing intervention at home is that, at times, the therapeutic intervention can negatively impact the parent-child relationship (Lillo-Navarro et al., 2015; Novak, 2011). A focus on training parents for parent-delivered intervention without focusing on the relationship may result in parents compromising emotionally available parenting behaviors in order to deliver the intervention as instructed (Barfoot et al., 2017; Novak, 2011). In response to this type of interaction children may disengage from the parent and repress their expression of needs or may over-express their needs in a dysregulated and unsatisfying way. These types of interactions are not enjoyable or productive for parents or children, resulting in diminished motivation to perform the home-based interventions, leaving children without the dosage needed for clinical change. Supporting and enhancing dyadic EA during EI, can nurture mutually enjoyable, satisfying, and growth-fostering interactions which parents and children willfully engage in during and long after intervention has ended.

START-Play is an early physical therapy intervention effective in advancing short-term (3 month) change in cognition and fine motor skills and long-term (12 month) change in fine motor skills for children with significant motor delay and short-term change in receptive language in children with mild motor delay (Harbourne et al., 2021). To understand the mechanism of the effect of START-Play both moderation and mediation analyses have recently been completed. Long-term change in cognition was indirectly impacted through short-term changes in motor-based problem-solving (Koziol et al., 2023). As caregivers played a critical role in START-Play, there was interest in understanding how caregiver behaviors influenced the success of intervention. Koziol et al., found that within START-Play, children of caregivers who provided more learning opportunities at baseline had greater growth in cognition. The authors hypothesized that the effectiveness of START-Play on children's gains in cognition are contingent on parents providing ample opportunities for children to practice cognitive skills. Although novel, a limitation of this study was that the parent outcome focused solely on the parent's behavior but did not capture the child's engagement or readiness to learn.

Emotional availability is dyadic in that it not only considers the parent's action, but importantly how the parent's action meet the needs of the child and/or how the child responds to their parent s action. Quantifying reciprocity of the relationship is in line with the transactional model of development which posits that parents and children are equal members during interactions, always influencing and being influenced by one another. A previous study on the effectiveness of START-Play on caregiver's emotional availability identified short- and long-term effects on Adult EA (Short-term EST=5.69, p=.015, g=0.38; Long-term EST=7.83, p=.012, g=.49).

The purpose of this study was to investigate the moderating effect of Adult Emotional Availability on global development in children with motor delay after receiving START-Play. Results will highlight if EA following intervention boosts children's development and if that boost is dependent on the type of intervention the family received. To understand if the effect of EA at the end of intervention differed in response to type of intervention the family received, trajectories of global development of children in START-Play vs. UC-EI were compared. Specifically, aim 1 investigated the moderating role of Adult EA on children's cognitive, motor, and language development in children with mild motor delay in START-Play or UC-EI, whereas aim 2 investigated this relationship in children with significant motor delay. The third aim of this study was to compare the effect of Adult EA on child outcomes in dyads within the START-Play group. We hypothesized that children in START-Play whose parent scored high in EA after intervention would have steeper change in developmental outcomes compared to children whose parent scored low. However, it may also be possible that the effectiveness of START-Play on child outcomes may be protective and optimize child outcomes despite parent's scoring low in EA. All participants are included in this analysis, but results will be stratified by baseline motor severity. Given the success of

START-Play in children with significant motor delay, we anticipated a greater effect of high EA on child outcomes in children with significant motor delay.

Methods

Participants

One-hundred and twelve parent-child dyads were included in the primary outcomes analysis for START-Play (Harbourne et al., 2021). Children with neuromotor delay were recruited when they were corrected ages 7 to 16 months on a rolling basis between 2016 and 2019 and followed up to one year (Harbourne et al., 2018, 2021). All participants were recruited when they were learning to sit which included an ability to sit propped up on the arms for at least 3 seconds and an inability to transition in and out of sitting (Harbourne et al., 2018, 2021). Additional inclusion criteria were a score of >1.0 SD below the mean on the Bayley Scales of Infant and Toddler Development, Third Edition (Bayley; Bayley, 2006) gross motor subtest (Harbourne et al., 2018, 2021). Exclusion criteria were medical complications limiting participation (e. g., severe visual disorder), a primary diagnosis of autism, Down syndrome, or spinal cord injury, a reported uncontrolled seizure disorder; or a neurodegenerative disorder (Harbourne et al., 2018, 2021).

Following the baseline assessment, blocked randomization was completed with stratification into START-Play plus UC-EI or UC-EI only (Harbourne et al., 2018, 2021). To achieve equivalent groups, participants were stratified by clinical site (Newark, DE; Omaha, NE; Pittsburgh, PA; Richmond, VA; Seattle, WA) and baseline movement ability (mild, moderate, or severe) (Harbourne et al., 2018, 2021). Baseline movement ability was based on a rubric developed by the study investigators that considered the child's scores on the Gross Motor Function Classification System and Manual Ability Classification System, along with information about the child's distribution of motor impairment and level of active movement (Harbourne et al., 2018)

Procedure

Assessments and interventions took place at children's homes, childcare settings, family-friendly lab spaces or clinical settings, per caregiver preference. Children were assessed at the end of intervention and 3 and 6 months post intervention (Harbourne et al., 2018, 2021). Prior to the analysis, children were stratified into mild or significant motor delay delay based on baseline scores on the Bayley motor composite score (Harbourne et al., 2021). Participants categorized as having mild motor delay scored > 1.0 to <2.5 SD below the mean and those with significant motor delay scored ≥ 2.5 SD below the mean for the Bayley motor composite score (Harbourne et al., 2021).

To account for family level differences in household income and parent reported education a composite variable (SES/ED) was created. The SES/ED variable first categorized parent education as "some high school or less" (score of 0), "high school graduate" (score of 1), and anything above this (some college or beyond) received a score of 2. Secondly, the poverty income ratio was calculated as the ratio of household income to the poverty level based on the number of individuals living in the household. The poverty level was specified in the Department of Health and Human Services according to the year 2018. Blended education and income was considered "high" (education > or equal to 1 (high school graduate or above) and poverty income ration greater than or equal to 2) or "low" (education = 0 (some high school or less) and poverty income ration less than 2) (Karlamangla et al., 2010).

A five minute, unstructured, parent-child interaction was videotaped at each assessment. Parents were instructed to "interact with their child as they normally would" and were provided with the same set of toys at each assessment to standardize access to toys. Parents were not encouraged or discouraged from using other toys or moving around the home with their child. The filmer captured the faces of both the parent and child and if one member left the frame, then the filmer was instructed to follow the child. Assessors and filmers did not interfere with the dyad during the five minutes in any way including watching the dyad, making eye contact with parent or child, talking to the parent/child, retrieving toys for the dyad, or otherwise reacting to or engaging with the dyad. If siblings were present, researchers engaged with the sibling in a different location to limit distractions to the dyad. If both parents were present, one or both could be in the filmed interaction depending on parent preference.

Intervention

The START-Play intervention consisted of 2 sessions per week (average of 51.5 minutes, SD =4.4 minutes) for 3 months (mean = 21 visits), in addition to their UC-EI sessions. Licensed physical therapists delivered the intervention in collaboration with at least 1 parent/caregiver within the child's natural environment (Harbourne et al., 2018, 2021). UC-EI was performed by the child's usual interventionist (physical, occupational, or speech therapist) at their prescribed frequency (Harbourne et al., 2018, 2021). As part of the study protocol, differentiation of START-Play and UC-EI interventions was evaluated. Videotaped intervention sessions for both groups were scored and key statistical differences were noted. START-Play interventionists were required to maintain a priori set levels of adherence to intervention key principles resulting in significant differences from UC-EI in cognitive opportunities, encouraging self-initiated movements, and brainstorming with caregivers. Interventionists in UC-EI often provided greater motor assistance than needed, maintained rigid adherence to moving with "normal patterns", and performed intervention activities not START-Play related (An et al., 2021). While some of the therapists in UC-EI demonstrated START-Play behaviors, such as encouraging parent led activities, they occurred at lower rates than with the START-Play therapists (An et al., 2021).

Outcomes

Emotional Availability Scale. Five-minute parent-child interaction videos were scored using the Emotional Availability Scales, 4th edition (Biringen, 2008). The EA Scale is composed of six dimensions, four focused on the adult and two focused on the child (Biringen 2008; Biringen et al., 2014). Although each member of the dyad has individually scored EA dimensions, the EA Scale is considered dyadic in that the child's response to the adult's actions are considered when formulating the adult score (Biringen 2008; Biringen et al., 2014). Therefore, it is possible that two adults may provide similar qualities but receive different scores based on their child response. The four adult EA Scale dimensions are: (a) *Sensitivity,* which includes affect, responsiveness, timing, flexibility, acceptance, amount of interaction, and managing conflict; (b) *Structuring,* which includes provision and success of guidance, amount and types of structuring implemented, setting and remaining firm in limit setting; (c) *Non-intrusiveness,* which describes the adults ability to follow the child's lead, enter interaction without physically or verbally intruding, and talking and relating in a way that teaches rather than commands; and (d) *Non-hostility,* which includes the absence of negativity in face or voice and overall the parent is composed, patient, pleasant, and available to comfort and support the child. The two child EA dimensions include: (a) *Responsiveness*, which describes the child's balance between age-appropriate autonomous exploration and responding to parent's interaction bids, enjoyment of the interaction, and organized affect regulation; and (b) *Involvement*, which includes the child's willingness to simply and elaboratively initiate interaction with their parent (Biringen 2008; Biringen et al., 2014).

Each of the six EA dimensions contains seven scored items, with higher scores indicating more optimal EA behaviors. The first two items of each dimension are scored on a 7-point Likert scale from non-optimal (1) to optimal (7). The remaining five scored items of each dimension are scored on a 3-point Likert scale from non-optimal (1) to optimal (3). The potential score range for each dimension is 7-29. The two child dimensions of *Responsiveness* and *Involvement* are added together to form a *Child EA* score with a potential score ranging from 14-58. The four adult dimensions of *Sensitivity, Structuring, Non-Intrusiveness,* and *Non-Hostility* are summed to produce an *Adult EA* with a potential score ranging from 28-116. Clinical cutoffs for the 6 EA dimensions have been reported as scores greater than 26 considered optimal EA, scores of 18-25 as inconsistent EA, and scores less than 17 as nonoptimal EA (McLean 2022).

If both parents were in the five-minute video, the coders watched the video in full to identify which parent was the main interactor and then identified if the other parent had enough interaction with the child to be scored. In total, there were 6 visits in which both parents were scorable, but for this study only data from one caregiver was included. In addition to scoring the EA scale, coders kept track of any assessor or sibling interference, which parent was in the video, and if other family members were also in the video including siblings, other caregiver, grandparents, nurses, or a nanny.

Twenty percent of all visits were scored twice for inter-rater reliability. ICC's for Adult EA inter-rater reliability were .88.

Bayley Scales of Infant and Toddler Development, Third Edition (Bayley). The Bayley is a well-known norm-referenced test designed to assess multiple developmental domains in infants of 3 to 42 months of age (Bayley, 2006). The Bayley assesses development in five domains: cognition, motor, language, socio-emotional, and adaptive. This analysis will include information on cognition, motor, and language. The cognitive scale consists of 91 items; the motor scale consists of fine (66 items) and gross (72 items) motor domains and the language scale consists of receptive (49 items) and expression (48 items) domains. The sum of the gross and fine motor domains provides the motor composite score used to stratify participants into motor delay groups. Although the Bayley allows for composite and scaled scores, only the raw scores are used in this analysis.

Analysis

Analyses were performed in SAS. Statistical significance was .05. All models controlled for intercept-level differences in recruitment site, SES/ED and intercept- and slope-level differences in baseline motor delay with random intercept to allow for child level variation. Five linear mixed models were estimated, one for each Bayley outcome. Each model included main, 2-way, and 3-way interaction effects of time since intervention, type of intervention (START-Play or UC-EI), and 3-month Adult EA on change in Bayley from post-intervention to 9 months post-intervention. Time since intervention was treated as continuous variable to account for dyad-level variations in time between assessments. To answer Aims 1 and 2, three-way interactions between time since intervention x intervention group x post-intervention were run in children with mild or significant motor delay respectively. To answer Aim 3, three-way interactions between time since intervention x baseline motor delay x post intervention Adult EA were investigated within the START-Play group only.

3. Results

Sample characteristics are provided in Table 9. Adult EA after intervention significantly moderated 9-month post intervention change in receptive language (EST=.51, p=.00) and expressive language (EST=.78, p=.00), with fine motor approaching significance (EST =.43, p=.05).

Moderating effect of post-intervention Adult EA on Bayley trajectories in children with mild motor delay in START-Play vs UC-EI (Aim 1)

There were no significant differences in effects of Adult EA following intervention on Bayley outcomes in children with mild motor delay in START-Play vs UC-EI (Supplemental Table 9 and Supplemental Figure 2). Predicted scores for each developmental outcome stratified by intervention group and HIGH (scoring .5 SD above the aggregated post-intervention mean) or LOW (scoring .5 SD below the aggregated post-intervention mean) Adult EA are presented in Supplemental Table 8.

Moderating effect of post-intervention Adult EA on Bayley trajectories in children with significant motor delay in START-Play vs UC-EI (Aim 2)

Adult EA at the post-intervention visit significantly moderated post-intervention trajectories of Bayley cognition (EST=.49, SE=1.02, p=.04), gross motor (EST=.71, SE=.22, p=.00), receptive language (EST=.44, SE-.12, p=.00), and expressive language (EST=.51, SE=.16, p=.00).

To visualize these findings, the continuous Adult EA variable was categorized into HIGH or LOW Adult EA based on scores at the post-intervention visits. The criteria for HIGH EA included scoring .5 SD above the aggregated average Adult EA score at the post-intervention visit, while LOW EA was considered scoring less than .5 SD below the mean. Children with significant motor delay in START-Play whose parent scored HIGH in Adult EA at the post intervention visit had significantly greater trajectories in Bayley fine motor (EST=4.39, *p*=.00), gross motor (EST=6.67, *p*=.00), and receptive language (EST=2.52, *p*=.04) than children with significant motor delay in UC-EI whose parent scored HIGH in EA at the post intervention visit (Table 12, Figure 11). Among children with significant motor delay whose parent scored LOW in EA at the post-intervention visit, there were no group differences in Bayley trajectories (Table 12, Figure 11).

Children with significant motor delay in START-Play whose parent scored HIGH in Adult EA at the post intervention visit scored significantly higher than children with significant motor delay in UC-EI whose parent scored HIGH in Adult EA at the 9 mo post intervention visit in all 5 Bayley outcomes (*p's* <.02) and scored higher at the 3 mo post intervention visit in all Bayley outcomes (*p's*<.04) except expressive language (Table 11). However, when comparing differences in Bayley outcomes at each of the three post-intervention visits, there were no differences between START-Play vs. UC-EI in children with significant motor delay whose parent scored LOW in EA (Table 11).

Moderating effect of post-intervention Adult EA on Bayley trajectories in children in START-Play stratified by severity of baseline motor delay (Aim 3)

Mild Motor Delay There were no differences in scores or trajectories of Bayley outcomes in children with mild motor delay in START-Play whose caregiver scored HIGH v LOW in EA at the post-intervention visit (Supplemental Table 10 and Supplemental Figure 2).

Significant Motor Delay Within START-Play, children with significant motor delay whose parent scored HIGH in EA at the post-intervention visit had significantly greater growth in Bayley fine motor (EST=2.51, p=.02), receptive language (EST=3.51, p<.00), and expressive language (EST=4.44, p<.00) compared to children with significant motor delay in START-Play whose parent scored LOW in Adult EA at the post-intervention visit (Table 13; Figure 11).

Discussion

Early childhood is a time of great neural plasticity as well as a time in which children are most dependent on their caregivers for survival, nurturing, and learning. The intrinsic relationship between experience-dependent brain development and the experiences provided by parents supports the long-standing impact that early relationships have on children's neurological, behavioral, and emotional development. The purpose of this study was to investigate the effect of Adult's emotional availability on children's developmental outcomes after receiving the START-Play physical therapy intervention.

Participants with mild or significant motor delay were included in this analysis. However, when investigating the effects of Adult EA and type of intervention on development in children with mild motor delay, no differences were found for any outcomes. Lack of significance potentially indicates that the importance of EA or type of intervention are less critical in children with fewer barriers to development. In contrast, our results highlighted the influential role of EA and the caregiving environment on global development in children with significant motor delay. These findings for children with mild or significant motor delay align with the primary outcomes of START-Play which found that overall the treatment was most effective for children with significant motor delay. The discussion will focus on the findings for children with significant motor delay.

When comparing trajectories of cognitive, motor, and language development in children with significant motor delay differences between treatment groups was seen only in dyads scoring high in EA. Child outcomes in dyads whose parent scored low in EA did not differ between START-Play or UC-EI. In contrast, children in START-Play whose caregiver scored high in EA after intervention had higher scores and steeper trajectories for most child outcomes compared to children in UC-EI whose caregiver also scored high.

Children in START-Play with caregivers with HIGH Adult EA had greater growth in Bayley fine and gross motor as well as receptive language domains and scored higher than children in UC-EI whose caregiver had HIGH EA in all 5 developmental outcomes by the end of the study. These results highlight that the type of intervention received and adult EA both factor into children’s development. Higher than average adult EA at the end of the START-Play intervention may indicate a family that is considered to have responded well to intervention. They may be able to integrate many of the start play ingredients during interactions in a way that promotes children's global development. START-Play skills such as structuring hard but challenging tasks, engaging in sustained joint attention, and providing children with the autonomy and time to act, think, and verbalize independently all may have contributed to growth across multiple developmental domains. Parents in START-Play scoring high in EA may have been able to seamlessly integrate learning activities into daily routines and because the interactions were enjoyable, the dyad engaged in countless reps of therapeutic activities.

Lastly, we wanted to explore if receiving the START-Play intervention could serve as a source of resilience in dyads scoring low in EA following intervention. We hypothesized that although in most situations high EA is associated with optimal child outcomes, it may be possible that the effectiveness of START-Play on child outcomes may compensate for lower Adult EA (Harbourne et al., 2021; Venuti et al., 2008). However, our results indicated that children in START-Play whose parent scored high in Adult EA benefited from START-Play above and beyond than children whose parent scored low. Clinically, these results support that while child level work is important, interventions must also focus on the dyadic relationship. By supporting the parent-child relationship, intervention effectiveness can magnify.

Limitations

When considering the results of this study, the following limitations must be weighed. The follow-up interval consisted only of 9 months, longer follow-up across childhood would provide more insight. Our follow-up window ended at the beginning of pre-school, following children during the transition to kindergarten strength the results as EA has been found to help this transition and historically children with motor delay have difficulties during this big life transition.

Clinical Relevance

Results from this study highlight that children with significant motor delay in START-Play whose caregiver scored high in EA after intervention had the greatest growth in outcomes compared to other children with significant motor delay. When considering factors that influence child development in young children receiving therapeutic interventions, it is important to consider both the type of intervention received as well as EA. Clinicians working with young children with motor delay and their families need to equally prioritize developmental activities as well as ways to support the parent-child relationship. As interactions between caregivers and children are fun and enjoyable, the dyad is likely to spend more time together. Providing parents with education on how to advance development within this playful and enjoyable shared interactions presents the context in which caregivers can foster their child's development.

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Table 11. Predicted scores of Bayley outcomes at post-intervention, 3- and 9-mo post intervention in children with significant motor delay whose caregiver had High (.5 SD above the aggregated post-intervention standardized Adult EA mean) or Low EA (.5 SD below the aggregated post-intervention standardized Adult EA mean) stratified by treatment group (START-Play or Usual Care Early Intervention, UC-EI).

SIGNIFICANT MOTOR DELAY	Post-Intervention			3mo post intervention			9mo post intervention		
	MEAN	SE	DIFF	MEAN	SE	DIFF	MEAN	SE	DIFF
BAYLEY COGNITION									
START-Play HIGH EA	28.69	1.73	.08	31.70	1.65	.02	37.72	1.95	.01
UC-EI HIGH EA	24.65	1.92		26.50	1.84		30.21	2.21	
START-Play LOW EA	27.33	1.83	.91	29.48	1.73	.98	33.78	2.12	.91
UC-EI LOW EA	27.07	1.57		29.53	1.52		34.45	1.88	
BAYLEY FINE MOTOR									
START-Play HIGH EA	18.72	1.22	.08	21.23	1.17	.01	26.26	1.23	.00
UC-EI HIGH EA	15.84	1.35		16.89	1.30		18.99	1.52	
START-Play LOW EA	18.70	1.29	.83	20.38	1.23	.48	23.74	1.46	.83
UC-EI LOW EA	18.37	1.11		19.33	1.08		21.24	1.29	
BAYLEY GROSS MOTOR									
START-Play HIGH EA	23.96	1.45	.11	27.80	1.36	.00	35.46	1.67	<.00
UC-EI HIGH EA	20.90	1.60		22.51	1.52		25.72	1.91	
START-Play LOW EA	22.12	1.53	.67	25.17	1.43	.68	21.27	1.83	.67
UC-EI LOW EA	22.91	1.32		25.87	1.26		31.80	1.63	
BAYLEY RECEPTIVE LANGUAGE									
START-Play HIGH EA	10.85	.75	.27	12.64	.70	.04	16.21	.87	.00
UC-EI HIGH EA	9.74	.83		10.68	.78		12.58	1.00	
START-Play LOW EA	10.17	.79	.94	10.78	.73	.53	12.02	.96	.94
UC-EI LOW EA	10.24	.68		11.34	.65		13.54	.85	
BAYLEY EXPRESSIVE LANGUAGE									
START-Play HIGH EA	9.77	1.11	.51	12.42	1.05	.15	17.71	1.26	.02
UC-EI HIGH EA	8.79	1.23		10.42	1.17		13.69	1.43	
START-Play LOW EA	8.92	1.18	.71	10.09	1.11	.43	12.42	1.38	.71
UC-EI LOW EA	9.45	1.01		11.14	.97		14.51	1.22	

TABLE 12. Estimated change within and between children with significant motor delay whose caregiver had HIGH EA (.5 SD above the aggregated 3mo Adult EA mean) or LOW EA (-.5 SD below the aggregated 3mo Adult EA mean) stratified by treatment group (START-Play or Usual Care Early Intervention, UC-EI)

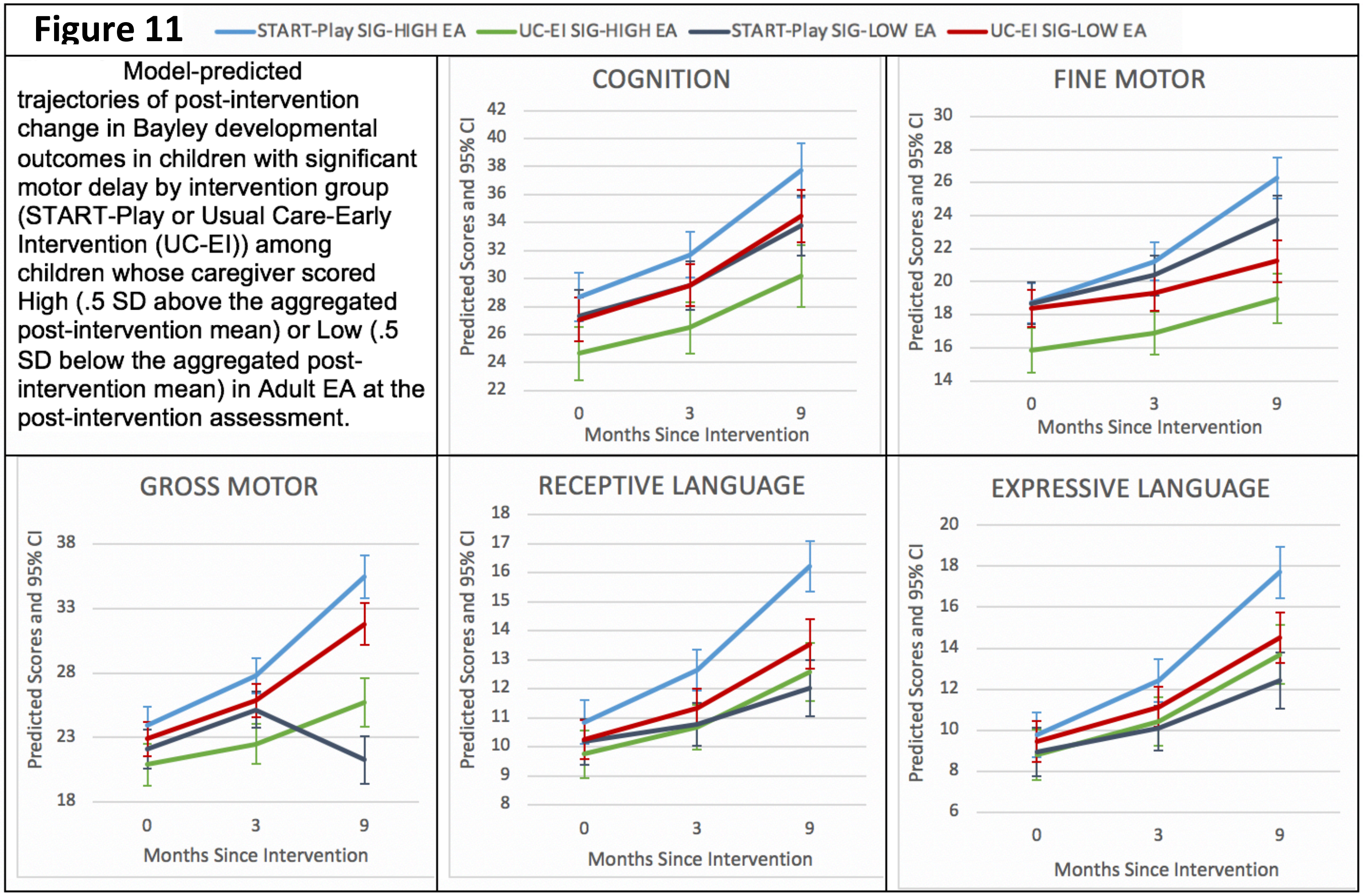
SIGNIFICANT MOTOR DELAY	9mo change within group			Difference in change between intervention groups		
	EST	SE	*p*	EST	SE	*p*
BAYLEY COGNITION						
START-Play HIGH EA	9.03	1.56	<.00	3.46	2.36	.14
UC-EI HIGH EA	5.56	1.78	.00			
START-Play LOW EA	6.45	1.82	.00	-.93	2.37	.70
UC-EI LOW EA	7.38	1.53	<.00			
BAYLEY FINE MOTOR						
START-Play HIGH EA	7.54	.99	<.00	4.39	1.50	.00
UC-EI HIGH EA	3.15	1.13	.01			
START-Play LOW EA	5.04	1.16	<.00	2.17	1.51	.15
UC-EI LOW EA	2.87	.97	.00			
BAYLEY GROSS MOTOR						
START-Play HIGH EA	11.49	1.46	<.00	6.67	2.22	.00
UC-EI HIGH EA	4.81	1.67	.00			
START-Play LOW EA	9.15	1.71	<.00	.26	2.22	.91
UC-EI LOW EA	8.89	1.43	<.00			
BAYLEY RECEPTIVE LANGUAGE						
START-Play HIGH EA	5.36	.79	<.00	2.52	1.19	.04
UC-EI HIGH EA	2.84	.89	.00			
START-Play LOW EA	1.85	.92	.04	-1.45	1.19	.23
UC-EI LOW EA	3.30	.77	<.00			
BAYLEY EXPRESSIVE LANGUAGE						
START-Play HIGH EA	7.94	1.05	<.00	3.04	1.58	.06
UC-EI HIGH EA	4.90	1.19	<.00			
START-Play LOW EA	3.50	1.22	.00	-1.56	1.59	.33
UC-EI LOW EA	5.06	1.02	<.00			

Table 13. Comparison of model-predicted 9-month post intervention change in children with significant motor delay in START-Play whose caregiver had High v Low EA

	Model predicted differences in 9-month change scores		
	EST	SE	*p*
BAYLEY COGNITION			
HIGH v LOW EA	2.58	1.64	.12
BAYLEY FINE MOTOR			
HIGH v LOW EA	2.51	1.05	.02
BAYLEY GROSS MOTOR			
HIGH v LOW EA	2.35	1.54	.13
BAYLEY RECEPTIVE LANGUAGE			
HIGH v LOW EA	3.51	.83	<.00
BAYLEY EXPRESSIVE LANGUAGE			
HIGH v LOW EA	4.44	1.10	<.00

Figure 11

Model-predicted trajectories of post-intervention change in Bayley developmental outcomes in children with significant motor delay by intervention group (START-Play or Usual Care-Early Intervention (UC-EI)) among children whose caregiver scored High (.5 SD above the aggregated post-intervention mean) or Low (.5 SD below the aggregated post-intervention mean) in Adult EA at the post-intervention assessment.



Aim 1 – compared blue and green; Aim 2 – compared navy and red; Aim 3 – compared blue and navy.

Supplemental Table 8. Predicted scores of Bayley outcomes at post-intervention, 3- and 9-mo post intervention in children with mild motor delay whose caregiver had High (.5 SD above the aggregated post-intervention standardized Adult EA mean) or Low EA (.5 SD below the aggregated post-intervention standardized Adult EA mean) stratified by treatment group.

MILD MOTOR DELAY	Post-Intervention			3mo post intervention			9mo post intervention		
	MEAN	SE	DIFF	MEAN	SE	DIFF	MEAN	SE	DIFF
BAYLEY COGNITION									
START-Play HIGH EA	35.06	1.51	.64	40.71	1.46	.58	52.00	1.76	.62
UC-EI HIGH EA	34.05	2.04		39.59	1.96		50.68	2.46	
START-Play LOW EA	35.19	1.73	.85	40.28	1.67	.89	50.47	2.10	.99
UC-EI LOW EA	34.77	1.85		40.01	1.78		50.48	2.11	
BAYLEY FINE MOTOR									
START-Play HIGH EA	25.77	1.06	.34	28.09	1.04	.40	32.72	1.21	.67
UC-EI HIGH EA	24.33	1.44		26.87	1.04		31.94	1.69	
START-Play LOW EA	25.78	1.21	.62	28.18	1.18	.46	32.99	1.44	.34
UC-EI LOW EA	25.01	1.30		27.09	1.26		31.25	1.45	
BAYLEY GROSS MOTOR									
START-Play HIGH EA	31.91	1.26	.76	37.13	1.21	.92	47.59	1.52	.79
UC-EI HIGH EA	31.34	1.71		36.96	1.62		48.20	2.14	
START-Play LOW EA	32.68	1.45	.32	37.52	1.39	.64	47.20	1.83	.60
UC-EI LOW EA	30.86	1.54		36.72	1.47		48.42	1.81	
BAYLEY RECEPTIVE LANGUAGE									
START-Play HIGH EA	12.48	.65	.19	15.21	.62	.16	20.67	.79	.32
UC-EI HIGH EA	11.26	.88		13.98	.84		19.43	1.12	
START-Play LOW EA	12.43	.75	.26	14.92	.71	.14	19.90	.96	.16
UC-EI LOW EA	11.34	.80		13.62	.76		18.18	.94	
BAYLEY EXPRESSIVE LANGUAGE									
START-Play HIGH EA	12.56	.97	.46	15.84	.93	.71	22.42	1.14	.74
UC-EI HIGH EA	11.55	1.31		15.36	1.25		22.99	1.60	
START-Play LOW EA	12.64	1.11	.75	15.94	1.07	.58	22.55	1.37	.44
UC-EI LOW EA	12.19	1.19		15.20	1.14		21.22	1.36	

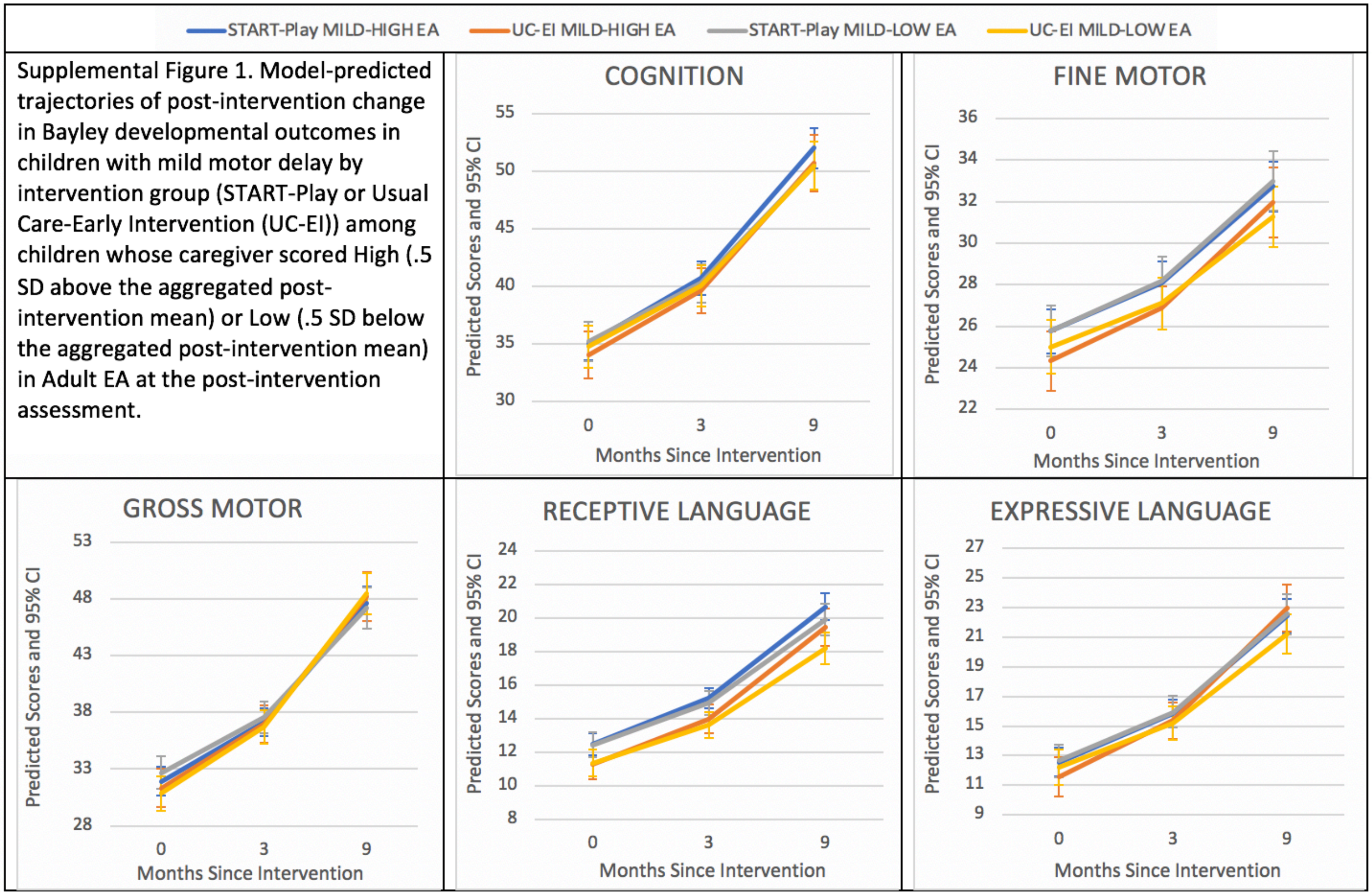
Supplemental Table 9. Estimated change within and between children with mild motor delay whose caregiver had HIGH (.5 SD above the aggregated 3mo Adult EA mean) or LOW EA (-.5 SD below the aggregated 3mo Adult EA mean) stratified by treatment group (START-Play or Usual Care Early Intervention, UC-EI).

MILD MOTOR DELAY	9mo change within group			Difference in change between intervention groups		
	EST	SE	*p*	EST	SE	*P*
BAYLEY COGNITION						
START-Play HIGH EA	16.94	1.35	<.00	.31	2.48	.91
UC-EI HIGH EA	16.63	2.07	<.00			
START-Play LOW EA	15.28	1.76	<.00	-.43	2.41	.86
UC-EI LOW EA	15.71	1.64	<.00			
BAYLEY FINE MOTOR						
START-Play HIGH EA	6.95	.86	<.00	-.65	1.58	.68
UC-EI HIGH EA	7.61	1.32	<.00			
START-Play LOW EA	7.22	1.12	<.00	.98	1.53	.52
UC-EI LOW EA	6.24	1.04	<.00			
BAYLEY GROSS MOTOR						
START-Play HIGH EA	15.69	1.27	<.00	-1.17	2.32	.61
UC-EI HIGH EA	16.86	1.94	<.00			
START-Play LOW EA	14.52	1.65	<.00	-3.04	2.25	.18
UC-EI LOW EA	17.55	1.54	<.00			
BAYLEY RECEPTIVE LANGUAGE						
START-Play HIGH EA	8.19	.68	<.00	.02	1.24	.99
UC-EI HIGH EA	8.17	1.04	<.00			
START-Play LOW EA	7.47	.88	<.00	.63	1.21	.60
UC-EI LOW EA	6.84	.83	<.00			
BAYLEY EXPRESSIVE LANGUAGE						
START-Play HIGH EA	9.87	.91	<.00	-1.58	1.66	.34
UC-EI HIGH EA	11.44	1.39	<.00			
START-Play LOW EA	9.91	1.18	<.00	.88	1.61	.58
UC-EI LOW EA	9.03	1.10	<.00			

Supplemental Table 10. Comparison of model-predicted 9-month post intervention change in children with mild motor delay in START-Play whose caregiver had High v Low EA

	Model predicted differences in 9-month change scores		
	EST	SE	*p*
BAYLEY COGNITION			
HIGH v LOW EA	1.67	1.34	.22
BAYLEY FINE MOTOR			
HIGH v LOW EA	-.26	.86	.76
BAYLEY GROSS MOTOR			
HIGH v LOW EA	1.17	1.26	.35
BAYLEY RECEPTIVE LANGUAGE			
HIGH v LOW EA	.72	.67	.29
BAYLEY EXPRESSIVE LANGUAGE			
HIGH v LOW EA	-.05	.90	.96

Supplemental Figure 2



Supplemental Figure 1. Model-predicted trajectories of post-intervention change in Bayley developmental outcomes in children with mild motor delay by intervention group (START-Play or Usual Care-Early Intervention (UC-EI)) among children whose caregiver scored High (.5 SD above the aggregated post-intervention mean) or Low (.5 SD below the aggregated post-intervention mean) in Adult EA at the post-intervention assessment.

Aim 1 – compared blue and orange; Aim 2 – compared gray and yellow; Aim 3 – compared blue and gray

Vita

Rebecca Molinini was born on March 9th, 1984, in Danbury, Connecticut. In 2006 she received her Bachelor of Arts in Physical Education from the University of North Carolina at Wilmington. In 2010 she received her Doctor of Physical Therapy from the University of South Carolina. After graduating, Dr. Molinini worked for 8 years as a pediatric physical therapist in a variety of settings domestically and abroad. She joined the Rehabilitation and Movement Science PhD program at Virginia Commonwealth University in Fall 2018 and received doctoral candidacy in the Spring of 2021. Dr. Molinini successfully defended her dissertation research on April 26, 2023.