"HEY BABY! MUMMY WANTS YOU TO BE HAPPY AND PLAY!" THE RELATIONSHIP BETWEEN MATERNAL PITCH CONTOURS, INFANT TEMPERAMENT AND SYMPTOMS OF AUTISM IN INFANCY

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Declarations

STATEMENT OF ORIGINALITY

I hereby certify that the work embodied in the thesis is my own work, conducted under normal supervision. The thesis contains no material which has been accepted, or is being examined, for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made. I give consent to the final version of my thesis being made available worldwide when deposited in the University's Digital Repository, subject to the provisions of the Copyright Act 1968 and any approved embargo.

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Preface

Mother-infant interactions are a crucial part of the early environment of an infant and they facilitate healthy development and wellbeing (Goldberg, 1988). During these reciprocal interactions, mothers and their infants influence each other in terms of their attention, affect and activity (Katz et al., 1996). Mother-infant interactions serve a socio-communicative purpose, teaching the infant how to interact with others, which is mediated via the mother's infant-directed speech (IDS). IDS is the universal speech register used by humans when interacting with infants (for a review, see Soderstrom, 2007). Extensive research has characterised the components of IDS (e.g. higher pitch). In addition, the impact of maternal characteristics such as mental health on IDS has been explored (Kaplan et al., 2015). However, relatively little attention has been given to how the infant's characteristics during these interactions impact a speaker's IDS use. This thesis focusses on the relationships between infant characteristics – specifically, temperament and early symptoms of Autism Spectrum Disorder (autism), and a component of maternal IDS; pitch contours.

Infant temperament, which refers to an infant's behavioural reactivity and regulation style, has been thought to have a profound influence on the mother-infant interaction (Rothbart & Bates, 2006). In the current thesis, it is posited that infant temperament can influence the way mothers speak to their infants. Further, as IDS facilitates infant socio-communicative and language development, the inter-relationship between IDS, infant temperament and infant socio-communication and language development is important to understand. Autism Spectrum Disorder (autism) is related to significant socio-communication and language impairment, thus early symptoms of autism in infancy are posited to influence the way mothers interact with their infant through their use of IDS.

The first chapter outlines the literature on mother-infant interactions, and how this important relationship relates to infant development. This chapter also defines IDS, and pitch contours, and explains how they are important for infant language learning, emotional and social development. Chapter 2 outlines the infant characteristics explored in this thesis. The literature exploring the construct of infant temperament is summarized, particularly in relation to mother-infant interactions, and how this construct is likely to relate to maternal pitch contours. Autism and early symptoms of autism in infancy are then defined, and background literature regarding the interaction difficulties experienced by infants with autism symptoms is explained, which led to one of the research questions.

Chapter 3 is a scoping review of literature investigating what characterises IDS used with infants and young children either already diagnosed with autism or later diagnosed with autism. This is the first review to investigate IDS characteristics within this population, and the results of the study are discussed. Chapter 4 then outlines the gaps in the literature, which stem from the previous chapters. The research questions and aims of the thesis are also presented in chapter 4.

Chapter 5 outlines the methods used for this study, including participants, procedures used, apparatus and materials, and the data analysis procedures used. Chapters 6, 7 and 8 report the results of the study. Chapter 6 describes the study sample, the mother's IDS, and compares the infant's temperament profiles and symptoms of autism with normative data. Chapter 7 outlines the findings on how maternal pitch contours relate to infant temperament. Chapter 8 outlines the findings pertaining to the relationship of maternal pitch contours and infant autism symptoms. In Chapter 9, I discuss the results relating to maternal pitch contours and infant temperament. Followed by, Chapter 10 in which I discuss the results regarding maternal pitch contours and infant autism symptoms. To conclude, Chapter 11 includes a broad discussion of the entire study, including limitations, future recommendations, implications and general conclusions.

Abstract

Mother-infant interactions during the first year of life are crucial to healthy infant development. The communication that occurs during these interactions involves infant-directed speech (IDS), which contributes to infant language learning, social communication, and emotional development. One aspect that is useful in encouraging infant development, and arguably the most salient aspect of IDS for infants early on, is the prosodic characteristic known as pitch contours. Pitch contours relate to the trajectory of pitch. There are prototypical contours used in IDS which serve different functions like increasing infant arousal or communicating the speaker's affect. The functions of pitch contours are well known in the literature. It is less known how infant characteristics influence the use of pitch contours by mothers. Two infant characteristics known to influence mother-infant interactions are the infant's temperament and whether the infant is displaying symptoms of Autism Spectrum Disorder (autism). The aim of the current thesis was to investigate whether infant temperament and early symptoms of autism in young infants (12-months of age) were related to the pitch contours mothers used with them during an interaction.

First, a scoping review of the literature was conducted to determine if parents speak differently to infants and children who are diagnosed, or not currently but later diagnosed, with autism. Twenty-seven studies were identified as relevant, and across these studies it was concluded that infants and children diagnosed or later diagnosed with autism do not hear either more or less speech than neurotypical infants. The speech that they do hear, however, may be different in that some studies suggested parents speaking to these infants use more exaggerated acoustic features, use more directive speech, and use more attention-bids during their speech. This scoping review demonstrated the heterogeneity of methodology and results with studies investigating IDS with infants displaying autism features, and recommended more research be undertaken in this arena, which supported the work in this thesis.

Second, in a primary study investigating maternal IDS, infant temperament and infant autism symptoms, 109 mother-infant dyads were recruited from three infant development studies at the University of Newcastle Babylab. Infant temperament was assessed via a parent-report questionnaire, the Toddler Temperament Scale (TTS; Fullard et al., 1984), given to the mothers on the day of the appointment. The TTS provided nine domain scores for the infants (activity, rhythmicity, approach, adaptability, mood, intensity, persistence, distractibility, and threshold) as well as a clinical profile (easy, intermediate low, intermediate high, and difficult). Infant autism symptoms were assessed using a parent-report questionnaire, the First Year Inventory (FYI; Reznick et al., 2007). A subset of infants (*n*=26) also received the observation-based Autism Detection in Early Childhood assessment (ADEC; Young, 2007). Infants received a FYI and ADEC total risk score, as well as a FYI social-communication and FYI sensory regulation score. The mothers' pitch contours were measured via a recorded 15-minute dyadic play interaction. 36,128 maternal pitch contours were classified into one of nine contour types (rising, bell-shaped, sinusoidal, u-shaped, flat, complex, rapidly-falling, rapidly-rising, and slowly-falling). Spearman's correlation coefficient was conducted to determine any relationships between maternal pitch contours and infant temperament and infant autism scores. Backwards elimination regressions analyses were conducted on the key variables including known covariates (infant cognitive and language skills, maternal depressive symptoms).

Infant temperament was related to maternal pitch contours. Infants rated as having a more negative mood had mothers who used more bell-shaped (r^2=.22, *p*=.04), rapidly-falling (r^2=.27, *p*=.01), and rapidly-rising contours (r^2=.24, *p*=.02). Infant distractibility was related to mothers using fewer flat contours (r^2=.22, *p*=.04). Less infant activity was related to mothers using more slowly-falling contours (r^2=.29, *p*=.008). Several models of prediction also emerged to explain variance in infant temperament scores. Infant activity scores were predicted by the mother's use of bell-shaped, complex and slowly-falling contours, R^2=.09, $F(3, 81)$= 3.74, p=.01. Infant rhythmicity scores were predicted via the mother's depressive symptoms and sinusoidal contours, as well as the number of days the infant was born preterm, R^2=.19, $F(3, 74)$= 4.94, p=.004. Infant adaptability was predicted by the mother's depression symptoms, and her use of sinusoidal and rapidly-falling contours, R^2= .12, $F(3, 44)$= 3.04, p=.04. Infant intensity scores were predicted by the number of days the infant was born preterm and the mother's use sinusoidal contours. Finally, the infants' mood scores were predicted by the number of days preterm the infant was and also the mother's use of rapidly-falling contours, R^2=.12, $F(2, 85)$= 6.91, p=.002.

Infant autism symptoms were also related to maternal pitch contours. Mothers used fewer sinusoidal contours when their infant displayed more autism symptoms (r^2=-.30, p=.004) and more autism-related sensory regulation issues (r^2=-.31, p=.001). Mothers also used fewer flat contours if their infant displayed more autism symptoms (r^2=-.39, p=.04). Again, several models of prediction emerged from the key study variables that explained variance in infant autism symptoms. Infant FYI total score was predicted via the mother's depression symptoms and number of utterances she used during the interaction, as well as the infant's cognitive score on a developmental assessment, R^2=. 34 $F(3, 47)$= 9.58, p<.0001. Infant social communication score on the FYI was predicted by the mother's depression score as well as the number of utterances she spoke and her use of flat contours, R^2=.28 $F(3, 47)$= 7.46, p=.0003. Infant sensory regulation score on the FYI was predicted by the mother's depressive symptoms, and her rising and sinusoidal contours as well as the infant's cognitive score on a developmental assessment, R^2=.20 $F(4, 46)$= 4.22, p=.005. Finally, the infants' score on the ADEC was predicted by the mother's rising, bell-shaped, flat and complex contours as well as the infant's language skills, R^2=.70 $F(5, 20)$= 12.48, p<.0001.

This thesis provides the first evidence that maternal pitch contours are related to infant temperament and early autism symptoms in infancy. The functions thought to underpin the relationships between the infant characteristics and the maternal pitch contours are discussed in detail. These results support the theory that mother-infant interactions are bidirectional, with both the mother and the infant playing active roles. Further research into mother-infant interactions, IDS, pitch contours and the influence of infant characteristics is recommended. These results could inform or support early parent-training interventions involving the use of IDS to target early relationship, language, socio-communication difficulties, as well as improving the outcomes of infants displaying autism symptoms.

Abbreviations

Table 1. Abbreviations as they appear in the thesis

Relating to infant characteristics	
IDS	Infant-directed speech
Autism	Autism Spectrum Disorder
ASD	Autism Spectrum Disorder
HR	High-risk
LR	Low-risk
LDA	Later diagnosed with autism
CDS	Child-directed speech
ADS	Adult-directed speech
TD	Typically-developing
Experimental	
NYLS	New York longitudinal study
CTS	Carey Temperament Scales
PVR	Parental verbal responsiveness
MLU	Mean length of utterance
F0	Fundamental frequency (pitch)
dB	Decibel
HSJE	Higher level supported joint engagement
LSJE	Lower level supported joint engagement
BLT-ID	Breathing for life – infant development study
BLT	Breathing for life trial
BM	BabyMinds

SDPrem	Sensory modulation in preterm infants' study
RCT	Randomised control trial
HMRI	Hunter Medical Research Institute
JHCH	John Hunter Children's Hospital
NICU	Neonatal Intensive Care Unit
CAP	Clinical applications portal
TTS	Toddler Temperament Scale
ADEC	Autism Detection in Early Childhood
FYI	First Year Inventory
ADOS	Autism Diagnostic Observation Schedule
EPDS	Edinburgh Post-Natal Depression Scale
BSID-III	Bayley Scales of Infant and Toddler Development – Third Edition
Hz	Hertz
SE	Standard error

Table of contents

Chapter 1: Maternal interactive behaviours and characteristics

1.1 Mother-infant interactions

An infant's first socio-emotional relationship involves their primary caregiver, usually the mother, and is among the most important factors influencing the infant's development (Goldberg, 1988). The quality of mother-infant relationships and, crucially, the interactions that occur between the mother and her infant, have been linked to numerous infant outcomes including the physiological aspects such as the infant's sympathetic and parasympathetic response system (Luijk et al., 2010) and rhythmic cycles such as sleep and wake schedules (Bordeleau et al., 2012) to cognitive functioning (Tamis-LeMonda et al., 2001) and emotional and social development (Thompson, 2008). The impact of early mother-infant interactions on infant outcomes extend from infancy and childhood, all the way into adulthood (Haltigan et al., 2013; Jaffee et al., 2001).

The interactions that occur in this critically important relationship can be thought of as a feedback loop where, ideally, the infant signals the mother, the mother responds contingently and sensitively, and then the infant experiences their needs being met in a predictable and appropriate way (Tamis-LeMonda & Bornstein, 1989). Interactive feedback loops, such as vocal turn-taking, can occur between infants and their caregivers when they are as young as 8 weeks-of-age, and studies suggest that even at this early age infants can initiate turn-taking (Gratier et al., 2015). These kinds of ideal interactions (the mother and infant interacting in a mutually contingent and sensitive manner) have been suggested to influence infant development by encouraging the infant's self-efficacy and creates a sense of security, thereby giving them the opportunity and willingness to explore and learn in their surroundings (Beckwith & Cohen, 1989). Researchers use different terminology within this area of literature, however most agree that ideal interactions also involve mutuality (e.g.

sharing of feeling or action), reciprocity (mutual action), joint activity and attention, and affective sharing (Fawcett & Liszkowski, 2012). Despite the importance of factors such as reciprocity, to date, studies of the early interactions in an infant's life, which are predominantly informed by the attachment theory of development (Ainsworth & Bowlby, 1991), have largely focussed on the mother's role and in particular, her responsivity to her infant (for a recent review, see; Fearon & Roisman, 2017). Mothers who respond contingently and appropriately to their infant respond quickly to their infant's cries, they hold their infant more, pace interactions with their infant dependent on what the infant is doing, and show sensitivity to initiating and terminating feeding (Crockenberg, 1981). The more contingent and appropriate the mother's responses are during interactions, the better her infant's outcomes are in terms of cognitive, language and social development (Bell & Ainsworth, 1972; Harder et al., 2015; Masur et al., 2005; Tamis-LeMonda et al., 2001; Tamis-LeMonda & Bornstein, 1989). It is argued, in attachment theory, that these outcomes are achieved by mothers acting as a secure base from which the infants can explore the world around them, and that it is this sense of security that is vital to healthy development by fostering, for example, exploration (Ainsworth & Bowlby, 1991). Correspondingly, for children where this secure attachment is lacking, there is an increased risk of adjustment difficulties and later psychopathology (Carlson, 1998; Lyons-ruth, 1996; Van Ijzendoorn et al., 1999).

The way that the mother responds to her infant, both verbally and through nonverbal means, influences not only the immediate interaction, but also long-term developmental outcomes. Nonverbal aspects of interactions between mothers and their infants, particularly with infants that are preverbal, can include things like facial expression, bodily movement, and touch (Shai & Belsky, 2017). Of particular interest to this study though, early interactions involving speech can help shape the infant's socio-communicative environment and play a critical role in their acquisition of language (Masur et al., 2005). Mothers who display better vocal responsivity to their infants during interactions, as opposed to nonverbal responses like smiling, have been found to have children with higher cognitive competency and better language outcomes in later childhood (Gros-Louis et al., 2006; Tamis-LeMonda et al., 2001; Tamis-LeMonda & Bornstein, 1989). Another study found that mothers who contingently verbally stimulate their infant during interactions in the first year have children with better language and social-emotional competencies in later childhood (Page et al., 2010). This study found a predictive relationship between mothers who verbally stimulated the infant, for instance by praising their efforts in a task, and their infant's cognitive abilities on a developmental assessment at 9-months of age (Page et al., 2010). Contingent maternal verbal responsiveness has even been shown to improve infant language skills in infants who initially displayed language delays (Baumwell et al., 1997). Infants aged 9-13-months (when language development is occurring rapidly) displayed improvement in verbal comprehension which was predicted by the amount of maternal verbal responsiveness during a play interaction (Baumwell et al., 1997). Maternal verbal responsiveness is crucial to infant outcomes and mother-infant interactions, however, the *way* that mothers speak to their infant is also important in facilitating this development, especially during the first year of the infant's life, and is known as infant-directed speech (IDS).

1.2 Infant-Directed Speech

IDS is the speech register universally used by humans when interacting with infants. It is well established that infants prefer to listen to IDS over other forms of speech (i.e. adult-directed speech Cooper & Aslin, 1990; Dunst et al., 2012; Fernald, 1985; The ManyBabies Consortium, 2019) and this is most likely due to the characteristics that differentiate it from adult-directed speech (for reviews, see Saint-Georges et al., 2013; Soderstrom, 2007). IDS characteristics involve both the acoustic and linguistic structure of speech, and generally IDS include higher, wider, and more variable pitch (Fernald, 1989; Fernald & Simon, 1984), more consistent cues to the focus of words (Fernald & Mazzie, 1991), expanded vowel space (Kuhl et al., 1997), slower tempo and longer pauses between words (Fernald & Simon, 1984; Fisher & Tokura, 1995; Grieser & Kuhl, 1988), fewer and shorter words (Grieser & Kuhl, 1988; Fisher & Tokura, 1995; Soderstrom et al., 2008), more questions (Soderstrom et al., 2008), and isolated words and phrases (Soderstrom et al., 2008). IDS has been demonstrated to affect infant language and socio-emotional development (for a comprehensive review, see Saint-Georges et al., 2013).

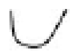
Infant language development has been a focus of research in relation to maternal IDS. It is argued that IDS makes word processing easier for infants. This is largely due to prosodic characteristics, which have been shown to facilitate syllable and vowel discrimination, speech segmentation, and word recognition (for an overview, see Saint-Georges et al., 2013). For instance, it is well established that infant word learning is more effective when words are presented in IDS, as opposed to adult-directed speech (Ma et al., 2011; Singh et al., 2009). One study found that 21-month-old infants will preferentially look at target words over non-target words when the target words are presented in IDS, but not adult-directed speech (Ma et al., 2011). Another study found that preverbal 7-8-month-old infants will preferentially listen to words in sentences that were previously presented to them in IDS rather words presented previously in adult-directed speech (Singh et al., 2009). Zangl and Mills (2007) found that infant neural activity increased when familiar words were presented to an infant in IDS, but not adult-directed speech. Further, maternal IDS has been shown to be positive predictor of infant expressive vocabulary over the first year of life (Masur et al., 2005), and has even been correlated with infant language outcomes at 5-years-of-age (Liu et al., 2009). Liu et al. (2009) postulate that the language-promoting features involved in IDS and (even child-directed speech at 5-years-of-age) include the heightened vowel space, and increased vowel duration, pitch and pitch range (although it should be noted this study was conducted on mandarin speaking families). Finally, Kuhl et al. (2003) showed that infants aged 9-months can learn foreign languages successfully when the language is presented in IDS, and, importantly, if the infants are taught in live sessions (rather than through the use of a tv or computer program teaching the infants). Infants in this study were from English speaking families who learnt Mandarin words as well as infants who were born to Taiwanese families who spoke native Mandarin at home, but, importantly, only if they were taught face-to-face during social interactions. This study highlights the overlap in the functionality of IDS in the literature, whereby it is both a didactic and social tool.

IDS is commonly thought to influence the socio-emotional development of infants. Schachner and Hannon (2011) propose that IDS acts as a cue for infants to direct attention and select social partners, and thereby learn about their social environment. This study showed that 5-month-old infants will prefer to look at a picture of a person who has spoken to them previously in IDS over a novel person (Schachner & Hannon, 2011). Further, it is argued that infant preference for IDS encourages adults to use IDS with them more, as one study found that adults rate infants listening to IDS as more interactive and thereby “attractive” than those listening to adult-directed speech, which may inherently encourage more social interaction and social development (Werker & McLeod, 1989). IDS also elicits neural activity in infants in areas of the brain related to socio-communication (Santesso et al., 2007). The study by Saito et al. (2007) found that the region of the brain that was stimulated by IDS, the orbitofrontal region, is associated with socio-emotional development. This increase in neural activity in this area in response to IDS has even been found in newborn infants (Saito et al., 2007).

Infant preference for IDS is suggested to be due to the prosodic characteristics, rather than the other characteristics typical to IDS (such as the lexical properties like simpler words). Prosody involves the rhythm, speech rate, pitch contour, intensity, and pauses in speech, which are affected by the speaker's language, culture and emotional state (Cenceschi et al., 2018). Fernald and Kuhl (1987) found that when given the choice between amplitude (loudness), duration (related to speech rhythm), or pitch during IDS, young infants will show a clear preference for the pitch, and in particular the pitch contours, present in IDS. Further, this preference for pitch seems to persist throughout the first year, making it a critical factor in IDS (Kitamura et al., 2001). Pitch contours are more distinct and simplified in IDS than those observed in adult-directed speech. Pitch contours are arguably the most salient aspect of IDS in the first year of life, as indexed by infant preference, and have been found to help communicate affect and the emotional signals of the speaker, regulate infant attention and arousal, and facilitate language acquisition (Fernald, 1989; Fernald & Mazzie, 1991). The salience of prosodic features, and in particular pitch contours, for infants makes it an important area of study in IDS literature.

1.2.1 Pitch contours Pitch is the acoustic counterpart of the frequency of the vocal cord vibrations within the larynx, where faster vibrations are perceived as higher pitch (Spinelli et al., 2017). Prior studies have examined different aspects of pitch, such as mean pitch and pitch range within IDS, however pitch contours are arguably the most salient aspect of speech for young infants as evidenced by infant preference studies (Fernald & Kuhl, 1987). Pitch contours are the trajectory of pitch over the course of an utterance. Pitch contours in IDS are less complex than those in adult-directed speech, and are typically visually represented as prototypical shapes. These shapes are rising, bell-shaped, u-shaped, sinusoidal, slowly-falling, rapidly-falling, rapidly-rising, flat or complex (see Table 1; Fernald, 1989; Fernald et al., 1989; Papoušek et al., 1990; Spinelli et al., 2017).

Table 1. *Descriptions and visual examples of prototypical contours in IDS (Gratier & Devouche, 2011)*

Contour	Description	Visual Example
Rising	Increase in F0 slope	
Bell-shaped	Increase and then decrease in F0 slope	
U-shaped	Decrease and then increase in F0 slope	
Sinusoidal	F0 slope has two changes in direction (rise-fall-rise or fall-rise-fall)	
Slowly-falling	Decrease in F0 slope at a gradual decline	
Rapidly-falling/rapidly rising	Decrease/increase in F0 slope at a steep decline	
Flat	No perceived change in F0 slope	
Complex	More than three F0 variations in one contour	

The prototypical contours observed in IDS are context specific and are believed to relate to the mother's communicative intent, as they have been observed to be effective in performing certain socio-communicative functions (Fernald, 1989; Stern et al., 1982). More specifically, it has been argued that pitch contours: 1) communicate the speaker's emotional state (Stern et al., 1982), 2) help regulate infant attention (Roberts et al., 2013), and 3) engage the infant in social communication and joint attention (Gratier & Devouche, 2011). The mother's communicative intent and sensitivity to their infant's arousal and attentional state during IDS has been extensively studied in terms of these functions (Fernald, 1989; Papousek et al., 1991; Papoušek et al., 1990; Stern et al., 1982). Specific contours assist in stimulating and maintaining infant attention and arousal (Stern et al., 1982). *Rising contours* allow the mother to gain infant attention, particularly in a context where the infant is looking away (Fernald, 1989; Papousek et al., 1991; Stern et al., 1982). They also have been suggested to encourage turn-taking during interactions, and have been used by mothers as a way of encouraging active participation from the infant (Papousek et al., 1991). *Bell-shaped, u-shaped*, and *sinusoidal contours* maintain infant attention, typically used when an infant is already engaged in an interaction and is smiling and gazing towards the mother (Stern et al., 1982). *Rising, bell-shaped, u-shaped,* and *sinusoidal* contours have all been demonstrated to 'reward' the infant by communicating the mother's positive emotion, thereby also encouraging a positive emotional response in the infant (Papousek et al., 1991; Stern et al., 1982). *Rising, bell-shaped, u-shaped*, and *sinusoidal* contours have been related to an increase in infant attention regulation over the course of infancy, where *rising* contours are associated with infants displaying lower attention scores on developmental assessments (Woolard et al., 2019). *Slowly-falling contours* have been demonstrated to be used during interactions when the infant is in a state of low arousal, and usually when the mother's intent is on keeping her infant at this arousal state (Fernald, 1989). The mother also uses these contours to counteract negative affect or 'soothe' an infant (Fernald, 1989; Papousek et al., 1991). *Rapidly-falling* and *rapidly-rising contours* are used to rapidly gain attention and increase infant arousal, usually in the context when a mother is warning the infant of impending danger or prohibiting an infant's undesirable behaviour (Fernald, 1989).

The functionality of pitch contours during early interactions highlights the reciprocity between mothers and their infants (Svejda et al., 1980). The mother-infant interactions are bi-directional, whereby: 1) the infant sends cues to the mother, for instance in relation to attention or affect, 2) the mother reads her infant's attentional and affective cues and responds appropriately and contingently, which influences, 3) the infant's behaviour and state. On this basis, it is reasonable to assume that maternal IDS is impacted by the nature of the infant behaviour and state which will influence infant signalling to the mother. Despite this reasoning, however, little is known the impact of infant traits - for instance, do the infant's early affective and attentional traits, or social-communication abilities, influence the mother's use of pitch contours? Specifically, do maternal IDS pitch contours vary as a function of infant temperament or infant risk for social-communication and language disorders such as Autism Spectrum Disorder (autism)?

Chapter 2: Infant interactive behaviour and characteristics

The mother's role in early interactions is unquestionably important, however, it is also proposed that the infant's role is equally important and can significantly impact these interactions (Crawford, 1982; Woolard et al., 2016). Infants can detect contingency (i.e. predictable aspects of an interaction) from a very early age, and can even imitate others during interactions (Heimann, 1989). Infants will typically react positively (i.e. positive affect, increased attention, and higher responsiveness) to increased contingency during interactions (Tronick et al., 1977). Individual characteristics can differentially affect interactions as well, for instance the temperament, health and developmental status of infants. Infants displaying negative mood have poorer interactions with their mothers, and the mothers themselves report being less responsive with their infants (Tester-Jones et al., 2015). Medical status of the infant influences mother-infant interactions, where interactions between preterm and low-birth-weight infants and their mothers have been described as non-synchronous when compared to full-term infants, which is suggested to be due to early-birth complications (Misund et al., 2016). Mothers of preterm infants have been shown to be less responsive at 20 months of age, which has been associated with their infants displaying less active involvement in play interactions with their mother (Barratt et al., 1996). Further, infants who later go on to receive a diagnosis of autism have been observed to interact with their mothers differently. Specifically, these infants display decreased episodes of joint attention and the initiation of social interactions with others reportedly decrease over the first two years (Deconinck et al., 2013). Thus, it is clear that both the mother and infant are responsive partners in early interactions.

2.1 Infant Temperament

Temperament has been described as the development of expectations and assumptions about the physical and social world, as well as values, attitudes, self-regulation and coping strategies which are stable over time (Rothbart, 1989; Thomas & Chess, 1986). Temperament is comprised of a group of traits, rather than a single entity, and several models have attempted to quantify these temperamental traits (Goldsmith et al., 1987).

The four theoretical frameworks that are most widely cited in the literature come from Buss and Plomin (1975), Goldsmith and Campos (1982), Rothbart (1981), and Thomas and Chess (1968). All approaches agree that the dimensions of temperament reflect behaviours and are underpinned by biology (i.e. they are inherent from birth). The four models disagree in the dimensions that are proposed to make up temperament. Buss and Plomin (1975) argued that temperament is made up of emotionality, activity, and sociability. Goldsmith and Campos (1982) defined the dimensions of temperament as emotion and emotional arousability. Rothbart (1981) suggested that temperament is comprised of surgency, negative affectivity, and effortful control. Thomas and Chess (1986) took a comparatively more clinical stance (relying on objective ratings of behaviour, not parental interpretation) and posited that temperament is made up of nine dimensions; activity, rhythmicity, approach, adaptability, threshold, intensity, mood, distractibility, and attention (see Table 2). It is this last temperament model, put forward by Thomas and Chess (1986), which I have utilised in the current study.

Chess and Thomas (1986) based their temperament model, and the subsequent nine domains of temperament, on the findings of the large-scale New York Longitudinal study (NYLS). The NYLS followed 133 participants from infancy to early adulthood (Thomas & Chess, 1986) and developed their model of the behavioural dimensions of temperament by observing areas of infant behaviours. Thomas and Chess also described temperamental styles, comprised of certain combinations of temperamental traits. These styles included ‘difficult’, ‘slow-to-warm-up’, and ‘easy’. Infants who were difficult in temperamental style were identified as irregular in bodily function, more withdrawn in response to novelty, having more intense reactions to stimuli, expressing negative affect regularly, and having difficulty adapting to changes in the environment (Thomas & Chess, 1986). Infants identified as slow-to-warm-up displayed low activity levels, were slow to adapt to changes in the environment, would withdraw in response to novelty, and were somewhat negative in mood. Infants who were described as ‘easy’ displayed highly regular bodily functions, were adaptable to environmental change, and would approach novel stimuli and situations.

Table 2. *The nine infant temperamental dimensions derived from the NYLS, first demonstrated by Thomas et al. (1968)*

Trait	Description	Example
Activity level	The motor component that an infant or child displays.	This involves information on the infant’s motility during daily movements as well as their sleep-wake cycle.
Rhythmicity	The predictability in their regular functioning.	This involves aspects such as sleep-wake cycle, feeding pattern and hunger, and elimination schedule.
Approach/Withdrawal	The infant’s response to a new stimulus.	Approaching responses include those such as smiling, verbalisations, reaching for toys, active play. A withdrawing response includes crying, fussing, grimacing, moving away, spitting out food, pushing toys away.
Adaptability	The infant’s response to new situations.	This does not involve the infant’s initial reaction, but rather how easily they are placed or encouraged in desired directions.

Threshold of responsiveness	The intensity level of stimuli needed to evoke a response in the infant.	These types of behaviours concern reactions to social, environmental, and sensory stimuli.
Intensity of reaction	The energy level of response from the infant.	The intensity of response is irrespective of its direction or characteristic.
Quality of mood	The valence of the infant's mood.	This involves the amount and duration of the infant's pleasant, joyful, and friendly behaviour as opposed to the infant's unpleasant, crying, and unfriendly behaviour.
Distractibility	The effectiveness of extraneous stimuli in interfering with the infant's ongoing behaviour.	The more distractible an infant is, the easier it is for peripheral stimuli to alter the direction of their behaviour.
Attention span and persistence	Attention span relates to the length of time an infant pursues an activity. Persistence is the continuation of an activity in the face of an obstacle.	A high attention span and a high level of persistence will represent an infant who spends a long time pursuing an activity, even if the activity is frustrating or if extraneous obstacles interfere.

A number of studies have examined the match of parenting style to the infant's temperamental traits (Rubin et al., 2002; Russel et al., 2003; Thomas et al., 1968; Zarra-

Nezhad & Noona Kiuru, 2015). These studies report associations between parenting styles, such as controlling or authoritarian, and infant temperamental dimensions such as increased inhibition (Rubin et al., 2002). Conversely, there have been additional studies examining the impact of infant temperament on maternal responses. Fox & Henderson (1999) observed that infants who smile and vocalise in response to social stimuli typically achieve a different interactional environment than those who respond negatively, by encouraging the interactional partner to continue providing social stimuli to them. A study by Milliones (1978) demonstrated that the more 'difficult' a mother rated her child's behaviour, the less responsive she was during interactions with her child, however, this study was correlational and therefore cannot indicate a cause-and-effect relationship between infant temperament and maternal responsiveness. Further, this study relied on a maternal-report measure of maternal responsiveness, and therefore is subject to bias. Another study though, investigated infant temperament in relation to attachment style during an interaction, and found infants who were less sociable were less likely to have secure attachments with their mothers (Bates et al., 1985).

One study to date has investigated the relationship between IDS during mother-infant interactions and infant temperament (Woolard et al., 2016). Infant temperament was found to be related to maternal pitch contours during mother-infant interactions. We found in that study that mothers who rated their 6-month-old infants as less likely to approach novel stimuli used more rising contours, which are used to attain attention. Mothers who rated their infants as more negative in mood also used more slowly-falling contours during interactions, which are generally used to soothe and lower arousal levels. This study provided preliminary evidence that infant temperament may influence mothers' interaction with their infants and how they use IDS.

The literature investigating infant temperament and mother-infant interactions has focused on characteristics such as maternal responsivity or infant attachment, but not specifically on IDS. It has also been highlighted in a review by Sanson, Hemphill & Smart (2004) that the associations between mother-infant interactions and infant temperament focus solely on *difficult* temperament, which tend to relate to negative parenting attributes. There is less known in the literature about how easy infant temperament relates to mother-infant interactions. The current thesis aims to address this gap in the literature, by focussing on IDS used in mother-infant interactions, as well as all traits encompassed within the Thomas et al. (1986) model of temperament, which not only allows us to identify whether an infant has an easy or difficult temperament, but also gives an indications of the nine other domains of temperament (Thomas et al., 1968). Further, the relationship between infant temperament and maternal IDS was evidenced in the study by Woolard et al (2016). This study demonstrated that the use of pitch contours during interactions – as they are critical to the development of infant attention and affect regulation- are likely to be related infant temperament, and should be further investigated (Woolard et al., 2016).

Temperament has been demonstrated to be related to language acquisition and difficulties with speech, as well as socio-communicative outcomes (for a review, see; Conture et al., 2013). Socio-communication, as well as language difficulties, are related to the presence of disorders such as Autism Spectrum Disorder (autism) in childhood. This is because autism is characterised by deficits in language and social developmental outcomes (American Psychiatric Association, 2013). Infant language and socio-communication outcomes are highly related to IDS (as outlined in chapter 1), which are also implicated in developmental disorders such as autism.

2.2 Autism

Autism Spectrum Disorder is defined by persistent deficits in social communication and interaction, and restrictive or repetitive patterns of behaviour, interests, or activities (American Psychiatric Association, 2013). In 2015, the Australian Bureau of Statistics estimated that 164,000 people in Australia had autism, representing approximately 0.7% or 1 in 150 people. During childhood (ages 5-14 years), however, the prevalence of autism in Australia is higher at approximately 2.8% (Australian Institute of Health and Welfare, 2017). The Centre for Disease Control and Prevention estimate that the prevalence of autism in the United States is closer to 1 in 59 people, which is a 15% increase since the previous report only two years prior (Baio et al., 2018). It was also reported that the gender gap in autism diagnoses had reduced, where it has historically been reported as 4:1 (m:f), recent estimates put this figure closer to 3:1 (Loomes et al., 2017). This increase in prevalence and reduction in the gender gap reflects the improving early assessment and identification of the disorder, which can help reduce the burden associated with autism. Early identification methods focus on early behavioural markers of the disorder, such as sensory features, language and socio-communication issues.

2.2.1 Infants early signs of autism Investigation into the prodromal symptoms of autism in infancy have become a top priority in this field of research, particularly as identifying early risk-factors for autism can assist in early diagnosis, facilitate early interventions, and ultimately lessen the burden of this disorder (Interagency Autism Coordinating Committee, 2014). Early features of autism, particularly among preverbal infants, can include difficulties with joint attention or the ability to follow or direct the attention of another person to an object or event in the environment, making interactions with others more difficult (Loveland & Landry, 1986; Mundy & Newell, 2007). Advances have been made in the early detection of autism, largely due to prodromal studies, however the mean age of diagnosis is after the age of three (for Australian statistics see; Bent et al., 2015; Brian et al., 2008). Prodromal studies generally fall into one of two categories: retrospective studies relying on parent report or home videos of infants later diagnosed with autism, or prospective studies investigating cohorts of infants at a higher risk of being diagnosed with autism later in life. High-risk (HR) infant population studies involve infants with an older sibling diagnosed with autism, those with familial history of autism and a genetic predisposition, or infants born prematurely (Brian et al., 2008; Limperopoulos, 2009; Nele et al., 2015). Some studies have suggested infant siblings have up to an 18.7% higher probability of being diagnosed than infants without familial risk, with this risk increased if the infant has more than one older autistic sibling, or if the infant is male (Ozonoff et al., 2011). Furthermore, of the infants that have older autistic siblings that do not go on to receive a diagnosis, 25% will display what is termed the ‘broader autism phenotype’ (Yirmiya et al., 2006). The broader autism phenotype describes behaviours such as difficulty in social responsiveness, communication, and limited interests or stereotyped behaviour that are similar to those experienced in autistic individuals, but insufficient to meet diagnostic thresholds.

Preterm infants are also at heightened risk of not only developmental issues, but autism diagnosis. When compared with term infants, infants born between 28-30 weeks’ gestation have been reported to have a 3-7 times higher probability of being diagnosed with autism, and for infants born between 23-27 weeks’ gestation, this probability rises to 10 times more likely to be diagnosed (Kuzniewicz et al., 2014; Moster et al., 2008). Abnormal brain development and cerebellar-hemorrhagic injury, which is often observed in preterm infants, has been suggested to be linked to the increased risk of autism in this population (Johnson et al., 2010).

HR infant studies demonstrate that the symptoms of autism can emerge as early as 6-months of age. Symptoms can include impaired social interactions and language development (Deconinck et al., 2013; Wetherby et al., 2004). Functional socio-communication has been demonstrated to be a behavioural marker for autism risk, with autistic infants usually displaying difficulty with prelinguistic skills such as protodeclarative pointing, showing objects, joint attention, affective communication, pretend play, and imitation (Baranek, 1999; Dawson et al., 1990). Other socio-communicative markers of autism include difficulty maintaining eye contact and lack of social smiling or facial expression, reduced response to name, and fewer demonstrations of shared enjoyment (Baron-Cohen et al., 1996; Loh et al., 2007; Zwaigenbaum et al., 2005). Atypical sensory-motor functioning has also been cited to be an early marker for autism (Baranek, 1999; Lane & Heathcock, 2014). Parents report hyperresposiveness (heightened sensitivity or aversion to stimuli), hyporesponsiveness (reduced or absent response to stimuli), or sensory interests, repetitions, and seeking behaviours (intense fascination with specific stimuli, craving for stimuli, or repetitive actions with body parts or objects) during infancy (Baranek et al., 2019). Abnormal muscle tone, posture, and movement patterns have also been reported in these infants (Esposito et al., 2009; Fournier, Hass, et al., 2010; Fournier, Kimberg, et al., 2010; Teitelbaum et al., 1998). Parents also report a distinct set of temperamental traits in early infancy as behavioural markers prior to an autism diagnosis (Zwaigenbaum et al., 2005).

2.2.2 Temperament in autism Temperament has been investigated for its potential to aid in early detection and diagnosis in autism research. As stated earlier, temperament refers to early differences in reactivity and self-regulation as well as the emotional, attentional, and activity-related characteristics of an infant (Derryberry & Rothbart, 1988). Temperamental profiles of children and infants with autism have been the subject of recent research and suggested as one possible ‘modifier’ of the expression of autistic symptoms (Mundy et al., 2007). Further, it is posited that temperament can affect the course of psychopathology (which may include autism), and it is even suggested that in some cases temperament can increase the risk of an individual being diagnosed with a psychopathology (Carey, 1970).

Parents often report that their autistic child demonstrated extremes in temperament, even as early as the first year. Specifically, autistic children are rated by their parents as less rhythmic, adaptable and persistent, more negative in mood, more withdrawn, and having a higher threshold for response to stimuli than other infants their age with developmental issues (Bailey & Skinner, 2000; Konstantareas & Stewart, 2006). Autistic children are also rated as having poorer effortful control than neurotypical age-matched peers, and have issues with focussing and shifting attention as well as inhibiting responses (Konstantareas & Stewart, 2006). Retrospective parent report suggests that these infants display less positive affect, alongside greater detachment to others, hypersensitivity, and poorer self-regulation compared to neurotypical peers (Clifford & Dissanayake, 2008). In an effort to characterise behavioural trajectories of autism, Zwaigenbaum et al. (2005) suggested that HR 12-month-old infant siblings of autistic children who go on to receive a diagnosis of autism demonstrate a specific temperamental 'profile' characterised by decreased activity at 6 months of age, followed by extreme distress reactions, fixation on objects in the environment, and decreased expression of positive affect. At 24 and 36 months of age, toddlers who were confirmed to have autism, displayed a temperamental profile, marked by low positive affect, high negative affect, and issues with attention regulation (Garon et al., 2009).

2.2.3 Social interactions and autism Early interactions between HR infants or infants later diagnosed with autism and their mothers are different to mother-infant interactions that their neurotypical peers experience, likely due to the infants' difficulties with inter-personal communication and social cues. Interaction quality has also been demonstrated to worsen as autism symptoms become more severe (Beurkens et al., 2013). Mother-infant interactions between mothers and their autistic children involve less enjoyment, coordination, communication and a more negative mood (Beurkens et al., 2013). Parents of autistic children tend to use more directive interactional style, involving more non-verbal cues, high physical proximity, and more intense behaviours, compared to interactions involving neurotypical children (Doussard–Roosevelt et al., 2003).

Mother-infant interactions with HR infants are also less synchronous (Steiner et al., 2018; Yirmiya et al., 2006). Synchrony is an important aspect of early interactions, as it has been shown to predict communication outcomes in children diagnosed with autism (Siller & Sigman, 2002). Further, parent-targeted intervention that involves enhancing the communication style and interaction synchrony has been shown to improve child communicative outcomes (Green et al., 2010). One study demonstrated that when comparing interactions between HR and low-risk (LR) infants and their mothers, infant play did not differ, however the synchrony during the interactions did differ (Yirmiya et al., 2006). The authors suggest that this is due to mothers not being able to respond and match their infant's affect and activity- particularly if their HR infant displays reduced affect and activity to social cues. Studies also show that HR infants are not as physically active during interactions, which has been shown to affect interaction synchrony and quality (Wan et al., 2012). As stated earlier, these infant characteristics, in particular socio-communication and even temperament, are important variables to consider in mother-infant interactions and can provide great insight within the context of a HR infant.

IDS is an important aspect of early social interactions, especially when the infant is preverbal and is learning about the social and linguistic environment. A scoping review of the literature was conducted to investigate IDS within the context of HR infants or infants who were later diagnosed with autism. This scoping review highlights important gaps in the autism literature and forms the basis of one of the research questions addressed for this thesis.

Chapter 3: Infant and child-directed speech used with infants and children at-risk or diagnosed with Autism Spectrum Disorder: A scoping review

Early interactions with primary caregivers comprise the socio-communicative and language environment for young infants. Children diagnosed with Autism Spectrum Disorder (autism) have difficulty with socio-communication and language development and can display difficulties in early interactions with others (Beurkens, Hobson, & Hobson, 2013). Early interactions are mediated by infant-directed speech (IDS), which is the way that adults speak to infants. As IDS facilitates socio-communicative and language development, an investigation into the use of IDS with infants who are at high-risk, infants later diagnosed with autism (LDA), and young children with autism is warranted. The aim of the current study is to scope and summarise the existing literature related to IDS used with HR infants, infants LDA, and young children with autism.

3.1 Infant-directed speech

IDS is the speech register used by caregivers (and other individuals including adults and older children) when interacting with infants. IDS is a conglomerate of acoustic and linguistic characteristics that are different to adult-directed speech and occur near-universally across languages and cultures (for reviews, see; Saint-Georges et al., 2013; Soderstrom, 2007). For example, when compared to adult-directed speech, IDS generally involves: 1) higher and more variable pitch (Fernald et al., 1989; Fernald & Simon, 1984), 2) more distinctive, wider and simple pitch contours (Fernald & Simon, 1984), 3) more consistent cues to the focus on words (Fernald & Mazzie, 1991), 4) longer pauses between words or sentences (Fernald & Simon, 1984; Fisher & Tokura, 1995; Grieser & Kuhl, 1988), and 5) possibly a slower speaking rate (Han, 2018; Martin et al., 2016). Linguistically, when compared to adult-directed speech, IDS includes fewer and shorter words (Fisher & Tokura, 1995; Grieser & Kuhl, 1988; Soderstrom et al., 2008), more questions (Soderstrom et al., 2008), isolated words (Soderstrom et al., 2008), and frequent use of proper names (Durkin et al., 1982). It is well established that infants prefer to listen to IDS over other forms of speech; however, it is also hypothesised to be an important tool for teaching language and social competencies, attracting and maintaining attention, and conveying affect (Cooper & Aslin, 1990; Dunst et al., 2012; Fernald, 1985). More extensive reviews of IDS in wider contexts are available, however, for the purpose of this paper we will outline salient features of IDS in early infant development (see; Papoušek, 2007; Saint-Georges et al., 2013; Soderstrom, 2007).

There is extensive evidence that supports the didactic, attentional, and affective functions of IDS (for a comprehensive review, see Dunst et al., 2012). IDS is a didactic tool, with research supporting the notion that it aids in language acquisition during infancy. For example, word recognition in 7-8 month-olds is improved when words are spoken in IDS rather than adult-directed speech (Singh et al., 2009), probably due to the slower speech and more clearly-articulated vowels that occur in IDS (Song et al., 2010). Further, word recognition may be increased in IDS due to the increased attention infants display to IDS, as shown by event-related potentials during electroencephalograms as an indication of brain activity (Zangl & Mills, 2007).

In terms of attention, infants prefer to listen to IDS over other forms of speech (for a metanalysis, see Dunst et al., 2012; The ManyBabies Consortium, 2019). Further, studies utilising eye-tracking joint attention paradigms demonstrate that infants will follow an adult's gaze to a stimulus only when it was preceded by ostensive cues such as direct gaze or IDS (Senju & Csibra, 2008). A study by Gergely, Egyed & Király (2007) also demonstrated that when positively valanced IDS (i.e. spoken in a happy voice) was paired with an object, this positively influenced infants' attending to objects and subsequent looking preference.

Finally, IDS may provide important cues for infants on the affective state of their interactional partner although a recent metanalysis has highlighted the need for more empirical evidence for this function (Spinelli et al., 2017). IDS may also facilitate emotional regulation in infants. For example, varying intonation can be used when an infant is displaying certain affective characteristics like fussiness or negative mood (Stern et al., 1982; Woolard et al., 2016). Infants show greater affective responsiveness (e.g. smiling and laughing more) when presented with IDS during interactions, thereby making them more attractive social partners, even to adults with little experience interacting with an infant (Santarcangelo & Dyer, 1988). Further, infants are sensitive to the affective cues of IDS, smiling more often to approvals and positively valanced IDS and displaying negative affect in response to prohibitions and negatively valanced IDS (Fernald, 1993). The social back-and-forth during these early interactions suggest that IDS is tool in which parents can teach social skills. Further, the bidirectional nature of these interactions implicates both the parent and infant as active participants in this social interplay.

In order to provide a broad scope of the literature, the current review include child-directed speech (CDS). CDS is also included as many studies use the terms 'IDS' and 'CDS' interchangeably. CDS involves very similar characteristics to IDS, however there is more emphasis on the didactic characteristics that facilitate language acquisition in CDS. These characteristics include simplified words, shorter utterances, repetitions, wide pitch range, and a slow speaking rate (Foulkes et al., 2005).

Given the multitude of functions that IDS and CDS serve in the development of typically developing infants it is important to understand impacts on IDS/CDS when one or both partners do not display typical language, attention, or socio-communication skills. Specifically, is the early linguistic environment disrupted for infants (and very young children) who have difficulty in these areas, such as infants and children who are showing early signs of autism?

3.2 Autism in early infancy

At the core of a diagnosis of autism are persistent difficulties in social communication and social interaction including language, and restrictive or repetitive patterns of behaviour, interests, or activities (American Psychiatric Association, 2013). Delay in social communication is considered an early behavioural marker of autism (for a review, see Szatmari et al., 2016). Confirmed diagnosis of autism is usually given after the age of three years, as it is after this age that core symptoms can be reliably observed and other developmental delay or comorbid issues can be ruled out (Elsabbagh & Johnson, 2007). A diagnosis of autism, however, can be made confidently at around 14 months of age in research settings however, and early signs in infants as young as 6 months of age are being investigated (Brian et al., 2008; Chawarska et al., 2013; Pierce et al., 2019). Studies have also investigated prodromal symptoms of autism in early infancy in order to develop early diagnosis and subsequent interventions to improve outcomes (Bryson et al., 2007).

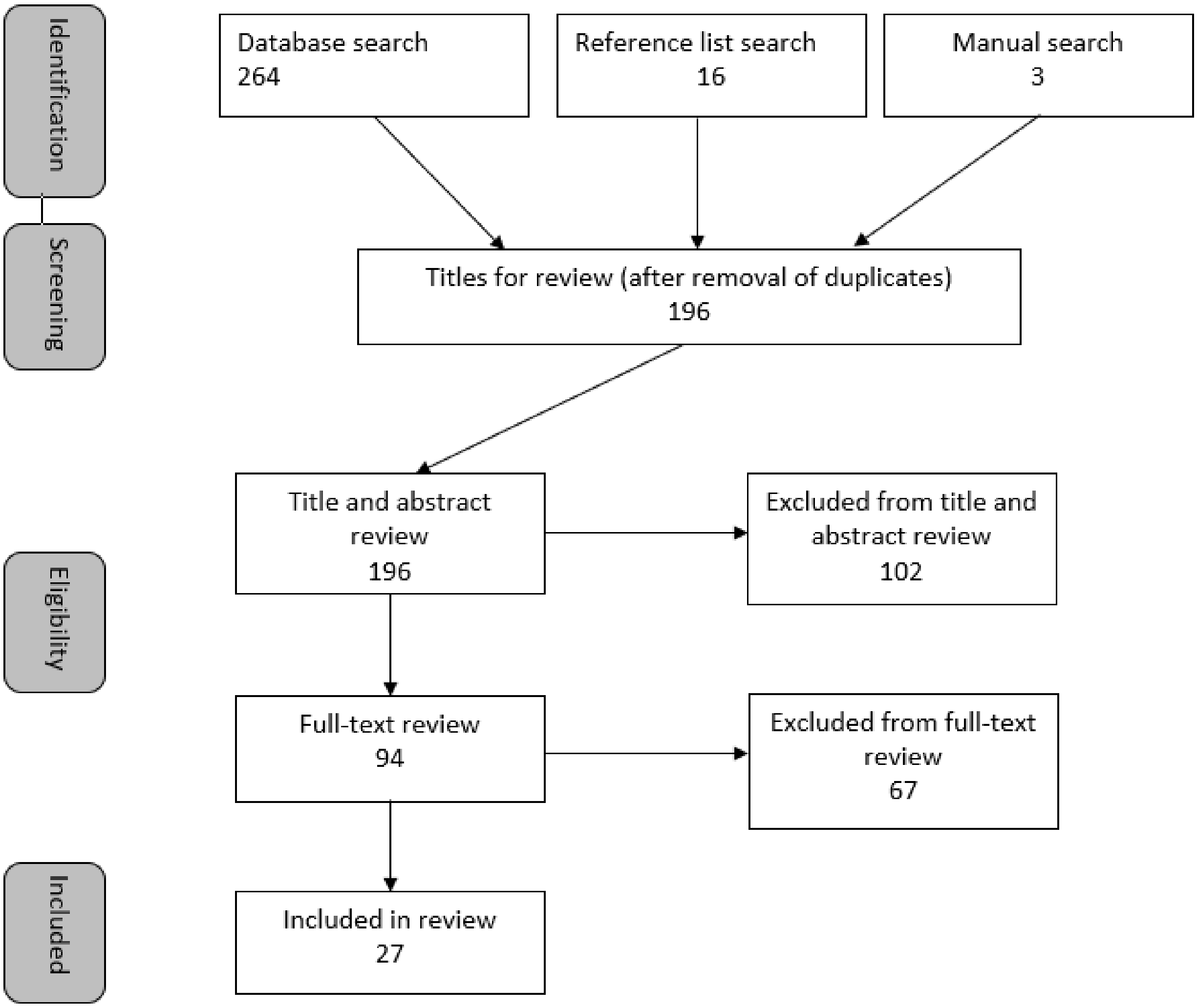
Socio-communication is affected in autism, and it has been suggested that children with autism display specific impairments in social orienting, joint attention, and attention to the distress of others (Dawson et al., 1998; Osterling et al., 2002; Sigman et al., 1992). The socio-communicative impairments observed in infants with autism can affect interactions with others; infants who go on to receive a diagnosis have been observed to display less synchronous interactions with their parent (Yirmiya et al., 2006), and, generally speaking, the more severe the autism symptoms, the worse the interaction quality (Beurkens et al., 2013). A recent review and meta-analysis investigated parental-verbal-responsiveness (PVR) to HR infants and children with autism (Edmunds et al., 2019). This review found that PVR was related to infant communication, specifically that PVR to the child’s communication and focus of attention was related to later child language outcomes, and that PVR to HR infants was more variable than PVR to typically developing infants. The review suggests that PVR could be an important aspect of intervention for HR infant and children with autism, however there are more aspects to infants' early communicative environment than PVR alone. PVR and IDS are similar, in that IDS often involves the speaker responding to the infant, and thus IDS is also suspected to play an important role in HR infants' (and even infants not identified as HR but later diagnosed with autism; LDA) early communicative environment.

The purpose of this scoping review is to identify and summarise the extant literature investigating IDS used with infants who are HR or LDA, and young children who have been diagnosed. A scoping review methodology was chosen to capture the breadth of work in this area. This review will scope the literature on the characteristics of IDS (including prosodic, lexical, phonological, and syntactic characteristics) used with HR and LDA infants, and children with autism (birth>4yrs).

3.3 Method

The study follows the scoping review framework set out by Arksey and O'Malley (2005). We adopted a search strategy using the following methods; electronic databases, reference lists, and hand-searching relevant journals (see Figure 1 for review process). Six databases were searched for relevant articles published up to November 2019 (no beginning date). The databases were EMBASE (*n*= 31), Medline (*n*= 19), PsycINFO (*n*=159), Scopus (*n*= 29), CINAHL (*n*= 26) and Informit Health (*n*= 0). One hundred and ninety-six articles were found following the initial search after duplications were removed (*n*= 68). A manual search of the reference lists of included articles and relevant review articles identified a further 19 articles.

Figure 1. Article review and selection process



3.3.1 Identifying relevant studies Inclusion criteria for the scoping review were broad in order to include as much literature that may be relevant as possible (see Table 3 for search terms), therefore studies were included if they involved: 1) infant or young child populations (<4yrs), 2) parent or adult speech and language directed toward the infant or child, and 3) infants or children that were identified as being HR (born preterm, at genetic risk, at familial risk) and/or later diagnosed with autism. Studies were excluded that involved: 1) speech directed at the adult, 2) adolescent and older child populations (4+ years), 3) risk for or diagnosis of developmental delay or intellectual disability without autism, 4) articles not written in English, 5) intervention studies, and 6) child (not adult) speech. Abstracts were first screened for inclusion criteria independently by two of three investigators (AW, OW, LS), who were all completing a PhD program in psychology. Any disagreements regarding inclusion between the reviewers were resolved by a fourth independent investigator (TB). Full-text articles were obtained for studies that were determined from the review process to be relevant to the scoping review, or for those in which it was unclear whether it was a relevant study from the abstract alone.

Of the 196 studies that were screened against title and abstract, 102 were excluded (see Fig 1.). Ninety-four full-text articles were assessed for relevance by two investigators, 66 were excluded for various reasons including the child population being too old (*n*= 30), the study being an intervention design (*n*= 24), the article was not published in English (*n*= 4), the infant/child speech (not parent) was measured (*n*= 4), parent/adult speech not measured (*n*= 3), and developmental disorder other than autism (*n*= 2). Twenty-seven studies were relevant to the scoping review and included in the final analysis. Analysis of the twenty-seven studies revealed several common themes and constructs which have been defined in Table 3.

Table 3. *Key words used in database searches*

Autism OR ASD OR Autism spectrum disorder OR Autistic disorder	AND: Diagnos* OR high-risk OR genetic risk OR familial risk OR autis* adj5^ symptom* OR autis* adj5 sign* OR autis* adj5 marker* OR autis* adj5 trait* OR autis* adj5 indicator* OR autis* adj5 precursor*	AND: Infant-directed speech OR Baby talk OR Child-directed speech OR motherese	AND: Child* OR infan* OR toddler* OR baby OR babies OR newborn*

Adj5^ indicates a search run for 5 words adjacent to the key search term and only separated by a single space

3.4 Results and Discussion

3.4.1 General characteristics of included studies A summary of key features and findings of the 27 studies included in the final review can be seen in Table 2. As there were a range of ages included in the studies, we will refer to study participants aged between 0-23 months as `infants', and participants aged 24-48 months as `children'. Upon analysis, the studies revealed common constructs (as outlined in Table 4) and therefore results and discussion of the studies will be addressed in sections, per construct. Studies that examined more than one construct in their analysis are mentioned in more than one section. Studies will be discussed in the following order; mean length of utterance, questions used, content of IDS, complexity of language, the frequency of speech, acoustic features, and attentional features. We have ordered the studies in this way to follow the hierarchy of linguistic structure as closely as possible. Studies that looked at each construct will be grouped as such, and methodology and findings, as well as a discussion of the studies will be included in each section.

Of the 27 studies included in this review, the most frequent outcome measures were attention-related speech. Twenty-three studies were conducted on infants LDA or children that had been diagnosed, and 5 studies were on HR/LR infants. Samples sizes of the studies varied, ranging from case studies to samples as large as 108 infants. The age ranges for the infants and children included in the studies also varied from birth to 4 years-of-age.

Table 4. *Definitions of constructs within the studies included in the scoping review*

IDS construct	Characteristics within construct	Definition
Mean length of utterance		The mean length of an utterance (MLU) is the mean number of (usually) morphemes per utterance.
Questions used	Wh questions	Questions starting with 'wh'-words, e.g. 'what...?', 'where...?' etc., which require a different response than "yes" or "no"
	Yes/No questions	Questions asked that require a "yes" or "no" response
Content of IDS	Expansions	Expanding on the infant/child's utterances
	Information salient language	Information-salient speech is used to encourage exploration by the

		infant/child, which includes types of speech (e.g., direct statements, questions, or descriptions) and referents (to the environment, the child's actions or internal states, or the parent him/herself)
	Internal state language	Language referring to thoughts, feelings, or beliefs of animate beings
Complexity of language	Language promoting vocalisations	Acknowledgements, imitations, labels
	Non-language promoting	Attributes, directions, play
	Omission of determiners	Determiners (e.g., articles, possessive pronouns) omitted from noun phrases in which they were required by the grammatical rules of the language, e.g. 'eat cookie' rather than 'eat *the* cookie'
	Syntactic distance	Distance between mother's and child's MLUs
Frequency of speech		The number of utterances spoken within a given time frame

Acoustic features	F0/Pitch	The highness or lowness of a tone as perceived by the ear, depending on the number of vibrations per second produced by the vocal cords
	Pitch contour	The trajectory of pitch over time, such as rising or falling
	Intensity	Vocal intensity of the speech (in decibel, dB)
Attentional features	Attention Bids	Attempts to gain an infant's attention
	Follow-in comments	An utterance that contains linguistic information that would facilitate language learning, is non-directive, and matches the infant's focus of attention
	Repeats	Repetition of the speakers/infant/child's utterance or vocalisation

Table 5. *Summary of the included studies*

Study	Sample Size	Child Age	Language Spoken	Outcome Variables	Results (HR or infants LDA compared to TD)
Frank, Allen, Stein & Myers (1976)	11 ASD 8 with mothers who have Schizophrenia	18-31 months	Not specified	• Number of utterances • ‘wh’ questions • Number of responses	• More utterances • Higher than normal amount of syntactic distance • Higher number of ‘wh’ questions • Equal level of responding • Lower complexity of language
Adamson, McArthur, Mrkov, Dunbar & Bakeman (2001)	18 (9 with ASD)	32 months (range 25-44)	American English	• Attention regulating bids	• Less communicative bids • Focused attention on shared objects or events without the use of words • Mothers used both literal and conventional attention-regulating bids (compared to conventional only for neurotypical infants)

Dousshard-Roosevelt et al. (2003)	24 ASD 24 TD	36-59 months	Not specified	• Social approaches	• Fewer social approaches • More physical contact
Trevarthen & Daniel (2005)	Case study of twins, one with ASD	11 months	Not specified	• Verbal and nonverbal behaviours in a game	• Less warmth • Less synchronous • Less rhythm
Swensen et al. (2008)	10 ASD 10 neurotypical	33.4 months	Not specified	• Maternal Yes/No questions • Maternal mean length of utterances • Maternal expansions	• Correlation between amount of Yes/No questions used and infant language production longitudinally • Correlation between maternal expansion use and infant language production longitudinally • No differences between mothers of infants with autism and mothers of neurotypical infants
Kay-Raining Bird, Cleave, Curia & Dunleavy (2008)	1 (case study, ASD)	44 months	French and English	• Compared use of internal state language	• Mother spoke more often • Mother used more internal state language than father

				between mother and father	• Sensory internal state language used most • Both parents spoke fewer utterances than what is shown for parents of neurotypical infants and children • Parents used more internal state language than what has been observed in neurotypical infants
McDuffie & Yoder (2010)	32 ASD	18-60 months	English	• Responsiveness	• Expansions of infant verbal utterances predicted infant vocabulary scores • Number of utterances that followed into child's focus of attention, and responses to infant verbal utterances predicted change in spoken language
Jakubowski (2011)	11 HR 11 LR	36 months	English	• Utterances • Attention buds	• More attention directing speech

				• Directiveness • Labelling	• More utterances consisting of speech accompanied by salient nonverbal behaviours • Less object labelling than LR • Used more suggestive speech
Saint-Georges et al., (2011)	15 ASD 12 Intellectual disability 15 neurotypical	6 months, 12 months, greater than 12 months	Not specified, from an Italian HM database	• Regulation of infant behaviour • Touching • Gesture • Vocalisation	• Found little difference in vocal responses • More regulation and touching
Adamson, Bakeman, Deckner & Nelson (2012)	108 53 Neurotypical 23 ASD 29 Down Syndrome	30 months (ASD and Down Syndrome) 18 months (neurotypical)	American English	• Style of verbal interaction • Follow-in comments	• Highlighted symbols more • Less supportive scaffolds • Effective communication heightened when requesting
Shizawa, Sanefuji & Mohri (2012)	Case study 2 (1 infant with ASD and 1	12 months	Japanese	• Frequency of ostensive cues • Type of ostensive cues	• Used more ostensive cues • Used more infant-directed actions • Less name-calling

	neurotypical infant)				• Less pointing • More visible and direct cues
Venuti, de Falco, Zaninelli, Bornstein (2012)	20 Neurotypical 20 ASD 20 Down Syndrome	24 months	Italian	• salient speech • discouragement • nonsense • greetings • mimic • Singing • onomatopoeia • conventions • info salient speech	• More use of child's name • More controlling • More references to child's action • Language was more focussed on orienting child's actions than to environment • Reference to themselves (mother) more • Same total amount of speech, reference to child state, and frequency of descriptive speech
Xu, Gilkerson, Richards & Rosenberg (2012)	71 ASD 49 LD 106 TD	ASD- 60 months TD 30 months	Not specified	• Parental speech to toddlers vs adults	• Broader, more exaggerated prosodic characteristics • Greater vowel durations • Greater vocal intensity • Higher pitch

					• More non-speech sounds
Cohen et al., (2013)	15 ASD 15 Neurotypical	18 months	Not specified	• IDS use	Fathers: • Used more IDS
Haebig, McDuffie & Weismer (2013)	40 ASD	24-39 months	American English	• Parent verbal responses	• Follow-in comments were significantly related to better language outcomes
Haebig, McDuffie & Weismer (2013)	34 ASD	31.35 and 66.91 months	Not specified	• Follow-in comments • Directives • Parent descriptions	• Follow-in comments predicted later language abilities • Redirective language was negatively associated with later language outcomes
Perryman, Carter, Messinger, Stone, Ivanescu & Yoder (2013)	37 ASD	21 months	Not specified	• Follow-in comments	• Linguistic responsiveness was a predictor of early receptive language growth • Follow-in comments were associated with increases in receptive language
Quigley & McNally (2013)	10 LR 7 HR	3.7 months LR 5.2 months HR	Irish English	• Utterances • Attention bids • Interrogatives	• Equal amount of utterances

				• Responses	• Lower contingently responsive utterances • Higher rates of attention-bids • Equal rates of questions
Bottema-Beutel, Yoder, Hochman & Watson (2014)	63 ASD	24-47 months	Not specified	• Parental higher- and lower-supported joint attention strategies • Follow-in utterances • Infant language development (receptive and expressive) and social communication	• Higher-supported joint attention was predictive of expressive language and social communication • Follow-in utterances were predictive of receptive language and social communication
Brisson, Martel, Serres, Sirois & Adrien (2014)	13 ASD 13 Neurotypical	0-6 months	French	• Duration of IDS • Mean pitch of IDS • Pitch contour characteristics	• Mothers utterances are shorter
Cassel, Saint-Georges, Mahdhaoui, Chetouani, Laznik,	Case study 2 (1 ASD, 1 TD)	Longitudinal 0-18 months	Not specified	• Caregiver solicitation and stimulation towards infant	Mother of infant with ASD: • Higher and longer vocalisation rate during

Muratori, Adrien & Cohen (2014)	(one infant with ASD and one neurotypical infant)			• Motherese production	semester 1 and 2, but not semester 3 • Rate of vocalisations decreased faster (between semesters 1 and 2) Father of infant with ASD • Lower rates of speech towards infant
Leezenbaum, Campbell, Butler & Iverson (2014)	12 (HR) 14 (LR)	13 and 18 months	American English	• Maternal vocalisations	• Mothers of HR infants produced higher proportions of translations in response to gives/requests at 13 months • Mothers of LR infants increased verbal responses to infant vocalisations between the two time points, mothers of HR infants did not
Adamson, Bakeman & Brandon (2015)	104 56 Neurotypical 23 ASD	30 months (ASD and Down Syndrome infants)	American English	• Amount of speech • Attention seeking behaviour towards novel	• Parents of infants with ASD were more likely to attempt to gain attention before

	29 Down Syndrome	18 months (neurotypical infants)		objects when presenting new words	presenting infant with novel object and new word
Venker et al. (2015)	55 ASD	3.5-4.5yrs	American English	• Parent speech	• Parents who used a higher rate of single words and determiner omissions in phrases had children with lower grammatical complexity and lexical diversity
Yoder, Watson & Lambert (2015)	87 ASD	24-48 months	Not specified	• Amount of parental responses	• The amount of parental linguistic responses were a predictor of expressive and receptive language growth
Quigley, McNally & Lawson (2016)	10 HR 9 LR	12 and 18 months	Irish English	• Mean pitch • Pitch range • Vocal intensity dB	• Vocal intensity became more evident over time (rather than less with LR) • Increased mean pitch for HR, decreased mean pitch for LR

Talbott, Nelson & Tager-Flusberg (2016)	30 HR 30 LR	6-18 months	American English	• Maternal responses • Maternal language	• More object labelling • More acknowledgements

Note: Low-risk (LR)

3.4.2 Frequency of speech and/or IDS Nine studies investigating the frequency of speech and/or the frequency of IDS used by parents have looked at three outcomes; the frequency of IDS, the frequency of speech in general, and responses to the infant/child. The studies presented differed in terms of population of infants/children, as well as in their methodology, and as such it is difficult to directly compare their findings. Three studies found no difference in the amount of speech directed to children LDA compared to typically developing (TD) children (Cohen et al., 2013; Quigley & McNally, 2013; Talbott et al., 2016), two studies found mothers of autistic children spoke more to their infant (Frank et al., 1976; Shizawa et al., 2012), one found differences in the patterns of the frequency of speech mothers use to HR and LR infants (Leezenbaum et al., 2014), and two others found they spoke less (Cassel et al., 2014; Kay-Raining Bird et al., 2008). One study suggested that the more the parent used linguistic responses, the better the language outcome for the child (Yoder et al., 2015).

Frank, Allen, Stein & Myers (1976) investigated the amount of speech produced by mothers to their autistic 4 year-old children compared to mothers with schizophrenia and their children. The mothers of autistic children produced more speech and responded more than the mothers with schizophrenia. It should be noted that there was no control population with whom to compare these clinical groups, nor did the authors disclose the developmental status of the children born to the mothers with schizophrenia.

Shizawa, Sanefuji & Mohri (2012) compared the frequency of IDS and infant-directed action (i.e. non-vocal behaviours directed to the infant, like shaking toys) in a case study of two mothers and their infants, one TD and one with autism, during two conditions (play and feeding). The mother of the autistic infant used IDS more frequently in the play condition when compared to the mother of the TD infant. A case study by Kay-Raining Bird, Cleave, Curia & Dunleavy (2008) recorded interactions in the family home of a three-year-old girl with autism over a three day period, and compared this with reports from studies of parent speech with TD children of the same mental age (approx. 9-12-months). The study found that, in general, parents of the child with autism spoke fewer utterances than reported by parents of TD children but used internal state language to a similar extent. The parents of the child with autism spoke most frequently of the sensory, desire, and judgement internal states, compared to studies on TD children that find perception and desire are the most commonly parental referenced internal states. In another case study conducted by Cassel et al. (2014), the IDS vs ‘other speech’ (i.e. adult-directed speech) from both the mother and father over the first 18 months of life for two single cases were compared; one with a TD child and a one with an autistic child. They reported that the number of maternal vocalisations decreased earlier for the autistic child (i.e. between 6- and 12-months-of-age) compared to the TD child (not until after 12-months). The father of the autistic child also demonstrated fewer vocalisations compared to all other parents in the study.

Cohen et al., (2013) retrospectively studied home videos of children and their families from the Pisa home movie database, which is a repository of home videos from the first 18 months of life for children that were either LDA or not (Maestro et al., 2005). This study found that mothers and fathers used a similar total amount of speech to infants LDA and TD infants. Likewise, mothers in both groups of infants used a similar amount of IDS. However, fathers of infants LDA spoke to their infants using more IDS compared to fathers of TD infants. A study by Tallbott et al. (2016) investigating mothers of HR and LR infants also looked at frequency of utterances and found no differences between mothers of HR infants compared to those of LR infants. Another study by Yoder, Watson & Lambert (2015) investigated the frequency of parental linguistic responses to child leads during interactions with autistic children. They found that the frequency of responses could positively predict the amount of expressive and receptive language growth of the autistic children. A prospective study by Quigley and McNally (2013) investigated the speech styles of mothers and their HR infants in relation to their language and socio-communicative development. Ten infants in this study were LR and seven were HR (with older autistic siblings). The infants were approximately 3 months old at the start of the study, and most mother-infant dyads were recorded interacting every month for approximately 9 months. The study found no difference in the number of utterances between mothers of HR or LR infants, however they did find that mothers of HR infants produced more attention-soliciting utterances and fewer directly contingent responses (i.e. responding to the infant's behaviour in some way) to their infants compared to mothers of LR infants.

Finally, a prospective study by Leezenbaum et al. (2014) investigated differences in attention-regulating vocalisations in a population of HR infants (*n*=12) with siblings that had been diagnosed with autism compared to a LR control group (*n*=14) at two time points; 13 months and 18 months of age. The study found that mothers of LR and HR infants differed in their pattern of verbal response to non-word vocalisations from the infants. Mothers of LR infants increased their responses to their LR infants over time whereas mothers of HR infants decreased their responses. The study did not find differences in responses to words spoken by the infant, however the authors state that this may be because too few HR infants were using words at 18 months, thus any differences could not be detected statistically.

The differences in these outcomes highlight the need for further research into the amount of speech and IDS provided to HR or LDA infants. The two studies converging on the conclusion that HR or LDA cohorts and TD children are exposed to similar amounts of speech used vastly different methodologies (Cohen et al., 2013; Quigley & McNally, 2013). This may mean that methodology is not the attributing factor for two studies finding a difference in the frequencies of speech input (Frank et al., 1976; Kay-Raining Bird et al., 2008). This suggests the necessity of looking beyond measures such as utterance frequency in order to tease apart differences between populations.

3.4.3 Acoustic features Studies looking at the acoustic structure of IDS and overall prosody studies demonstrated that HR infants, infants LDA, and children with autism do not hear less exaggerated pitch. Three studies looked at acoustic features of IDS and language input with autistic or children LDA. Brisson, Martel, Serres, Sirois & Adrien (2014) studied the pitch contour characteristics of mothers speaking to infants either LDA or not. They found no difference in mean pitch or frequency of the different types of pitch contours used by mothers, however they did find that the mothers of infants LDA used shorter utterances when interacting with their baby than the other mothers.

Xu, Gilkerson, Richards & Rosenberg (2012) found that mothers of autistic children spoke at a higher pitch and higher vocal intensity compared to mothers of developmentally-matched TD peers. Similarly, Quigley, McNally & Lawson (2016) found that mothers of HR children increased their vocal intensity from 12 months to 18 months of child age (compared to a decrease in vocal intensity for LR mothers), and had a wider pitch range than mothers of LR children. They also found that mean pitch increased for HR children and mothers, compared to the typical decrease for LR children and mothers.

The heterogeneity of methodology could have affected the comparability of the results in these studies, as they tested different aged infants and children, and some were diagnosed, and some were not. Further, the paucity of studies looking specifically at acoustic characteristics of IDS used with HR and LDA infants and children highlights the need for more robust research to be undertaken in this area. This is particularly relevant to young populations of HR infants, infants LDA and children with autism, as prosody is often cited as one of the most important features in early IDS due to its functionality in the acquisition of social communication and language abilities (for a review, see Spinelli et al., 2017).

3.4.4 Mean length of utterances (MLU) Children with autism show differences in MLU when compared to age-matched neuro-typically developing (TD) peers, where they produce shorter utterances with fewer morphemes (Tager-Flusberg et al., 2009). Two studies focussed on the MLU in the input to children who had been diagnosed with autism (Frank et al., 1976; Swensen et al., 2008). Frank et al., (1976) compared the correspondence of MLU of mothers with schizophrenia and their children and mothers with their autistic children. The mothers of the autistic children displayed better MLU correspondence with their child than the mothers with schizophrenia. The authors, however, did not have a control group of mothers without schizophrenia with TD children with which to compare results. Swensen et al. (2008) examined the MLU spoken to either TD children or children diagnosed with autism, both groups with a mean age of 33 months. This study found that there were no significant group differences between the mothers, however the MLUs were positively related to child language development four months later (i.e. the children scored better on language assessments and had longer MLUs).

Key differences in the studies investigating MLU in these populations exist, making the results difficult to compare. Unfortunately, as stated previously, the study by Frank et al. (1976) did not include a control group with which to make comparisons, and therefore is not particularly generalizable. Swensen et al. (2008) did have a comparison group of TD children and their mothers who were developmentally (rather than age) matched, which do make results easier to generalise to TD studies on MLU. The authors of this study did not interpret the MLU data in their paper, however, most likely because the two groups of children were on par with their language abilities and therefore they did not find any differences in maternal MLU. Of note, the results of this study by Swensen et al., (2008) may have been affected by the nature of the study, as the ASD population were receiving Applied Behavioural Analysis therapy at the time of the study, which focuses on improving communication skills in autistic children. This would have affected the results to some extent, as parents are expected to participate in the therapy program, increasing opportunity for communication between themselves and their child.

3.4.5 Complexity of IDS and language input The study by Frank, Allen, Stein & Myers (1976) also compared the complexity of speech spoken by mothers of autistic children with mothers of TD children with schizophrenia. The mothers of autistic children produced much less complex speech, with more syntactic distance. A study by Venker et al. (2015) investigated how complexity of parental language input related to language abilities in three-year-old autistic children, and found that parents' rate of omission of obligatory determiners from noun phrases predicted their autistic child's language development: parents of autistic children who omitted more determiners had children with less developed language abilities one year later.

The study by Venker et al. (2015) included only children with autism (i.e. there was no control group), and found parents' rate of determiner omissions negatively predicted language. This is in line with the authors' predictions, as more determiner omissions limit children's exposure to certain aspects of language which would arguably help them acquire better language abilities. This study, although providing valuable information on determiner omissions generally, would have benefitted from a control group to investigate whether this finding is more pronounced in an autistic population. The study by Frank et al. (1976) suggests that mothers of autistic children use less complex speech. Taken together, these findings suggest that the tendency to speak less complex language to children with autism may not be beneficial to the child's language development.

3.4.6 Content: General content Studies investigating the content of the IDS and language input provided by parents involved use of the child's name, use of information salient language, and the use of language focussed on directing the infant actions. A study by

Venuti, de Falco, Esposito, Zaninelli & Bornstein (2012), which compared maternal IDS spoken to children with autism, Down Syndrome, and TD children, observed that mothers of children with autism use the child's name more often than the other groups. The mothers of autistic children also used more information-salient utterances than mothers of TD children and referenced the infant's actions more. One study on language content found no differences between parents of HR and LR infants (Talbott et al., 2016). This study investigated maternal IDS towards 9-month-old HR infant siblings of children with autism, in relation to the infant's vocal production as well as the parent's own broader autism phenotype characteristics and the severity of the older sibling's autism symptoms. The study found that both groups of mothers responded to their infants with similar amounts of language promoting (acknowledgements, imitations, labels) and non-language promoting (attribute, directive, play) vocalisations, although mothers of infants LDA tended to label objects more. The study by Swensen et al., (2008) also investigated mothers use of expansions with their child who was either diagnosed with autism or were TD. They found the mothers' use of expansions to be positively correlated with their child's language use.

One case study investigated the content of the language used during interactions (Trevarthen & Daniel, 2005). This was a retrospective study which investigated 11-month-old monozygotic twins (one LDA and one TD). The authors micro-analysed the father's speech and other vocalisations (e.g., 'aaahs') from home videos of the father's interactions with the twins, finding that interactions involving the autistic twin were more directive when compared to the TD twin. Unfortunately, this conclusion was drawn without further specification of the features related to directiveness.

The studies investigating content vary in participant age, size, and diagnosis. Further, the dependent variables differ significantly, and while all are of interest to the autism research community, they are not comparable to each other. Much more research investigating each variable within this content section (i.e. use of name, information salient language, language about the infant's actions etc.) is needed in order to confidently compare the general content of speech and IDS towards autistic children and infants. This would allow researchers and clinicians to identify content that is salient for these children, and further, content that helps them learn social skills and acquire language. It would also allow parents to be able to connect and communicate more successfully with their child.

3.4.7 Content: Use of questions The studies examining question use in this review have yielded mixed results with one finding parents use more questions and another finding the opposite direction. The study by Frank, Allen, Stein & Myers (1976) comparing mothers of autistic children and mothers with schizophrenia found that the mothers of autistic children showed higher frequency of wh-questions (e.g. '*what* is that?'). The study by Swensen et al. (2008) examined the rate of yes/no questions spoken by mothers of 33-month-old children diagnosed with autism compared to mothers of developmentally-matched TD children (mean age of 16-months). This study found that the number of yes/no question asked was positively related to infant language development four months later. Venuti, de Falco, Esposito, Zaninelli & Bornstein (2012) compared maternal CDS spoken to children with autism, Down Syndrome, and TD children, all of whom had a developmental age of 24 months. The mothers of autistic children asked fewer questions than the other two groups of mothers.

The studies investigating question use have all utilised differing methodologies, for instance one was looking at longitudinal data, and all studies asked differing research questions, which may have contributed to this variance in conclusions. In order to uncover whether there is a difference in question use with these populations, the types of interactions that have been studied need to be quantified in order to be generalizable.

3.4.8 Content: Attention regulating characteristics Ten of the studies included in this review investigated the content of speech directed towards children that specifically involved attention regulation, such as attention bids. It is of note that many of the studies in this area are predictive, focussing exclusively on children with autism, rather than using a TD group of children as a comparison. Of these studies exploring attention regulation, the majority focus on attention bids. Adamson, McArthur, Markov, Dunbar & Bakeman (2001) investigated the attention bids elicited by mothers when interacting with their preschool-aged child (*n*=18). Nine of the children had been diagnosed with autism, and the other nine were developmentally-matched children (aged 18.9-21.4 months) who were assumed to be TD. This study found that when interacting with their child, there were no differences between groups in terms of the rate of attention bids mothers used, however mothers of TD children used a higher rate of bids that afforded shared commenting compared to the mothers of autistic children. A later study by Adamson, Bakeman, Deckner & Nelson (2012), using the same interaction protocol, compared the attention bids of mothers and their children who were developmentally matched and either TD, diagnosed with Down Syndrome or diagnosed with autism. This study found that mothers and children who had autism have interactions with less joint attention when compared to mothers and their typically developing children or those diagnosed with Down syndrome. In a subsequent study investigating mother-child interactions again using the same interaction procedure and sample of children, Adamson, Bakeman & Brandon (2015) investigated attention grabbing techniques used by mothers when teaching their child about a novel object. Mothers of children with autism were more likely to attempt to gain or draw their child's attention before introducing a novel object when compared to the TD children or those with Down syndrome.

Saint-Georges et al. (2011) investigated a cohort of infants via retrospective home movie analysis (LDA: *n*=15, intellectual delay *n*= 12, TD *n*= 15). Interactions between the infants and their caregivers were analysed to assess social exchanges, and they found that maternal regulating vocal behaviours were higher in the group of infant LDA. Similarly, a study by Jakubowski (2011) compared the regulating aspects of IDS spoken to HR infant siblings of children with autism with LR infants. This study found that mothers of HR infants used more attention bids in their speech than mothers of LR infants.

Another area of interest in terms of attention regulation is the use of follow-in comments. Perryman et al. (2013) investigated parental follow-in commenting and analysed interactions between 37 infants diagnosed with autism, aged 21 months of age and their parents. The study found that parental use of follow-in commenting was associated with increases in receptive language. McDuffie & Yoder (2010) conducted a study investigating two categories of parental verbal responsiveness; responsivity to a child's focus of attention, and responsivity to a child's communication. In their study, 32 autistic children between the ages of 18-60 months interacted with their parent and an examiner for 15 minutes. The study also found parental follow-in commenting was a predictor for later language development, and further, there was a positive association between utterances that specifically followed into the child's focus of attention and the child's later vocabulary. This study also found positive associations between parental use of repeats and expansions when responding to child communication and the child's later spoken language ability. Similarly, Haebig, McDuffie and Weismer (2013a, 2013b) investigated parental follow-in commenting during interactions between thirty-four parent child dyads, and whether this communication contributed to the child's language development one year (2013b) and three years later (2013a). Interactions occurred when the children were approximately 32-months-old. Again, these studies found that when parents used more follow-in comments with children who were minimally verbal, the children had better gains in language skills three years later. Parent's use of follow-in commenting, however, did not have any effect on children who were verbally fluent. Bottema-Beutel, Yoder, Hochman & Watson (2014) conducted a study on 63 minimally-verbal autistic children aged between 24-47 months. The study focussed on not only follow-in comments but also joint engagement, and whether different levels of joint attention would predict later language and social communication in children with autism. The different levels of joint engagement were defined as 'Higher-level supported joint engagement' (HSJE) or 'lower-level supported joint engagement' (LSJE). HSJE is defined as interactions where the child demonstrates engagement with the adult through their play with objects, whereas LSJE occurs when the parent influences the child in their play with toys, but the child does not demonstrate engagement with the adult as a play partner. The study demonstrated that the presence of HSJE and parental follow-in comments predicted receptive language and social communication abilities in the children.

Studies focussing on attention bids and attention-regulating language generally find parents of HR infants or those later diagnosed with autism use more attention bids (Adamson et al., 2012, 2015; Quigley & McNally, 2013) and attention-regulating language (Saint-Georges et al., 2011), although one study found no differences in attention-regulating language (Adamson et al., 2001). Interestingly, they also found that caregiver use of touch was higher in this group, compared to neurotypical and intellectually delayed infants, which suggests the need for more directive engagement with HR infants. Further, the authors suggest that these results are due to a lack of response from the baby, therefore the caregivers need to provide more stimulation to get a response during interactions from the infant. Another study also found mothers use more infant-directed actions when interacting with HR infants, which is seen as a more direct way of interacting and attracting attention, which again suggests the need for more stimulation during interactions (Shizawa et al., 2012). One study found parents of HR infants displayed decreased linguistic responsiveness but no differences in the amount of language spoken (Leezenbaum et al., 2014).

Follow-in commenting has been researched the most in terms of our scoping review, with studies finding that follow-in comments during interactions predict later language development and more instances of follow-in comments are associated with increases in language abilities (Bottema-Beutel et al., 2014; Haebig et al., 2013a, 2013b; McDuffie & Yoder, 2010; Perryman et al., 2013). Another area involving attention that has been investigated is how directive interactions are between parents and infants, with studies generally finding that parents are more directive when interacting with their HR or later diagnosed infant (Jakubowski, 2011; Shizawa et al., 2012). Like many of the previously mentioned studies in this review, the studies looking at attention-regulation in IDS are heterogeneous in their population and methodology. Some studies investigated diagnosed infants and children (Adamson et al., 2001, 2012, 2015; Haebig et al., 2013a, 2013b; McDuffie & Yoder, 2010; Perryman et al., 2013; Shizawa et al., 2012), while others investigated HR infants and infants LDA (Jakubowski, 2011; Leezenbaum et al., 2014; Quigley & McNally, 2013), and another used a prospective design where home videos were used with infants and their families with no known risk and the autism diagnosis was made later in the infant's life (Saint-Georges et al., 2011). Despite this heterogeneity in methodology, most studies support the notion that infants and children diagnosed or LDA are met with more attention regulating characteristics in the speech of their parents.

3.5 General Discussion

The evidence collected across these 27 studies provides no evidence that HR infants or infants with autism hear either less or more speech than TD children. However, the speech they hear may be different in several respects: it may have more exaggerated acoustic features, contain more content that directs the infants' actions, and contain more attention-bids. These results suggest that these infants and children may be displaying early differences in social interactions and mothers are picking up on these early cues.

Although the studies included in this review are representing a shift towards investigating IDS within autism research, this review has also emphasised the need for more robust investigation of speech and IDS in these populations. The studies included in this review vary in the scope of their outcome measures, analyses, and populations. The studies included in this review are an impressive start, however the given the heterogeneous nature of the results, further investigation is needed in order to ascertain whether this is due to the nature of the disorder (which in itself is heterogeneous) or whether it is due to other issues such as the diverse methodology. We therefore recommend that future studies focus more on replicable methodology, whether that be moving towards measures being replicated by numerous studies or reporting more background information necessary for interpretation of findings (e.g. native language spoken by parents).

The findings of studies in this review highlight that parents adapt their speech to the developmental, and specifically linguistic, abilities of their children. This can be seen in the studies comparing infants or children on the basis of their developmental (*n*=7) rather than their chronological age (*n*=15), where autistic children will display delay in areas like language and communication when compared to age-matched TD peers. This mismatch in the comparison groups makes it difficult to make comparisons between the IDS or speech directed towards the infants/children in autistic populations and other clinical and non-clinical populations. This is because parents usually match their speech to the developmental level of the child, which may hide subtle differences between the speech children with autism hear when compared with TD children. It is recommended that future studies focus on implementing developmental age matching in their methodology when investigating parental IDS within the context of autism, as developmental age/language-matching children with autism to TD peers is a more comparable way of measuring the outcome variables (in this case, the IDS and speech of the parents).

This review also revealed that there is great variety in the native language of the study populations, and it is recommended that future studies report the language spoken by participants. Most papers did not report on the native language (*n*=12), which is an issue as language spoken is a critical factor in language research. In the papers stating the language under investigation, American English/English was the most reported native language (*n*=9), followed by Irish English (*n*=2), French (*n*=2), Japanese (*n*=1), and Italian (*n*=1). One study also reported the family that participated in the study were bilingual (French and English spoken at home), which may have an impact on the results (Kay-Raining Bird et al., 2008). Future studies should focus on replicating studies that include a wide range of languages as well as investigating other native languages not included in this review to ensure results are generalisable.

It should be noted that within this review, there were three studies involving infant or child siblings of older children who had a diagnosis of autism (Jakubowski, 2011; Leezenbaum et al., 2014; Wan et al., 2012). This meant that within these studies, parents of these infants or children had another older child with autism, and this would imply the parents had knowledge of autism and additionally may have had experience with therapeutic interventions for that older child. This could have impacted their IDS, and future studies should consider investigating any differences between the IDS that is used with HR infants versus infants LDA, as the knowledge of could be an important factor to consider.

An encouraging finding that this scoping review has highlighted is that several features of parental input to infants and children with autism is associated with language development in this population (Bottema-Beutel et al., 2014; Haebig et al., 2013a, 2013b; McDuffie & Yoder, 2010; Perryman et al., 2013). In particular, follow-in commenting (related to responsivity during interactions) is suggested to positively predict language gains related to expressive and receptive language in children with autism (Bottema-Beutel et al., 2014; Haebig et al., 2013a, 2013b; McDuffie & Yoder, 2010; Perryman et al., 2013). The studies looking at follow-in commenting utilise longitudinal design, suggesting that this type of design could be fruitful for determining whether there are other predictors of language development within this population. Parent's use of questions were also found to influence child language development. (Swensen et al., 2008). Such associations between input and language development are promising for a population who are known to have language issues associated with the disorder. Future research could therefore focus on the potential therapeutic benefit of these characteristics of IDS and speech in order to inform future parent-implemented interventions.

IDS facilitates language and socio-communicative learning for young infants, both areas that children with autism struggle with, and is therefore an important avenue of research. The communicative environment that autistic infants and young children are exposed to hold important implications for clinical practice. Infants hear the most language in everyday situations, mostly involving parents, and thus the findings of this scoping review support parent-implemented interventions. Further, improving the quality of parent-infant interactions will not only improve the outcomes for the child, but also the parents who will be able to connect and communicate in meaningful ways with their child. Parental education is an important area of intervention in autism research, and these studies in IDS (particularly those indicating IDS can be predicting of later language abilities) highlight that caregivers should be encouraged and supported to provide a quality communicative learning environment for their children in order to give them the best outcome.

Chapter 4: Research gaps

The scoping review in chapter 3 has highlighted the paucity of studies investigating pitch used by mothers with infants and children displaying early symptoms of autism, or those LDA. IDS, and in particular pitch contours, are one of the most salient aspects of early mother-infant interactions. Pitch contours encourage affect communication and attention regulation, and they also facilitate socio-communicative and language development. The only study to investigate pitch contours was by Brisson et al, (2014) who did not find any conclusive results regarding pitch contours, and importantly, also only studied infants prior to 6 months-of-age- before autism symptoms can be reliably assessed. There is a gap in the research regarding how mothers use pitch contours with infants who are displaying symptoms of autism. In order to understand the trajectory of autism, this investigation into the early social environment of autistic infants is warranted. Although the exact cause of autism remains unknown, there is a general consensus in the research community that autism can emerge as a result of the interplay between many genetic, pre- and post-natal, and environmental factors (Elsabbagh & Johnson, 2007). A major environmental factor in an infant's early life is the social interactions that occur between a primary caregiver (usually the mother) and her verbal communication through IDS. The relation between IDS and autism is, therefore, important to understand and will contribute to understanding the environmental factors at play within infancy. Another factor that is important to consider within the early social environment are the individual characteristics of the infant. Temperament in early infancy is implicated in interactions with others, as well as language and social development. It is therefore important to understand the relation between aspects of an infant's environment like IDS, and infant temperament.

There is currently a paucity of research investigating the effect that infant characteristics can have on specific aspects of early maternal-child interactions – like IDS.

Knowledge of the relation between maternal pitch contours used during early interactions and infant interactive characteristics and behaviours is needed. Further to this, understanding the impact that infant temperament and early signs of autism can have on the way a mother communicates with her infant has implications for early mother-infant interactions and infant developmental research in general. Implications of this research may involve taking infant temperament and early signs of autism into account when mothers use highly functional pitch contours, and subsequently interventions can then be targeted towards facilitating socio-communicative and language developmental outcomes in children.

4.1 The current study

The objective of this research program was to examine the relationship between IDS used by mothers during an interaction with their infant, and infant characteristics; infant temperament and early signs of autism during infancy. The research questions that guided the project were:

1. What is the relation between infant temperament and maternal pitch contours used during interactions when the infant is 12 months of age?
2. What is the relationship between early signs of autism in infants and maternal pitch contours used during interactions at 12 months of age?

Chapter 5: Methods

A cross-sectional, cohort study was used to address the study aims. 12-month old infants and their mothers completed developmental, temperament, autism and sensory assessments and questionnaires and a recorded play interaction. The IDS the mother used during the interaction was analysed and coded using established, specialised software. The resultant pitch contours were submitted to statistical analysis alongside infant temperament and autism symptoms.

5.1 Participants

Participants for the current study were 12-month old infants and their mothers recruited from three infant development projects; the Breathing for Life Trial- Infant Development study (BLT-ID), the BabyMinds (BM) study, and the Sensory Development Following Prematurity study (SDPrem). Participant numbers from each study and a listing of exclusion reasons can be found in Table 6 and Figure 2. An overview of each study is provided below. Participants were eligible for the study if they completed a 15-minute recorded, play interaction, in addition to other assessments which will be detailed in later sections.

Inclusion criteria for the parents from all studies were:

1. 18 years or older
2. Able to attend study visits at the study site
3. Have completed the interaction at the 12-month study visit

Exclusion criteria for the infants from all studies were:

1. Highly reliant on medical care

Participants in the BLT-ID and BM study participated at three time points; 6-weeks, 6-months, and 12-months of infant age. This thesis only utilised data from the 12-month appointment, as such only that study visit will be discussed below (for details on the 6-week and 6-month appointments see appendices 1-3). Previous studies have demonstrated that the affective- and attention-related salience of pitch contours peak between 6 and 12 months of age (Kitamura & Burnham, 2003). We excluded 6-week data, as pitch contours are less informative at this time regarding affect communication and attention regulation (Kitamura & Burnham, 2003) and mothers predominantly use soothing contours when addressing infants at 6 weeks of age (Kitamura & Burnham, 2003). Furthermore, infant temperament and behaviour at 6 weeks of age is insufficiently developed for reliable observation (Medoff-Cooper et al., 1993). Six-month data was not utilised in this study as autism symptoms cannot be reliably assessed at this age. Participants were recruited and tested between June 2015-April 2019.

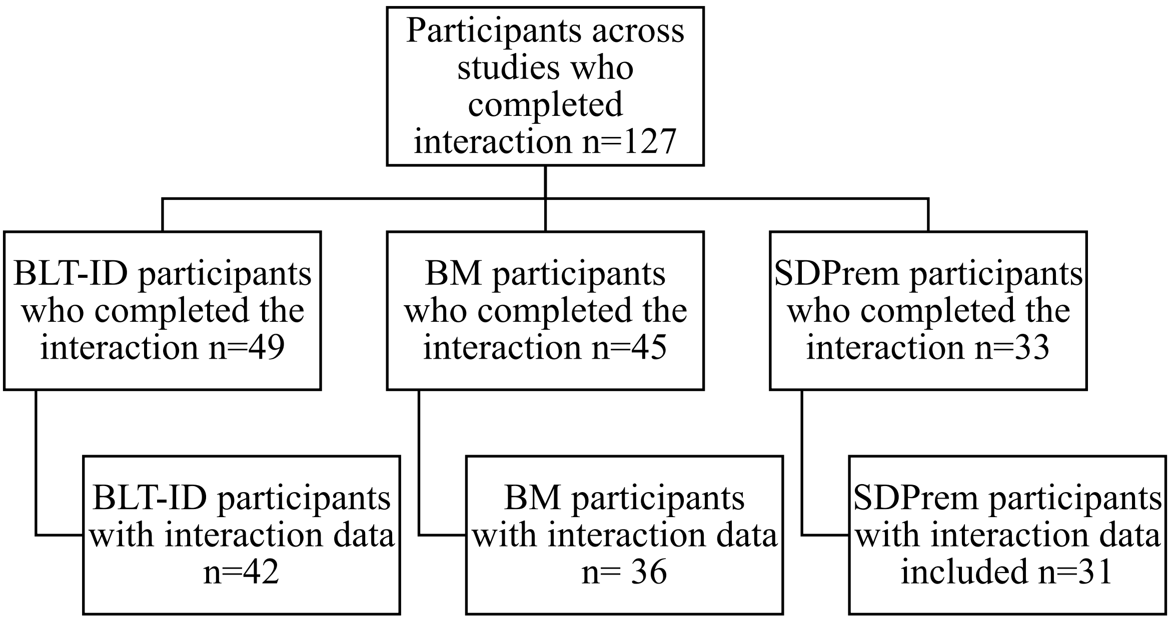


Figure 2. Flow chart of participant inclusion and exclusion for the BLT-ID, BM and SDPrem studies.

Table 6. *Exclusion reasons for interaction data for BLT-ID, BM and SDPrem studies.*

Reason for exclusion of interaction data	BLT-ID (*n*)	BM (*n*)	SDPrem (*n*)
Father participated in interaction	5	5	2
Mother used foreign language	1	3	3
Mother used own toys during interaction	1	0	0
Infant fussed out	0	1	0
Experimenter error	0	0	1
Total	7	9	6

5.1.1 BLT-ID The BLT-ID is a longitudinal study of cognitive, behavioural and sensory development of infants in their first year (at 6 weeks, 6 months, and 12 months gestational age), as well as the mental health and wellbeing of mothers (for more information on the full study protocol, see appendices 1-3). The BLT-ID project included only infants born to mothers with asthma, recruited through a larger randomised control trial (RCT) – the Breathing for Life Trial (described further in the next section).

Dyads were recruited when they attended a 6-week post-partum follow-up appointment with the BLT research team. Mothers were approached by a senior research member of the BLT-ID team who gave the participant information on the study (see appendix 6), explained the procedure, and obtained written consent. Dyads were then asked to participate at three time points; when the infant was 6-weeks, 6-months, and 12-months of age. Ethics approval was granted via the Hunter New England Research ethics committee

(Reference number: 15/05/20/4.05), Human Research Ethics committee (Reference number: HREC/15/HNE/164), and the University of Newcastle Human Ethics committee (Reference number: H-2015-0307), with site-specific approval (Reference number: SSA/15/HNE/196).

In addition to the general inclusion criteria outlined earlier, inclusion criteria for mothers participating in the BLT-ID were:

1. Physician diagnosed asthma and asthma symptoms (e.g. coughing, wheezing) and treatment (beta agonists or inhaled corticosteroids) for asthma in the last 12 months

Exclusion criteria for the BLT-ID included mothers who had:

1. Concurrent medical diagnosis that could affect participation (e.g. heart disease, multiple sclerosis, lung disease)
2. Drug or alcohol dependence

5.1.1.1 Breathing for Life Trial (BLT) The BLT-ID study is a sub-study of the Breathing for Life Trial (BLT). The BLT is a multicentre, parallel group RCT investigating a novel asthma treatment (fractional exhaled nitric oxide) during pregnancy (Murphy et al., 2016). The BLT was run at the Hunter Medical Research Institute (HMRI), Newcastle, Australia. Participants were recruited through antenatal classes, and BLT baseline study visits were at 12-20 weeks' gestation (supported by clinical assessment or dated ultrasound). Participants were then randomly assigned to the intervention group or the control group, who received usual care, and were asked to visit the study site ever 3-6 weeks (coinciding with antenatal visits). The outcome assessment of the trial was obtained after birth, within 6 weeks.

At this outcome assessment visit, mothers participating in the BLT were given the option of participating in the BLT-ID study. All mothers who expressed interest provided written informed consent prior to participation. Ethics approval was granted via the Hunter New England Health Ethics Committee (reference number: 12/10/17/3.04, approval number:

HREC/12/HNE/357), and the University of Newcastle Human Ethics Committee (reference number: H-2012-0422), with site-specific approval (reference number: SSA/12/HNE/393). Inclusion criteria for mothers participating in the BLT included:

1. 18 years or older
2. Physician diagnosed asthma and asthma symptoms (e.g. coughing, wheezing) and treatment (beta agonists or inhaled corticosteroids) for asthma in the last 12 months
3. Spirometry and fractional exhaled nitric oxide assessments completed

Exclusion criteria for the BLT included mothers who had:

3. Concurrent medical diagnosis that could affect participation (e.g. heart disease, multiple sclerosis, lung disease)
4. Drug or alcohol dependence

5.1.2 BM The BM project followed an identical procedure to the BLT-ID and was a community control sample (see appendix 4). Infants' cognitive, behavioural and sensory development was assessed at 6 weeks, 6 months and 12 months gestational age. Maternal mental health and wellbeing was also assessed.

62 mother-infant dyads were recruited from the community via flyers and brochures displayed at participating outpatient facilities, playgroups, childcare centres, GP facilities, community health nurses handing out brochures during postnatal appointments, and posts on social media. Mothers interested in participating called or sent a text message or email to a recruitment officer or senior researcher on the project and were given participant information. Those mothers who agreed were screened to ensure the project's inclusion and exclusion criteria were met.

In addition to the general inclusion criteria outlined earlier, inclusion criteria for the BM study included:

1. Mothers needed to have an infant aged between 4 weeks to 12-months of age

Exclusion criteria included:

1. Mothers under the age of 18
2. Drug or substance dependence
2. Participation in the BLT-ID study.

Ethics approval was granted via the Hunter New England Health Ethics Committee (reference number: 18/02/21/4.01), the Human Research Ethics Committee (approval number: HREC/18/HNE/28), and the University of Newcastle Human Ethics Committee (reference number: H-2016-0425), with site-specific approval (reference number: SSA/18/HNE/163).

5.1.3 Sensory Development Following Prematurity study (SDPrem) The SDPrem study investigated the sensory modulation and general development of infants born preterm (i.e. born <37 weeks gestation). 54 mother-infant dyads were recruited via a mailed invitation to families whose infants were born at the John Hunter Children's Hospital (JHCH) and admitted to the Neonatal Intensive Care Unit (NICU). Most infants (74%) who participated in this study were born preterm (born at <37 weeks' gestation), and the remaining 26% were admitted to the NICU directly after birth and were included as a convenience sample. These infants were identified via the Clinical Applications Portal (CAP), which is an electronic database containing information about the admissions to the hospital. An administrative assistant of the JHCH employed by Hunter New England Health screened CAP to identify potential mother-infant dyad participants. The SDPrem study assessed the cognitive, behavioural and sensory development of infants admitted to the NICU. As such, the majority of infants in this study were born preterm, and the infants were assessed when they were 12 months corrected age as it is at this age that autism signs become more reliably observed (Rogers, 2009).

In addition to the general inclusion criteria outlined earlier, inclusion criteria for the SDPrem study were:

1. Mothers had no drug or substance dependence
2. Infant born at JHCH or Newcastle Private Hospital and admitted to the NICU
3. Reside within 100km radius of JHCH at the time of birth

To ensure potential harm to participants was minimised, the administrative assistant ensured no contact was made with families whose child had been recorded as deceased in CAP. Envelopes inviting potential participants to participate were compiled and given to the administrative assistant. The administrative assistant affixed labels with the name and mailing address of potential participants and mailed them out. These envelopes included:

1. Invitation to participate (appendix 11)
2. Participant information statement (appendix 12)
3. Consent to contact form (appendix 13)
4. Reply paid envelope addressed to the University of Newcastle

Ethics approval was granted via the Hunter New England Health ethics committee (reference number: 16/05/18/4.11), the Human Research Ethics Committee (HREC/16/HNE/134), with site-specific approval (reference number: SSA/16/HNE/152). The SDPrem cohort was included in the current study in order to investigate autism risk, as infants born preterm have a higher likelihood of being diagnosed with autism than the general population (Joseph et al., 2017).

5.1.4 The current sample: Demographic information Sociodemographic information was obtained from the mothers at the 6-week, 6-month or 12-month appointment, depending on which infant development project they were participating in (see Table 7). Thirty-eight (90.5%) mothers in BLT-ID study, 34 (94.4%) mothers in the BM study, and 27 (87.1%) mothers in the SDPrem study returned sociodemographic questionnaires. The majority of women in the BLT-ID study were: born in Australia (97%), well-educated (68% had completed tertiary education), had varied income (63% reported an annual household income over $80,001), and multiparous (i.e had given birth to more than one child, 55%). The women in the BM study were: born in Australia (91%), well-educated (91% had completed tertiary education), had a high income (76% reported an annual household income over $80,001), and primiparous (66%). Within the SDPrem mothers, most were: born in Australia (96%), well-educated (83% had completed tertiary education), had varied income (67% reported an annual household income of over $80,001), and some were primiparous (33%). All mothers spoke Australian English during the interaction, and only 10 mothers reported the baby heard another language at home.

Table 7. *Maternal sociodemographic information across the BLT-ID, BM and SDPrem studies for mothers who filled out the sociodemographic questionnaire*

Maternal Characteristics		BLT-ID *N*= 38	BM *N*= 34	SDPrem *N*= 27
		N (%)	*N* (%)	*N* (%)
Country of birth	Australia	37 (97.37)	31 (91.11)	22 (95.65)
	England	1 (2.63)	0 (0.00)	0 (0.00)
	USA	0 (0.00)	0 (0.00)	1 (4.55)
	Germany	0 (0.00)	1 (2.94)	0 (0.00)
	Malaysia	0 (0.00)	1 (2.94)	0 (0.00)
	South Africa	0 (0.00)	1 (2.94)	0 (0.00)
Highest education level achieved	< School certificate	1 (2.70)	0 (0.00)	0 (0.00)
	School certificate	6 (16.22)	2 (6.06)	4 (16.67)
	Higher School Certificate	5 (13.51)	1 (3.03)	0 (0.00)
	TAFE diploma	11 (29.72)	6 (18.18)	6 (25.00)
	Bachelor's degree	11 (29.72)	15 (45.45)	13 (54.17)
	Postgraduate degree	3 (8.11)	9 (27.27)	1 (4.17)

Annual household income	$0-$18,200	2 (5.26)	0 (0.00)	3 (12.50)
	$18,201-$37,000	4 (10.53)	1 (2.86)	0 (0.00)
	$37,001-$80,000	8 (21.05)	7 (20.00)	5 (20.83)
	$80,001-$180,000	23 (60.53)	22 (62.86)	12 (50.00)
	$180,001 and over	1 (2.63)	5 (13.16)	4 (16.67)
Speak language other than English		4 (14.81)	5 (17.24)	1 (4.17)
Chronic Illness	Anxiety	5 (12.82)	2 (5.71)	
	Asthma	(100)	2 (5.71)	
	Bipolar disorder	3 (7.69)	1 (2.86)	
	CREST syndrome	1 (2.56)	0 (0.00)	
	Chronic dysthymia	0 (0.00)	2 (5.71)	
	Chronic fatigue	0 (0.00)	2 (5.71)	
	Chronic migraines	1 (2.56)	0 (0.00)	
	Chronic sinusitis	0 (0.00)	2 (5.71)	
	Diabetes	1 (2.56)	0 (0.00)	
	Depression	7 (17.95)	2 (5.71)	
	Endometriosis	2 (5.13)	0 (0.00)	
	Eczema	1 (2.56)	0 (0.00)	
	Epilepsy	3 (7.69)	0 (0.00)	
	Hashimotos-thyroiditis	1 (2.56)	0 (0.00)	
	Hip bursitis	1 (2.56)	0 (0.00)	
	High/low blood pressure	2 (5.13)	0 (0.00)	
	Hypothyroidism	1 (2.56)	1 (2.86)	
	Lupus	1 (2.56)	1 (2.86)	
	Other thyroid issue (not further defined)	0 (0.00)	1 (2.86)	
	Narcolepsy	2 (5.13)	0 (0.00)	
	Polycystic ovarian syndrome	2 (5.13)	1 (2.86)	

Post-natal depression	0 (0.00)	0 (0.00)	
Post-traumatic stress disorder	1 (2.56)	1 (2.86)	
Reflux	0 (0.00)	0 (0.00)	
Sjogrens syndrome	1 (2.56)	0 (0.00)	
Sleep apnoea	1 (2.56)	0 (0.00)	
Primiparous	17 (44.74)	23 (65.71)	8 (33.33)

*Note: many of the chronic illnesses were comorbid (i.e. many mothers reported more than one chronic illness); * percentages are those of the total number of mothers who responded to the sociodemographic questions, not all sociodemographic questionnaires were completed fully- some were completed only partially*

Infant demographic information was completed by the mother at the 12-month appointment (see Table 8). Infants in the BLT-ID study were mostly male (62%) and born to term (95%). The gender of the infants in the BM study was evenly split (53% female) and all infants were born to term. Within the SDPrem study, infants were mostly male (64%) and born preterm (76%).

Table 8. *Infant demographic information across the BLT-ID, BM and SDPrem studies*

Infant Characteristics	BLT-ID	BM	SDPrem
	N(%)	*N*(%)	*N*(%)
Gender (Female)	16 (38.10)	19 (52.78)	9 (36.00)
Premature (<36 weeks)	2 (4.76)	0 (0.00)	19 (76.00)
Admission to special care nursery	0 (0.00)	0 (0.00)	17 (68.00)

** Percentages are data from the mothers who responded to the sociodemographic questions*

5.2 Procedure

Mothers and infants attended a 2-hour face-to-face study visit at 12-months of age at HMRI or the Ourimbah campus of the University of Newcastle. At HMRI, the testing room consisted of a clinical office with a table for the developmental and autism assessments, floor space with a mat for the interaction, a change room and sink, and a separate small room for the eye-tracking procedure. The testing facility at the Ourimbah campus consisted of a room with a desk and chairs for the developmental and autism assessments, floor space for the interaction, and a curtained off section for the eye-tracking procedure. At this visit, babies were administered a developmental assessment and autism screen (SDPrem study only) and mothers and babies participated in a 15-minute recorded interaction. Mothers were 1) given questionnaires to complete on the day of the study visit *or* 2) were given questionnaires to take home along with a reply-paid envelope *or* 3) questionnaires were mailed out to the mothers' home address prior to the appointment for completion. Upon completion of the appointment, mothers were given a $20 gift voucher and a small gift for the baby (a hat).

Procedures relevant for the current study are outlined below. The full protocols and list of measures for each study are provided in appendices 1-5.

5.2.1 Recorded play interaction Mother-infant dyads participated in a 15-minute recorded interaction. Mother-infant dyads were asked to sit on a padded mat, in the middle of a quiet room, and mothers were instructed to "interact as naturally as you would in your own home". Free play was encouraged for the first 7.5 minutes of the interaction, followed by 7.5 minutes of toy play. The same toys were provided for all dyads, including a toy plane, tractor and phone. The interaction was captured using four cameras, set up in each of the four corners of the room. A Sennheiser ew112 G3 wireless clip-on lapel microphone was attached to the mother's clothing, which sent a recording of her speech during the interaction to a Roland R-26 or Zoom recorder.

5.2.2 Infant temperament Infant temperament was measured using the Carey Temperament Scales (CTS; Carey, 1970), specifically, the Toddler Temperament Scale (TTS) designed for infants aged 12-24 months (Fullard et al., 1984). The TTS has been demonstrated to have satisfactory psychometric properties, with a test-retest reliability (1 month) and internal consistency 20/5/20 5:27:00 pmof .81 and .70 respectively.

The TTS includes 107 items, rated by a parent on a 6-point Likert scale ranging from 1 (almost never) to 6 (almost always; see Table 9).

Table 9. *Example questions from the Carey Temperament Scales (Carey, 1970)*

CTS Temperament Domain	High score indication	Example Question
Activity	High activity	The child fidgets during quiet activities (storytelling, looking at pictures)
Rhythmicity	Arrhythmic	The child gets sleepy at about the same time each evening (within ½ hour)
Approach	Withdrawing	The child's initial reaction to a new babysitter is rejection (crying, clinging to mother, etc.)
Adaptability	Non-adaptable	The child allows face washing without protest (squirming, turning away)
Intensity	Intense	The child takes feedings quietly with mild expressions of likes and dislikes
Mood	Negative	The child is pleasant (smiles, laughs) when first arriving in unfamiliar places

Persistence	Non-persistent	The child pays attention to games with parent for only a minute or so
Distractibility	Distractible	The child continues an activity in spite of noises in the same room
Threshold	Low threshold	The child ignores the temperature of food, whether hot or cold

The CTS yields both temperament domain scores for the infant as well as an overall temperament profile based on the mother's rating of the infant's temperament domain scores (Carey & McDevitt, 1978). The temperament profiles for the CTS include 'easy', 'intermediate low', 'intermediate high', and 'difficult'. An easy infant would score as rhythmic, approaching, highly adaptable to change, mildly intense, and positive in mood. A difficult infant would score as arrhythmic, withdrawing, non-adaptable, intense, and negative in mood. Intermediate low infants score more towards the easy profile, and intermediate high infants score more towards the difficult profile. The statistical procedure used to classify the infants in this study is further outlined in the analysis section. This study used both the domain scores and the clinical profile scores.

5.2.3 Autism Measures

5.2.3.1 Autism questionnaire Early autism symptoms in all participants were measured via parent-report. The First Year Inventory (FYI; Reznick et al., 2007) is a caregiver report questionnaire which screens behaviours in 12-month-old infants suggestive of risk for developmental issues, particularly autism (see Appendix 16). The FYI is norm referenced and includes 63 items requiring the caregiver to rate the infant on two skill domains; social-communication and sensory-regulation (see Table 10). Some items (1-46) require the caregiver to rate the child on a 4-point Likert scale, ranging from 'Never' to 'Often', while some items (47-60) require the caregiver to select from multiple responses which would best describe behaviours their child exhibits. Items (61-63) are free response questions regarding concerns the caregiver has about the child. Positive predictive value of the FYI is .31 (optimal dual cut-off scores) and the negative predictive value is .99, indicating it as a moderate-strong tool for detecting autism in 12-month-old infants (Turner-Brown et al., 2013). The FYI yields a total risk score, a sensory regulation score and a social communication score. This study used all three scores in the analysis. Any infant who exhibited a total risk score or domain score exceeding cut-off was reviewed by AL, who made a determination about referral based on all of the available developmental data and a discussion with the caregiver.

Table 10. *Examples questions from the First Year Inventory (Reznick et al., 2007)*

First Year Inventory Domain	Example Question
Social Communication	Does your baby smile while looking at you?
Sensory Regulation	Does your baby seem bothered by loud sounds?

5.2.3.2 Autism observational assessment The Autism Detection in Early Childhood (ADEC) assessment (Young & Nah, 2016) was administered on SDPrem participants only. The ADEC screens for autistic symptoms in infants and toddlers aged 12-months to 3 years, which can then be followed-up by a clinician in order to formally diagnose the disorder. The assessment involves 16 play-based items that indicate atypical behavioural responses in the domains of social-communication, play, sensory-motor skills, and regulation. The ADEC takes approximately 10 minutes to administer. The ADEC yields high test-retest reliability (*r*=.83), inter-rater reliability (intra-class correlation coefficient, ISS=.83), and internal consistency (Cronbach's alpha ranging from .85-.93). The ADEC was also found to have high concurrent validity with the Autism Diagnostic Observation Scale (ADOS) – which is considered the gold standard in autism diagnosis and research assessment (Young & Nah, 2016). The ADEC also has high positive predictive value, .84, and negative predictive value, 1 (Young & Nah, 2016). Any infant who scored above 10 was identified as having 'moderate risk' (or higher) for developing autism and was followed-up by an occupational therapist (AL) and their usual GP.

5.2.4 Covariate measures Covariate measures included the mother's depressive symptoms, as well as the infant's prematurity status, days born premature, and the infant's cognitive, language and motor developmental score. Maternal depression was identified as a covariate as studies have demonstrated that the presence of depression can affect IDS, where depressed mothers will typically use flatter and less varied pitch (Kaplan et al., 2002, 2015). Infant prematurity status was identified as a covariate as premature infants are suggested to have different temperamental traits compared to infants born to term (Hughes et al., 2002). Infant developmental scores were included as covariates as language and motor deficits are a core symptom of autism, and cognitive deficits are often comorbid (American Psychiatric Association, 2013).

5.2.4.1 Sociodemographic questions Several questions from the sociodemographic questionnaire given to mothers to complete were used in this study in order to describe the sample (see appendix 15). Questions were either pertaining to the mother or the infant (see Table 11 for the questions used in this thesis).

Table 11. *Questions used for the current study taken from the sociodemographic questionnaire*

Characteristic	Question
Maternal	What is your country of birth?
Maternal	What is the highest level of education you have completed? (E.g. School Certificate, Higher School certificate, TAFE Diploma, Bachelor's degree)
Maternal	Which of the following best characterises your annual household income? (before tax): \$0-\$18,200, \$18,201- \$37,000, \$37,001 - \$80,000, \$80,001 – \$180,000, \$180,001 and over
Maternal	Does anyone speak to your child in a language other than English?
Maternal	Do any siblings live with your child?
Maternal	Does you suffer from any of the following: Speech or language disorder, Learning or behaviour problems, Depression Bipolar disorder, Schizophrenia, Other (please specify):
Infant	Infant's gender?
Infant	Was your child born preterm (earlier than 37 weeks gestation)? If you answered "yes", how many weeks early?

Infant	Was your child admitted to the special care nursery? If yes, how long did your child stay in the special care nursery?

5.2.4.2 Edinburgh Post-Natal Depression Scale The Edinburgh post-natal depression scale (EPDS, see appendix 17; Cox et al., 1987) was included as a covariate as maternal depression has been shown to affect IDS. Depressed mothers do not have the same exaggerated pitch as non-depressed mothers, and infants of depressed mothers do not learn language in the same way as infants of non-depressed mothers (Kaplan et al., 2002, 2015). The EDPS is a 10-item self-report questionnaire which screens women for symptoms of emotional distress or depression during or after pregnancy (Cox et al., 1987). Items are rated on a 4-point Likert Scale and require the mother to answer questions such as 'I have been anxious or worried for no good reason' indicating how she has been feeling in the past 7 days. Of the 10 items, 7 are reverse scored in order to discourage response style bias (the tendency to respond to questions in questionnaires without paying attention). The higher the score, the more severe the distress symptoms, and mothers who scored higher than a 9 were followed-up by a clinical psychologist. Any mothers who indicated thoughts of self-harm were immediately followed-up by a clinical psychologist to ensure their safety. The EPDS has been demonstrated to have good split-half reliability of .88 and Cronbach's alpha coefficient of .87 (Cox et al., 1987).

5.2.4.3 Developmental assessment Language deficits are a core symptom of autism (American Psychiatric Association, 2013)**.** Cognitive deficits are also often observed in autistic individuals (Rutter, 1983). Infant cognitive and language composite scores were, therefore, included as a covariate in our analysis. Infants were assessed by a senior researcher using the Bayley-III Scales of Infant and Toddler Development (BSID-III; Bayley, 2006). .

The BSID-III includes cognitive, language, and motor subscales. The cognitive subscale consists of 91 items. The language subscale consists of 49 items in the receptive language section and 48 items within the expressive language section. The motor subscale consists of 66 items within the fine motor section and 72 items within the gross motor section. The BSID-III is the gold standard tool for assessing an infant's development in the domains of cognition, language, motor, social-emotional, and adaptive behaviour. The BSID-III can give an indication of a child's relative strengths and weaknesses referenced against normative data. The assessment takes approximately 1 hour to complete for a 12-month-old. The abilities tested are similar to the screening test, covering problem solving, play skills, response to language and social cues, manipulating objects and mobility. Results of the assessment are presented in raw and scales scores, and also give the child's results in terms of percentiles based on the normed data. Any infant who scored below the 16th percentile received follow-up care from an occupational therapist (AL) and was referred back to their GP if needed. Upon completion of the appointment, parents were given the option to receive a summary report on their child's development. Test retest for the BSID-III ranged from .67 (fine motor) to .80 (expressive communication), internal consistency ranged from .86 (fine motor) to .93 (overall language), and stability coefficients were above .80 for all domains (Albers & Grieve, 2007).

Table 12. *Study protocol for the BLT-ID, BM and SDPrem projects for the 6-week, 6-month and 12-month appointments.*

Item	Appointment
Questionnaires	12m
Recorded Interaction	12m
BSID-III Full Version	12m
Autism Detection in Early Childhood assessment	12m†
Edinburgh Post-natal Depression Scale	12m~
Toddler temperament scale	12m
First year inventory	12m

Note: ~ indicates this questionnaire was given once at any appointment across the three time points, †indicates that this item was only administered in the SDPrem protocol.

5.3 Apparatus

The audio recordings taken during the 15-minute interaction were converted into WAV files, which were then analysed by trained research assistants or the PhD candidate using Praat 5.3.51 (Boersma & Weenink, 2019). The training procedure for research assistants included approximately 10 hours of supervised audio coding, and then unsupervised audio coding was double coded in order to ensure reliable classifications were made. Utterances were defined as segments of speech separated by more than 200 milliseconds of non-speech or a cycle of breath (Kitamura, Thanavishuth, Burnham, & Luksaneeyanawin, 2001). Pitch contours could be analysed within the utterances used by the mother via a pitch tracking function in Praat. Utterances interrupted by non-speech sounds (e.g. laughter, kissing, raspberries), infant noises, or involving whispered or croaky speech were excluded, as the pitch contour is not accurate or clear. Singing was also excluded as this type of speech has a predetermined pitch contour, regardless of the mother's communicative intent in terms of affect and attention regulation. A custom built praat script was run on each audio file (see appendix 18), and utterances were determined automatically on the basis of the intensity envelope, and then trained coders manually adjusted any utterance boundaries where the automatic procedure had missed utterances or erroneously inserted boundaries in the middle of an utterance. Once the utterances were identified from the mother's speech during the interaction using both the automatic and manual procedure outlined above, the pitch contours were then classified by one of five trained coders using audio impressions and visual inspection of the pitch track in the Praat Sound window. The standard settings for display of the Pitch track in the Sound window were between 100-500Hz and could be adjusted by the coder if necessary, to avoid pitch-tracking errors, such as pitch halving for very high-pitched utterances. The trained coders could classify the contours into one of the following ten categories; rising, bell-shaped, slowly-falling, rapidly-falling, rapidly-rising, u-shaped, sinusoidal, flat, complex, or other (for those that do not fall into one of the previously mentioned categories). If the pitch track, where necessary after adjustment of the pitch tracking settings, was deemed reliable, the utterances was also tagged for inclusion in the quantitative analyses of fundamental frequency measures. A total of 36,128 utterances were classified using this method.

5.4 Acoustic Analyses

A Praat script was written to extract all included utterances (i.e. without excluded utterances) in order to analyse pitch values. Pitch maximum, minimum, mean and median values of the mother's included utterances were calculated from the entire interaction. The interquartile range and 90^{th}-10^{th} values of the mother's pitch during the entire interaction were also calculated.

5.5 Statistical Analyses

After audio data was processed using Praat, all data were analysed using the Statistical Package Stata (Baum et al., 2010). Analyses were conducted by the PhD candidate, upon consultation from supervisors (AL, TB, DB). Data cleaning procedures were completed prior to analysis, including running descriptive statistics on variables to check for normality (see appendix 22).

In order to determine the temperament profile of the infants, we followed the same procedure as Carey (1970). ‘Difficulty’ on a domain for the TTS is arrhythmic, withdrawing, non-adaptable, intense, and negative in mood. Conversely, easier domain scores are rhythmic, approaching, highly adaptable to change, mildly intense, and positive in mood. Infants were classified as ‘difficult’ were those who scored more than 2 standard deviations away from the mean in the direction of difficulty on 4 or more domains. Infants were classified as ‘easy’ if they did not score more than one standard deviations away from the mean in the direction of difficulty for any domain. Intermediate infants scored between easy and difficult infants.

TTS, FYI and ADEC scores were compared to normative data for each of the assessments using t-tests or chi-squared tests as appropriate. Similarly, potential differences on key variables between cohorts (BLT-ID, BM and SDPrem) were assessed using chi-square or Kruskal-Wallis tests (depending on normality). We also determined any differences between the three cohorts in terms of key variables (total number of utterances, pitch values, and number of pitch contours) using chi square or Kruskal-Wallis tests. We ran Spearman’s or Pearson’s product moment correlation (depending on normality) on the dependent, independent and covariate variables in order to determine if any linear intercorrelation existed.

A backwards elimination (BE) variable selection process was selected based on the recommendations by Heinze, Wallisch and Dunkler (2018), which led to the current models included in this section. A global model was first run which included all variables, and then insignificant independent variables were removed if they did not meet the specified value of α=.157, as recommended by Heinze et al. (2018). This process was repeated until no insignificant variable remains, and the remaining variables in the model were the variables that best explained the variance in the data.

5.5.1 Aim 1: The relationship between infant temperament and maternal pitch contours at 12 months

Hypothesis: It was hypothesised that mothers who used more positively affective and attention-grabbing contours (rising, bell-shaped, u-shaped, sinusoidal) would rate their infants as having an ‘easy’ temperament. Mothers who used more negatively affective, prohibiting contours (rapidly falling and rising) were hypothesised to be more likely to rate their infants as having a ‘difficult’ temperament.

In order to address this aim, the data were visually inspected for any relations between dependent and independent variables. Spearman or Pearson product moment correlation analyses (depending on normality) were then conducted to assess any relation between infant temperament profiles and the number of pitch contours used by mothers during the interaction. We then conducted visual analysis of the scatterplots for each variable in order to determine linearity. Depending on linearity, we then fitted a regression model that best explained the data.

5.5.2 Aim 2: The relationship between infants displaying early signs of autism and maternal pitch contours at 12 months

Hypothesis: It was hypothesised that mothers of infants displaying more autism symptoms, as indexed by the FYI and the ADEC will use:

- More rising contours (related to attention regulation)
- Fewer bell-shaped and sinusoidal contours (related to attention maintenance)

- More rapidly-falling and rapidly-rising contours (related to attention regulation and prohibition of behaviour)

In order to address aim two, visual inspection of the data was conducted to see if any relations existed between dependent and independent variables. Spearman or Pearson product moment correlation analyses (depending on normality) were then conducted to assess any linear relation between infant score on the autism assessments (ADEC, FYI) and maternal pitch contours. Visual analysis of the scatterplots for each variable were then conducted to determine linearity. Depending on linearity, we then fitted a regression model that best explained the data.

Chapter 6: Descriptive Results and Preliminary Analyses

This chapter outlines a brief description of the key variables. This chapter also aims to:

1. Establish the range, distribution and validity of data collected in this study
2. Compare the data in our study to published normative data
3. Identify any instances of multi-collinearity within the key variables of the study
4. Describe the sub-samples (i.e. each cohort) and compare them to each other

6.1 Descriptive statistics: Maternal IDS

The frequency of included and excluded utterances by cohort is reported in Table 13. There was a significant difference observed between cohorts in the frequency of excluded utterances ($\chi^2(2, N=109) = 8.1, p= .02$), but not in the frequency of included utterances ($\chi^2(2, N=109) = 4.9, p= .09$). Mothers in the BM study used the most 'excluded' utterances (*M*= 193.94) per interaction (i.e. utterances that were excluded by researchers), followed by mothers in the SDPrem study (*M*=163.13) and then the BLT-ID study (*M*= 158.67). A list of the reasons for exclusion of utterances is provided in Table 14.

Table 13. *Frequency of included and excluded utterances used by mothers in the BLT-ID, BM and SDPrem studies per 15-minute interaction*

IDS variable	BLT-ID	BM	SDPrem
	M (SD)	*M (SD)*	*M (SD)*
Included utterances	178.57 (55.17)	160.50 (35.26)	185.32 (52.45)
Excluded utterances	158.67 (51.93)	193.94 (54.95)*	163.13 (69.75)

*Note: * indicates a significant difference between the cohorts at the α<0.05 level*

Table 14. *Reasons for utterance exclusion in the BLT-ID, BM and SDPrem cohorts*

Reason for exclusion	Definition	BLT-ID	BM	SDPrem
		N (%)	*N (%)*	*N (%)*
Doubt in transcription	Coder doubted whether the utterance was from the mother or the child	114 (1.8)	42 (.6)	79 (1.6)
Clicking mouth/tongue	Clicking noises made by mother	80 (1.2)	45 (.7)	56 (1.1)
Microphone	Microphone too loud or not calibrated correctly	75 (1.2)	64 (1.0)	13 (.3)
Raspberry	A sound made with the tongue and lips	110 (1.7)	204 (3.1)	101 (2.1)
Clapping	The mother clapping her hands overlapped the mother's utterance	46 (1.0)	73 (1.1)	21 (.4)
ADS	Mother was speaking to the researcher as they brought the bucket of toys in halfway through interaction	4 (.06)	10 (.2)	10 (.2)
Mum making toy noise	Mother made the noises a plane or truck would make	306 (4.7)	331 (5.0)	286 (5.9)
Kisses	Mother made kissing noises	58 (1.0)	68 (1.0)	31 (.6)
Sigh	Mother sighed loudly	140 (2.2)	185 (2.8)	132 (2.7)
Tickle noises	Mother made tickling noises consisting of mostly	149 (2.3)	164 (2.5)	105 (2.2)

	consonants which do not have pitch			
Whistle	Mother whistled	30 (.5)	7 (.2)	32 (.7)
Sound Overlap	Overlapping sounds can include baby vocalisation, toy noise	1338 (20.7)	1424 (21.4)	895 (18.4)
Whispering	Mother used whispered speech which does not have pitch	519 (8.0)	389 (5.9)	461 (9.5)
Croaky	Mother’s voice is too croaky for pitch track to be picked up by praat	701 (10.8)	1054 (15.8)	438 (9.0)
Laughing	Mother laughed	578 (1.0)	546 (8.1)	376 (7.8)
“Raa”/eating noise	Mother made a noise like a monster or pretended to eat the baby	87 (1.3)	3 (.05)	111 (2.3)
Singing	Mother sang a song with delineated pitch	714 (11.0)	864 (13.0)	594 (12.2)
Inhale	Mother inhaled loudly	1422 (22.0)	1188 (17.8)	1134 (23.3)

The frequency of mothers’ use of the pitch contours is shown in Table 15. Mothers used sinusoidal contours the most and rapidly-rising contours the least, in the interactions, regardless of cohort.

Table 15. *Frequencies of pitch contours used by mothers in the BLT-ID, BM and SDPrem cohorts per 15-minute interaction*

Pitch contour	BLT-ID	BM	SDPrem
	M (SD)	*M (SD)*	*M (SD)*
Rising	13.95 (11.75)	13.19 (8.32)	21.75 (12.40)
Bell	30.17 (19.39)	25.92 (14.29)	41.65 (20.33)
Sinusoidal	98.24 (49.44)	83.31 (33.73)	78.10 (32.83)
U-shaped	12.93 (10.55)	11.67 (5.41)	13.06 (7.04)
Flat	4.02 (3.88)	2.58 (2.06)	4.90 (4.38)
Complex	6.26 (7.96)	10.36 (13.34)	6.52 (6.36)
Rapidly-falling	3.17 (3.82)	3 (3.71)	5.42 (3.31)
Rapidly-rising	1.67 (2.73)	1.89 (1.94)	3.12 (3.53)
Slowly-falling	8.17 (6.60)	9.08 (5.77)	10.77 (6.42)

The pitch minimum, maximum and median pitch frequencies (Hz) across all three cohorts are reported in Table 16. There were no significant differences between the three cohorts in terms of pitch minimum and pitch median. The mothers in the SDPrem cohort, however, demonstrated a higher pitch maximum value (M=1904, SD=290.02) than the mothers in the BLT (M=1265.57, SD=176.56) and the BM (M=1188.91, SD=126.41; χ^2(2, N=109) = 7.24, p= .03).

Table 16. *Pitch frequencies (Hz) across the BLT-ID, BM and SDPrem cohorts per 15-minute interaction*

IDS Variables	BLT-ID	BM	SDPrem
	Hz (*SD*)	Hz (*SD*)	Hz (*SD*)
Pitch minimum	63.81 (5.61)	64.50 (5.93)	64.61 (7.74)
Pitch maximum	1265.57 (176.56)	1188.91 (126.41)	1904.97 (290.02)*
Pitch Median	274.81 (23.34)	272.17 (21.99)	276.25 (30.66)

*Note: * indicates a significant difference between cohorts at the α<0.05 level*

6.2 Checks for multi-collinearity in key variables

Bivariate correlation analyses were conducted on key study variables (see Table 17). The purpose of this analysis was to determine if any multi-collinearity existed between key study variables. Spearman's correlations (r_s) were run on all key variables, rather than Pearson's, as the assumption of normality was not met for many of the TTS scores, the FYI and ADEC scores, or the pitch contour frequencies (see Appendix 22.). There were correlations found between the variables, however, none of the correlations were of sufficient strength to indicate multi-collinearity.

Infant TTS: Intercorrelations between infant TTS scores are shown in Table 17. As can be seen, significant associations were observed between several TTS domains. Infants who were rated as more adaptable were also rated as more approaching and persistent. Infants who were rated as more positive in mood were also rated as more rhythmic in bodily function, more adaptable, more approaching and had a higher threshold for stimuli. Infants rated as more persistent were rated as more adaptable and less distractible. Infants rated as more rhythmic in bodily function were rated as less distractible. And finally, infants rated by their mothers as having a higher threshold for stimuli were also rated as more approachable.

Table 17. *Correlations between the TTS domains (r_s)*

Carey domain	Rhythmicity	Approach	Adaptability	Intensity	Mood	Persistence	Distractibility	Threshold
Activity	.15	-.16	.20	.12	.16	.03	-.08	-.11
Rhythmicity		.18	.07	-.17	**.43*** **	-.12	**-.53*** **	.02
Approach			.19	**-.21***	**.37*** **	-.04	-.12	**.31****
Adaptability				**.27****	**.30***	**.40*** **	.04	-.18
Intensity					.04	**.29****	.19	-.02
Mood						.14	-.15	**.26****
Persistence							**.38****	.06
Distractibility								.05

*Note: *indicates significance at the α<0.05 level, ** indicates significance at the α<0.01 level, *** indicates significance at the <.001 level*

Autism screening: The infant scores on the two domains of the FYI (social communication and sensory regulation) were correlated using Spearman's correlation coefficient (r_S). Infant scores on the social communication and sensory regulation domains of the FYI were moderately correlated ($r_S(92)=.30$, $p=.003$). Spearman's correlations were also used to determine if the two autism assessments, the FYI and the ADEC, were related. No significant correlations were found between the two constructs ($r_S(28)=-.09$, $p=.66$).

Maternal IDS: Spearman's correlations were conducted on the maternal pitch values and pitch contours (see Table 18). There were significant moderate correlations between the mothers' minimum and maximum values, and several of the contours.

Table 18. *Correlations between maternal pitch values and pitch contours (r_S) per 15-minute interaction (N= 109)*

	Pitch minimum	Pitch median	Pitch maximum
Excluded utterances	.08	.07	**.23***
Included utterances	-.07	.18	.13
Utterance total	.02	**.22***	**.30****
Rising contours	.02	.08	**.22***
Bell contours	-.03	**.26***	**.35****
Sinusoidal contours	-.03	.16	-.07
U-shaped contours	.05	-.01	.10
Flat contours	.01	.07	**.30****
Complex contours	**-.22***	.14	.12
Rapidly-falling contours	.03	.03	.09
Rapidly-rising contours	.11	.13	.37
Slowly-falling contours	-.10	.03	**.22***

*Note: *indicates significance at the α<0.05 value, ** indicates significance at the α<0.01 value, R values bolded if significant*

The pitch contours were correlated with each other using Spearman's correlation coefficient (r_s, see Table 19). Significant correlations were found between several of the pitch contours, but were only weak-moderate, suggesting no multi-collinearity.

Infant TTS and autism symptoms: Infant TTS scores and FYI and ADEC scores were correlated to investigate whether infant temperament was related to early presence of autism symptoms. Infant adaptability was weakly related to FYI total score ($r_s(109)=.29$, $p=.007$), and sensory regulation ($r_s(109)=.26$, $p=.01$). In other words, as infants displayed more autism symptoms, as rated by their mother, infants were also rated as being less adaptable. There were no significant correlations between the infant ADEC and TTS scores (see appendix 24).

6.3 Maternal covariates

Potential maternal covariates included chronic illness (yes/no) and presence of maternal depression. Maternal EPDS scores were weakly correlated with the utterance total ($r_s(109)=-.29$, $p=.03$), sinusoidal contours ($r_s(61)=-.27$, $p=.03$) and rapidly-rising contours ($r_s(109)=-.28$, $p=.03$, see Appendices 25 and 27). Maternal depression was not found to be significantly correlated with maternal pitch values or contours (p values were between .23>.95, see Appendix 26). Maternal chronic illness was not found to be related to pitch values, utterances, or pitch contours. As such, EPDS, but not chronic illness, was retained as a covariate in the final regression analyses.

6.4 Infant covariates

Potential infant covariates included BSID-III scores and the number of days the infant was born preterm. Infant cognitive composite scores were not found to be related to any TTS scores (see Appendix 28). BSID-III cognitive composite scores were weakly related to FYI total score ($r_s(89)=-.24$, $p=.02$) and FYI sensory regulation scores ($r_s(89)=-.24$, $p=.02$). BSID-III language composite scores were found to be strongly related to ADEC scores

($r_s(26)=-.63$, $p<.001$, see Appendix 29), and weakly related to maternal utterance total ($r_s(101)=.27$, $p=.005$) and excluded utterance total ($r_s(101)=.26$, $p=.008$). BSID-III motor composite scores were found to be weakly related only to maternal rapidly-falling contours ($r_s(100)=-.22$, $p=.03$, see Appendix 30). The number of days the infant was born preterm was weak-moderately related to TTS rhythmicity ($r_s(82)=.46$, $p<.001$), intensity ($r_s(88)=-.26$, $p=.02$), mood ($r_s(89)=.37$, $p=.0004$), and distractibility scores ($r_s(88)=-.35$, $p=.001$, see Appendix 31). Due to these findings, infant BSID-III cognitive and language scores, and the number of days the infant was born preterm were retained as covariates in the final regression analyses.

Table 19. *Correlations between maternal pitch contours (r_s)*

Pitch contours	Bell	Sinusoidal	U-shaped	Flat	Complex	Rapidly-falling	Rapidly-rising	Slowly-falling
Rising	**.70***	**-.23***	**.46***	**.48***	.11	**.47***	**.37***	**.57***
Bell		-.04	**.45***	**.58***	.17	**.52**	**.48***	**.55***
Sinusoidal			-.10	**-.25**	-.12	**-.32***	.12	**-.35***
U-shaped				**.26**	-.05	**.40***	**.48***	**.30***
Flat					-.03	**.44***	**.27***	**.55***
Complex						-.05	-.04	**.22***
Rapidly-falling							**.40***	**.53***
Rapidly-rising								**.20***

6.5 Descriptive statistics: Temperament

Descriptive statistics were conducted in order to understand the temperament characteristics of infants in our study in relation to normative data. TTS domain scores are reported in Table 20. There were significant differences between cohorts in rhythmicity scores (x^2(2, N=90) = 132.22, *p*=.003; see figure 3). There were no other significant differences in scores between the cohorts for any other TTS domain.

We compared the combined cohort TTS domain scores to normative data (see figure 4; Fullard et al., 1984). The only domain in which the infants in our study did not significantly differ from normative data was in the domain of distractibility. Bearing in mind a higher score on the TTS indicates more difficult or less desirable temperament, the scores in our study indicated infants: were more active (*t*(84)= 2.02, p=.04), more arrhythmic (t(89)= 3.08, p=.003), more withdrawing (*t*(91)= 2.48, p=.01), more non-persistent (*t*(90)= 13.36, p<.001), more non-adaptable, (*t*(86)= 6.25, p<.001) and had a more negative mood (*t*(91)= 6.55, p<.001) than normative infants. The infants in our study, however, had a higher threshold for stimuli (*t*(90)= -14.04, p=<.001), and were less intense (*t*(90)= -5.42, p<.001) compared to normative infants.

Table 20. *Mean and standard deviation TTS scores for the BLT-ID, BM, SDPrem, and normative cohorts.*

TTS Domain	BLT-ID		BM		SDPrem		Normative	
	M (SD)	*N*	*M (SD)*	*N*	*M (SD)*	*N*	*M (SD)*	*N*
Activity	3.94 (.65)	30	4.00 (.57)	28	4.79 (1.62)	27	4.13 (.80)	53
Rhythmicity	2.75 (.97)	32	2.73 (.58)	32	3.87 (.42)	26	2.49 (.81)	53
Approach	3.28 (.95)	32	2.87 (.84)	32	3.20 (.39)	28	2.97 (1.00)	53
Adaptability	3.57 (.83)	30	3.53 (.62)	30	3.33 (.44)	27	3.42 (.86)	53

Intensity	3.78 (.58)	31	3.94 (.61)	32	3.45 (.40)	28	4.03 (.76)	53
Mood	3.24 (.74)	32	3.14 (.47)	32	3.48 (.33)	28	2.96 (.69)	53
Persistence	3.85 (.63)	32	4.11 (.76)	31	3.34 (.39)	28	3.45 (.83)	53
Distractibility	4.30 (.63)	32	4.46 (.54)	31	3.42 (.44)	28	4.39 (.76)	53
Threshold	3.43 (.69)	31	3.52 (.76)	32	3.45 (.45)	28	3.61 (88)	53

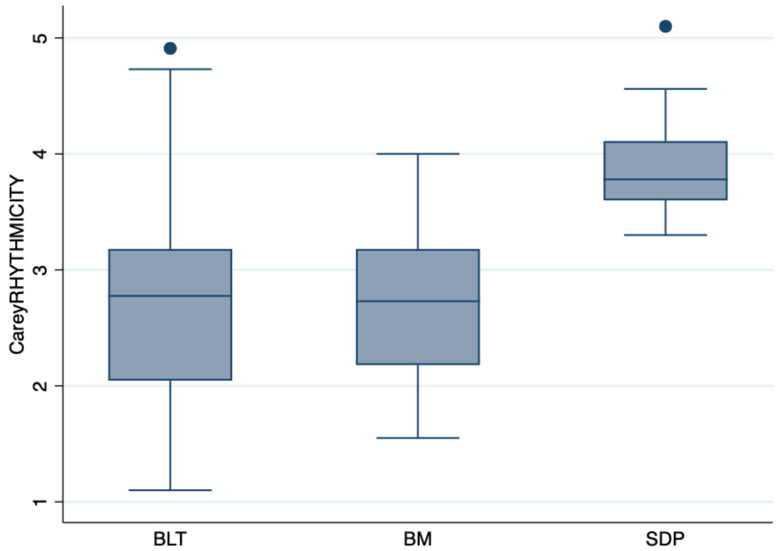


Figure 3. Difference in TTS rhythmicity scores between the BLT-ID, BM and SDPrem cohorts.

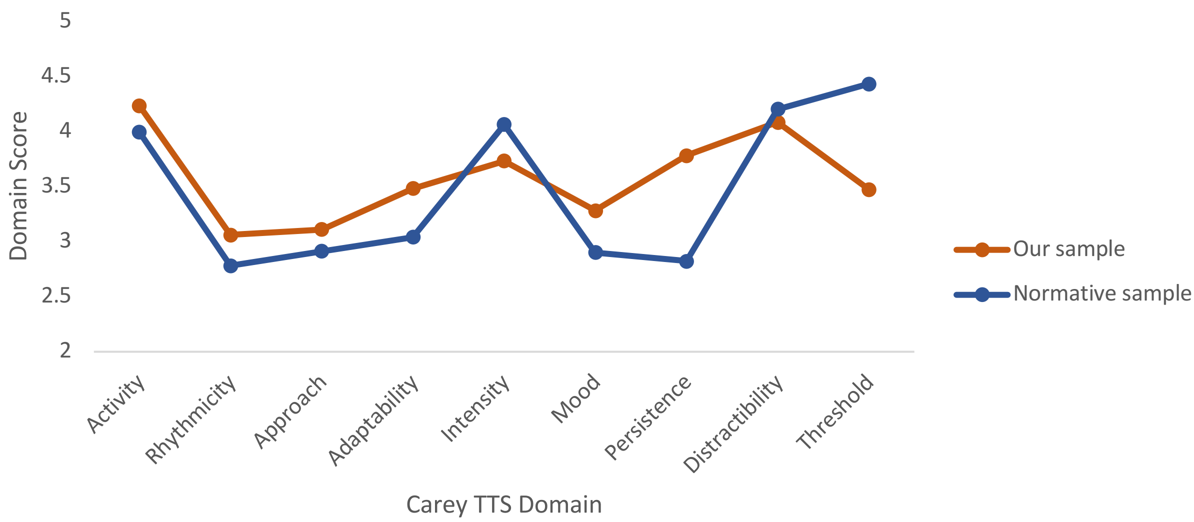


Figure 4. Mean TTS scores for the combined cohorts in our study with the TTS normative data from Fullard et al. (1984).

A clinical profile was generated for the infants using the individual domain scores compared with normative mean data (Fullard et al., 1984). A baby was categorised as 'easy' if they; scored no more than one SD higher than the mean in two domains, and less than the mean in all other domains. A baby was categorised as 'difficult' if it scored higher than one SD above the mean in four or more domains. A baby was categorised as 'intermediate high' and 'intermediate low' if they scored in between the easy and difficult categories. Interestingly, using this method of categorisation according to normative data, no infants in our study were categorised as easy (see Table 21). Further, most infants in the BLT-ID and SDPrem studies were categorised as being difficult by their mothers, and a large portion of the infants in the BM study were rated as being difficult also.

Table 21. *Descriptive statistics for the TTS clinical profiles for the BLT-ID, BM and SDPrem cohorts.*

Clinical Profile	BLT-ID	BM	SDPrem
	N (%)	*N (%)*	*N (%)*
Easy	0	0	0
Intermediate- Low	14 (43.75)	12 (37.5)	4 (14.29)
Intermediate- High	2 (6.25)	8 (25)	6 (21.43)
Difficult	16 (50)	12 (37.5)	18 (64.29)

6.6 Descriptive statistics: Autism

Descriptive statistics were conducted in order to understand where the infants in our study scored both generally and in relation to normative data in terms of early autism symptoms. FYI scores are reported in Table 22. The BLT-ID infants scored highest, indicating more autism symptoms, on all domains, followed by BM and then SDPrem, although these differences were not significant (p=.20-.80). We compared the FYI scores for infants in our study with normative data (Ben-Sasson & Carter, 2012). There were no significant differences between our sample and the normative data (*p*=.22). We did not compare individual domain scores (i.e. social communication and sensory regulation) with normative data, as this was not reported in the literature.

Table 22. *Descriptive statistics for the FYI for the BLT-ID, BM and SDPrem cohorts.*

FYI score	BLT-ID (*N*=30)		BM (*N*=34)		SDPrem (*N*=28)		Normative (*N*=471)
	M (SD)	Range	*M (SD)*	Range	*M (SD)*	Range	*N*
Total	11.12 (10.37)	0-43.75	9.47 (6.33)	0-32.50	7.42 (5.76)	0-24.50	10.40
Socio-communication	11.11 (12.04)	0-43.75	8.91 (7.73)	0-30.50	8.25 (8.49)	0-31.25	NA
Sensory regulation	11.15 (10.84)	0-43.75	10.03 (8.44)	0-34.50	6.60 (6.91)	0-22.50	NA

Infants in our study scored lower on the ADEC, indicating fewer autism symptoms (*N*= 29, *M*=6.86, *SD*=3.24) than the normative sample (*M*=8.6, *SD*=3.47); *t*(28)= -2.89, *p*<.01. This indicates that the infants in our study displayed fewer autism symptoms when compared to the infants in the normative study (Young & Nah, 2016). ADEC data was not available for BLT-ID and BM cohorts.

Chapter 7: Relationship between IDS and temperament

This chapter outlines the analyses of the relationship between infant temperament scores and maternal IDS. It was hypothesised that mothers who used more positively affective and attention-grabbing contours (rising, bell-shaped, u-shaped, sinusoidal) would rate their infants as having an ‘easy’ temperament. Mothers who used more negatively affective, prohibiting contours (rapidly falling and rising) were hypothesised to be more likely to rate their infants as having a ‘difficult’ temperament.

7.1 Infant temperament and maternal pitch values and utterances at 12 months

Spearman’s correlations were conducted to examine the association between maternal pitch minimum, median and maximum values and the infants’ TTS scores. There were no significant correlations observed between any of the maternal pitch values and infant TTS clinical profiles or domain scores (see Appendix 34 and 35). Maternal utterance totals, however, were correlated with infant TTS domain scores (see Table 23). Excluded utterance totals were weakly correlated with infant rhythmicity (r_S(85)=-.24, *p*=.02). Mothers who spoke more excluded utterances (non-speech, tickle noises, laughing etc.), had infants who were more regular in bodily function (i.e. had a lower TTS rhythmicity score). There were no other significant associations between TTS scores and utterances or pitch values.

7.1.2 TTS domain scores and maternal pitch contours Spearman’s correlations were administered to examine the association between maternal pitch contours and infant TTS domain scores (see Table 24). Bell contours were weakly related to infant mood (r_S(92)=.22, p=.04) . Flat contours were weakly related to infant distractibility (r_S(91)=-.22, *p*=.04). Infant mood was also weakly related to rapidly-falling (r_S(92)=.27, *p*=.01) and rapidly-rising contours (r_S(92)=.24, *p*=.02). Finally, slowly-falling contours were weak-moderately related to infant activity (r_S(85)=-.29, *p*=.008). In other words, as infant mood became more positive, mothers used fewer bell contours and more rapidly-rising and falling contours. Mothers used fewer flat contours with more distractible infants. Finally, mothers used more slowly-falling contours if infants were less active.

Table 23. Spearman *correlations (r_s) between maternal utterances during the 15-minute interaction and infant TTS scores.*

	Activity	Rhythmicity	Approach	Adaptability	Intensity	Mood	Persistence	Distractibility	Threshold
Utterance total	.01	-.20	.05	-.03	.01	-.05	.06	.04	-.01
Included utterance total	-.05	.03	.02	.05	-.16	.11	.09	-.08	.04
Excluded utterance total	-.04	**-.24***	.04	-.07	.11	-.16	-.03	.10	-.02

*Note: *indicates significance at the α<0.05 value, ** indicates significance at the α<0.01 value, R values bolded if significant.*

Table 24. *Correlations (r_s) between maternal pitch contours during the 15-minute interaction and infant TTS domain scores.*

	Activity	Rhythmicity	Approach	Adaptability	Intensity	Mood	Persistence	Distractibility	Threshold
Rising total	-.15	.09	.03	.01	.04	.20	.09	-.16	.05
Bell total	.06	.07	.00	-.07	-.02	**.22***	.07	-.20	.10
Sinusoidal total	.14	-.09	-.06	.02	-.12	-.12	.03	.14	-.04
U-shaped total	-.13	-.06	-.01	.04	-.13	.13	.05	.03	.04
Flat total	-.15	.06	.07	-.08	.04	.18	.03	**-.22***	.09
Complex total	-.13	-.06	.07	-.12	.03	.02	-.07	-.05	.18
Rapidly-falling total	-.04	.08	.17	.01	-.05	**.27****	-.07	-.19	.04
Rapidly-rising total	.09	.08	.05	.10	-.01	**.24***	.07	-.11	.04
Slowly-falling total	**-.29****	.10	.12	.01	.05	.18	.14	-.17	.15

*Note: *indicates significance at the α<0.05 value, ** indicates significance at the α<0.01 value, R values bolded if significant*

7.2 TTS profile scores and maternal pitch contours

Spearman's correlations were conducted to examine the relationship between maternal pitch minimum, median, and maximum values, utterances and pitch contours and infant TTS profiles. No significant associations were found between any of the maternal pitch, utterance or contour variables and infant TTS profiles (see Appendix 34).

7.3 Regression model for the TTS domain scores and maternal pitch contours

A backwards elimination (BE) variable selection process led to the current models reported in this section. Independent variables were the frequency of maternal pitch contours and utterances, maternal EPDS scores, infant number of days preterm, and infant cognitive and language scores on the BSID-III. The dependent variable was the infant TTS score for each domain. A global model was first administered, and then insignificant independent variables were removed if they did not meet the specified value of α=.157, as recommended by Heinze et al. (2018). The final model was selected once there were no insignificant independent variables left. No models were found to significantly predict the infants' TTS approach, persistence, distractibility, and threshold scores. Similarly, no statistically significant model was found to predict infant TTS clinical profile. There were, however, statistically significant models that predicted infant activity, rhythmicity, adaptability, intensity, and mood TTS scores.

7.3.1 Infant activity Mother's bell-shaped, complex and slowly-falling contours significantly predicted infant TTS activity scores, R^2=.09, F(3, 81)= 3.74, p=.01 (see Table 25). Mothers' bell-shaped, complex and slowly-falling contours accounted for 9% of the variability in infant activity score.

Table 25. *Regression model for infant TTS activity score*

Variable coefficient	Number of observations	Estimate (95% CI)	B (t statistic)	SE B
Bell-shaped contours	85	.00-.03	.02 (2.28)*	.01
Complex contours	85	-.04-.01	-.02 (-1.60)	.01
Slowly-falling contours	85	-.10--.02	-.06 (-2.76)**	.02
Constant	85	3.91-4.91	4.41 (17.56)***	.26

*Note: *indicates significance at the α<0.05 value, ** indicates significance at the α<0.01 value, *** indicates significance at the α<.0001 value*

7.3.2 Infant rhythmicity Regression analysis established that mother's EPDS score and sinusoidal contours, as well as the number of days born preterm, could significantly predict the infant's TTS rhythmicity score, R^2=.19, $F(3, 74)$= 4.94, p=.004 (see Table 26). Mothers' EPDS score, mothers' sinusoidal contours, and the number of days preterm the baby was born accounted for 19% of the variability in TTS rhythmicity score.

Table 26. *Regression model for infant TTS rhythmicity score*

Variable coefficient	Number of observations	Estimate (95% CI)	B (t statistic)	SE B
Number of days preterm	51	-.04-.01	-.01 (-1.55)	.01
EPDS score	51	.04-.16	.10 (3.54)**	.03
Sinusoidal contours	51	-.00-.01	.004 (1.66)	.00
Constant	51	1.35-2.58	1.96 (6.41)***	.31

*Note: *indicates significance at the α<0.05 value, ** indicates significance at the α<0.01 value, *** indicates significance at the α<.0001 value*

7.3.3 Infant adaptability Regression analysis established that mother's EDPS score, sinusoidal and rapidly-falling contours could significantly predict the infant's TTS adaptability score, R^2= .12, *F*(3, 44)= 3.04, *p*=.04 (see Table 27). Mothers' EPDS, sinusoidal and rapidly-falling contours accounted for 11.5% of the variability in infant adaptability scores.

Table 27. *Regression model for infant TTS adaptability score*

Variable coefficient	Number of observations	Estimate (95% CI)	B (t statistic)	SE B
EPDS score	48	.00-.11	.05 (2.17)*	.03
Sinusoidal contours	48	.00-.01	.01 (2.13)*	.00
Rapidly-falling contours	48	.00-.11	.06 (2.12)*	.03
Constant	48	1.90-3.32	2.61 (7.38)***	.35

*Note: *indicates significance at the α<0.05 value, ** indicates significance at the α<0.01 value, *** indicates significance at the α<.0001 value*

7.3.4 Infant intensity Regression analysis established that the number of days preterm the infant was, as well as the amount of sinusoidal contours that the mother used could significantly predict the infant's TTS intensity score, R^2=.12, *F*(2, 85)= 6.91, *p*=.002 (see Table 28). The number of days preterm the infant was, as well as the amount of sinusoidal contours the mother used accounted for 12% of the variability in infant intensity score.

Table 28. *Regression model for infant TTS intensity score*

Variable coefficient	Number of observations	Estimate (95% CI)	B (t statistic)	SE B
Number of days preterm	88	-.01--.00	-.008 (-3.48)**	.00
Sinusoidal contours	88	-001--.00	-.004 (-2.33)*	.00
Constant	88	3.87-4.53	4.21 (25.24)***	.17

*Note: *indicates significance at the α<0.05 value, ** indicates significance at the α<0.01 value, *** indicates significance at the α<.0001 value*

7.3.5 Infant mood Regression analysis established that the number of days preterm an infant was and the total amount of rapidly-rising contours that the mother used could significantly predict the infant's TTS mood score, R^2=. 10, F(2, 86)= 5.95, p.004, (see Table 29). The number of days preterm the infant was as well as the amount of rapidly-rising contours the mother used accounted for 10% of the variability in the infants' mood score.

Table 29. *Regression model for infant TTS mood score*

Variable coefficient	Number of observations	Estimate (95% CI)	B (t statistic)	SE B
Number of days preterm	89	.00-.01	.005 (2.62)**	.00
Rapidly-rising contours	89	.00-.08	.04 (2.05)*	.02
Constant	89	2.93-3.24	3.09 (39.92)***	.08

*Note: *indicates significance at the α<0.05 value, ** indicates significance at the α<0.01 value, *** indicates significance at the α<.0001 value*

Chapter 8: Relationship between IDS and autism symptoms

This chapter outlines the analyses of the infant autism assessments. We conducted Spearman's correlations on the FYI total and domain scores for the infants and the mothers pitch contours during the interactions, in order to determine any associations. We also conducted Spearman's correlations on the infant ADEC scores and the mother's pitch contour data to determine any associations. We then conducted a backwards elimination regression on the key study variables in order to determine if there was a significant predictive relationship between maternal pitch contours and utterances, and infant FYI and ADEC score.

8.1 Infant FYI scores and maternal pitch values and utterances

In order to investigate whether maternal pitch values were related to infant FYI score, Spearman's correlations were conducted between maternal pitch minimum, median, and maximum values and infant FYI total, FYI social communication and FYI sensory regulation scores. No significant associations were found (see Appendix 37). Spearman's correlations were also conducted between maternal utterances and infant FYI total, FYI social communication and FYI sensory regulation scores. Maternal excluded ($r_s(109)=-.21$, $p=.04$) and total utterances ($r_s(109)=-.29$, $p=.004$) were weak-moderately negatively associated with infant FYI total score. Further, maternal included ($r_s(109)=-.24$, $p=.02$) and total utterances ($r_s(109)=-.23$, $p=.03$) were significantly, negatively associated with infant sensory regulation score. In other words, as infant FYI total and sensory regulation scores increased, indicating more symptoms of autism, and in particular issues with sensory regulation, the mothers spoke less overall.

Table 30. *Correlations (r_s) between maternal utterances during the 15-minute interaction and infant FYI scores.*

	FYI total score	FYI social communication	FYI sensory regulation
Utterance total	**-.29****	-.145	**-.23***
Included utterance total	-.19	-.02	**-.24***
Excluded utterance total	**-.21***	-.16	-.11

*Note: *indicates significance at the α<0.05 value, ** indicates significance at the α<0.01 value, R Values are bolded if significant.*

8.2 Infant FYI scores and maternal pitch contours

Spearman's correlations were conducted between pitch contours and FYI total scores, social communication scores and sensory regulation scores to determine any associations (see Table 31). Sinusoidal contours were moderately negatively related to FYI total score (r_s(109)=-.30, *p*=.004) and sensory regulation score (r_s(109)=-.31, *p*=.002). The mothers of infants rated as displaying more sensory regulation and autism symptoms, used less sinusoidal contours.

Table 31. *Correlations (r_s) between maternal pitch contours during the 15-minute interaction and infant FYI scores. R values bolded if significant.*

	FYI total score	FYI social communication	FYI sensory regulation
Rising total	.02	.10	-.00
Bell total	-.06	-.01	-.08
Sinusoidal total	**-.30****	-.15	**-.31****
U-shaped total	.06	.11	.04

Flat total	.19	.15	.20
Complex total	-.02	-.03	.06
Rapidly-falling total	.11	.16	.08
Rapidly-rising total	-.04	-.04	-.04
Slowly-falling total	.19	.18	.19

*Note: *indicates significance at the α<0.05 value, ** indicates significance at the α<0.01 value*

8.3 Infant ADEC scores and maternal pitch values and utterances

Spearman's correlations were conducted between maternal pitch minimum, median, and maximum values and infant ADEC total score to determine any associations (see Appendix 38). No significant correlations were observed. Utterance totals were correlated with infant ADEC scores and, again, there were no significant correlations observed.

8.4 Infant ADEC scores and maternal pitch contours

Pitch contours were correlated with infant ADEC scores to determine if any associations existed (see Table 32). Flat contours were correlated with infant ADEC score ($r_s(109)=-.39$, $p=.04$). Mothers of infants displaying more autism symptoms on the ADEC, used fewer flat contours.

Table 32. *Correlations (r_s) between maternal pitch contours during the 15-minute interaction and infant ADEC scores. R values bolded if significant.*

	Total ADEC score
Rising total	.15
Bell total	-.29
Sinusoidal total	-.09

U-shaped total	-.01
Flat total	**-.38***
Complex total	.17
Rapidly-falling total	.00
Rapidly-rising total	-.22
Slowly-falling total	-.06

*Note: *indicates significance at the* α*<0.05 value*

8.5 Regression model for the infant FYI scores and maternal pitch contours

A backwards elimination (BE) variable selection process was conducted in order to determine any predictive models of infant autism symptoms. Independent variables were maternal pitch contours and number of utterances, maternal depressive symptoms, infant number of days preterm, and infant cognitive and language BSID-III scores. First, a global model was run, and then insignificant independent variables were removed if they did not meet the specified value of α=.157, as recommended by Heinze et al. (2018). The final model was selected once no insignificant variables remained. One regression analysis was conducted for each autism symptom variable (FYI total, FYI social communication, FYI sensory regulation, ADEC total).

8.5.1 Infant FYI total score Mother's EPDS score, the frequency of utterances spoken, and the infant's cognitive score on the BSID-III significantly predicted infant FYI total score, R^2=. 34 F(3, 47)= 9.58, p<.0001 (see Table 33) accounting for 34% of the explained variability in infant FYI total score.

Table 33. *Regression model for infant FYI total score*

Variable coefficient	Number of observations	Estimate (95% CI)	B (t statistic)	SE B
EPDS score	51	.21-1.21	.71 (2.83)**	.25
Utterance total	51	-.07--.01	-.04 (-2.93)**	.01
Cognitive BSID-III score	51	-.31--.02	-.16 (-2.26)*	.07
Constant	51	18.93-54.80	36.87 (4.14)***	8.91

*Note: *indicates significance at the α<0.05 value, ** indicates significance at the α<0.01 value, *** indicates significance at the α<.0001 value*

8.5.2 Infant FYI social communication score Mother's EPDS score, total amount of utterances and flat contours significantly predicted infant FYI social communication score, R^2=.28 $F(3, 47)$= 7.46, p=.0003 (see Table 34) accounting for 27.9% of the variability in FYI social communication score.

Table 34. *Regression model for infant FYI social communication score*

Variable coefficient	Number of observations	Estimate (95% CI)	B (t statistic)	SE B
EPDS score	51	.07-1.36	.72 (2.23)*	.32
Utterance total	51	-.08--.01	-.04 (-2.53)*	.02
Flat contours	51	.04-1.71	.88 (2.12)*	.41
Constant	51	4.34-30.52	17.43 (2.68)**	6.51

*Note: *indicates significance at the α<0.05 value, ** indicates significance at the α<0.01 value*

8.5.3 Infant FYI sensory regulation score Mother's EPDS score, the frequency of the mother's rising and sinusoidal contours, and the infant's cognitive BSID-III score significantly predicted the infant's FYI sensory regulation score, R^2=.20 F(4, 46)= 4.22, p=.005 (see Table 35) accounting for 20.5% of the variability in FYI sensory regulation score.

Table 35. *Regression model for infant FYI sensory regulation score*

Variable coefficient	Number of observations	Estimate (95% CI)	B (t statistic)	SE B
EPDS score	51	.09-1.37	.73 (2.28)*	.32
Rising contours	51	-.37-.01	-.20 (-1.72)*	.09
Sinusoidal contours	51	-.43-.03	-.06 (-2.17)*	.12
Cognitive BSID-III score	51	-.12--.00	-.18 (-1.95)*	.03
Constant	51	13.93-55.73	34.87 (3.35)**	10.38

*Note: *indicates significance at the α<0.05 value, ** indicates significance at the α<0.01 value*

8.5.4 Infant ADEC score Mother's rising, bell-shaped, flat and complex contours, as well as the infant's language BSID-III score strongly significantly predicted the infant's ADEC score, R^2=.70 F(5, 20)= 12.48, p=.00001 (see Table 36) accounting for 70% of the variability in infant ADEC score. It should be noted that the number of observations in this model is smaller than in the models predicting the FYI domain scores, and therefore normally the power to detect prediction would be reduced, however we still observed a strong significant result.

Table 36. *Regression model for infant ADEC score*

Variable coefficient	Number of observations	Estimate (95% CI)	B (t statistic)	SE B
Rising contours	26	-.01-.145	.07 (1.85)*	.37
Bell-shaped contours	26	-.15--.05	-.09 (-3.99)***	.02
Flat contours	26	-.30-.04	-.13 (-1.57)	.08
Complex contours	26	.02-.31	.16 (2.38)*	.07
Language BSID-III score	26	-.19--.04	-.11 (-3.12)**	.04
Constant	26	12.32-26.55	19.44 (5.70)***	3.41

*Note: *indicates significance at the α<0.05 value, ** indicates significance at the α<0.01 value, *** indicates significance at the α<.0001 value*

Chapter 9: Discussion of the relationship between infant temperament and maternal pitch contours

The first objective of this study was to examine the relationship between the pitch contours used by mothers, interacting with their 12-month-old infant, and their infant's temperament. The results of this study indicated partial support for our hypotheses, and will be discussed in this chapter. The first hypothesis, that mothers who use more positively affective and attention-grabbing contours will rate their infants as having an 'easy' temperament, was not supported. We did find support for our second hypothesis, however; that mothers who use more negatively affective and prohibiting contours will be more likely to rate their infants as having a 'difficult' temperament. While there was no observed relationship between the maternal pitch contours and TTS difficult *profile*, several pitch contours (bell-shaped, flat, rapidly-falling and rising, and slowly-falling) used by the mothers during the interaction were related to individual temperament *domains* indicative of more difficult temperament behaviours (activity, mood, and distractibility).

9.1 Interpretation of findings

Our findings provide initial support for the notion that maternal IDS varies in relation to infant temperament. Three themes emerged in our results relating to the way mothers use pitch contours in relation to their infant's temperament, which will be discussed below. Firstly, maternal rapidly-rising contours were found to be most strongly related to the infant temperament trait of mood. Secondly, slowly-falling contours were strongly related to infant activity. And finally, bell-shaped contours were also related to infant mood and infant activity. It is clear from our results that infant activity and mood are important temperament traits within interactions, and maternal rapidly-rising, slowly-falling, and bell-shaped contours are also important factors within interactions when considering these temperament traits.

9.1.1 Rapidly-rising contours The negatively affective and prohibiting rapidly-falling and rapidly-rising contours were moderately related to infant TTS mood scores, and further, a regression analysis revealed rapidly-rising contours were also significantly associated with infant mood. Infants who had a higher mood score (i.e. a more negative mood) had mothers who used more rapidly-falling and rapidly-rising contours (r_s= .27, p=.01 and r_s=.24, p=.02 respectively). Further, higher infant mood was associated with the number of rapidly-rising contours used by the mother along with the number of days the infant was born preterm, together explaining 10% of the variation in TTS mood scores (R^2=.10, p=.004).

Rapidly-falling and rapidly-rising contours are thought to be prohibitive in function and are used to quickly gain an infant's attention, increasing their arousal levels, in order to change their behaviour (Fernald, 1989). Mothers who use rapidly-falling and –rising contours are often interacting with an infant who is engaging in unwanted behaviour (for instance, infants who are more difficult). A higher mood score is one indication of more difficult infant behaviour, and is one of the TTS domains used to categorise the infant into the TTS difficult profile. Mood is defined within the CTS as the amount and duration of the infant's pleasant behaviour as opposed to unpleasant or 'unfriendly' behaviour (Thomas et al., 1968). Our results suggest that when a mother views her infant as being more negative in mood she uses more of these contours, and the literature indicates that this may be in an attempt to change her infant's unpleasant or unfriendly behaviour. We also found that preterm status is associated with infant mood in our results, which is in line with previous research. Preterm infants are rated by their parents as having a more difficult temperament, particularly in the domain of mood and adaptability (Langkamp et al., 1998).

We did not find a relationship between the rapidly-falling and -rising contours and other TTS domain scores associated with the difficult temperament profile. Therefore, it is clear from the associations found within our model and the correlations between variables that rapidly-rising contours are an important factor to consider within mother-infant interactions where the infant is expressing a more negative mood.

9.1.2 Slowly-falling contours The second theme emerging from our results was that slowly-falling contours were related to infant activity. Infant activity was found to be moderately related to maternal slowly-falling contours, with mothers using more slowly-falling contours if their infant was generally rated as less active (r_s=-.29, *p*=.008). Infant activity scores were associated with mothers using more bell-shaped contours and fewer complex and slowly-falling contours, explaining approximately 9% of the variance in activity scores (R^2=.09, *p*=.01).

Slowly-falling contours are typically used if an infant is in a state of low arousal (and therefore less active) and may signal the mother's intent to keep her infant in this state (e.g. preparing the infant for sleep; Fernald, 1989). Infant activity is assessed in the CTS depending on an infant's motor activity, daily movements and their sleep-wake cycle (Thomas et al., 1968). It follows then, that infants perceived as having low activity would therefore be encouraging mothers to use slowly-falling contours if, as previous research suggests, they are intent on keeping their infant at a state of low arousal.

9.1.3 Bell-shaped contours The third theme emerging from our results was that bell-shaped contours were related to both mood and activity, representing an overlap with the first two themes. Bell-shaped contours were correlated with infant mood (r_s=.22, *p*=.04). Infant activity scores were associated with mothers using more bell-shaped contours and fewer complex and slowly-falling contours, explaining approximately 9% of the variance in activity scores (R^2=.09, *p*=.01).

Bell-shaped contours are posited to be used by speakers to maintain infant attention, encourage participation in interactions, and are generally thought to communicate positive emotion (Papousek et al., 1991; Stern et al., 1982). We observed that bell-shaped contours were used more frequently by mothers if their infant was perceived as having a more negative mood. The mothers in our study may have been trying to counteract the infant's negative mood by using more of these positively affective contours. Further, these types of contours were found to be associated with infant activity, whereby more infant activity was related to mothers using more bell-shaped contours. In line with previous research, it is highly likely that infants who were generally rated as more activity, were engaging in more motor movements and were actively participating in the interaction more with their mother. Mothers use more bell-shaped contours with infants who are engaged in interactions with them (Stern et al., 1982). Infant activity, therefore, may be a marker for more successful interaction, which is signalled by the mother using more bell-shaped contours.

The three themes that emerged from our study in relation to infant temperament were that: 1) rapidly-rising contours were associated with infant mood, 2) slowly-falling contours were associated with infant activity, and 3) bell-shaped contours are related to both infant mood and activity. All three contours are likely important in managing different infant temperament traits, and activity and mood are plausibly important in mother-infant interactions.

9.1.4 Other findings of interest There were several other secondary findings of interest within our study. Other types of pitch contours used by the mothers in our study were correlated with infant temperament domains, however these results fell outside of the main themes that emerged in our results. These are discussed briefly below.

9.1.4.1 Flat contours Mothers were observed to use fewer flat contours during the interaction if their infant was rated as more distractible (r_S=.22, p=.04). Higher distractibility is indicative of a more difficult temperament profile. Flat contours, generally seen more in adult-directed speech, are less attractive to infants than other, more exaggerated and varied contours typical of IDS. One of the main functions of pitch contours in IDS is purported to be the regulation of infant attention (Roberts et al., 2013). Mothers may have been using fewer flat contours with infants who were distractible in order to maintain the infant's attention in the interaction.

9.1.4.2 Sinusoidal contours Sinusoidal contours emerged in predictive models for infant rhythmicity, adaptability, and intensity. Higher infant rhythmicity (indicating less rhythmicity) was associated with fewer maternal sinusoidal contours, more maternal depression symptoms (as indexed by the EPDS) and the number of days the infant was born preterm (R^2=.19, *p*=.004). Sinusoidal contours, like bell-shaped contours, are used to increase arousal and attention, communicate and encourage positive affect, and encourage infant participation in interactions (Papoušek et al., 1990). Rhythmicity has also been linked to not only sleeping and feeding schedules, but also rhythmicity with others when interacting (Olafsen et al., 2018). Arrhythmia is considered a trait of difficult temperament, and infants with poor sleep and feeding schedules often behave in a more difficult manner, particularly within interactions (Lavigne et al., 1999). Sinusoidal contours were used more frequently by mothers when their infants were more arrhythmic, potentially as an attempt to encourage the infant during the interaction to interact more and express positive affect, counteracting difficulty.

Sinusoidal contours (along with maternal depressive symptoms and rapidly-falling contours) were also associated with infant adaptability (R^2=.12, *p*=.04). Adaptability refers to the ease of which an infant is encouraged in a certain direction (e.g. playing with new toys; Thomas et al., 1968). Mothers used more sinusoidal contours with infants displaying less adaptability. The mothers in our study may be attempting to encourage the infant in the new surroundings with the use of sinusoidal contours, as, again, they are typically used to encourage interactions and convey positive affect (Fernald, 1993; Papoušek, 2007; Stern et al., 1982).

Finally, sinusoidal contours (as well as the number of days preterm the infant was born) were associated with infant intensity score (R^2=.12, *p*=.002). High intensity is viewed as a difficult temperament trait, where infants scoring highly on this domain react strongly and intensely to stimuli (e.g. crying frequently and loudly; Thomas et al., 1968). As stated earlier, sinusoidal contours are used to increase or maintain arousal levels (Papousek et al., 1991; Stern et al., 1982). The mothers in our study used fewer sinusoidal contours with highly intense infants. Sinusoidal contours, which are thought to function to increase arousal, may be less effective for infants whose arousal is already very high as evidenced by reacting to stimuli strongly (Langkamp et al., 1998; Papousek et al., 1991; Stern et al., 1982).

9.1.5 Maternal depression and preterm status as covariates Our results with regard to the role of maternal depression and infant preterm status in temperament are largely in line with previous research. Specifically, we observed that maternal depressive symptoms were associated with infant rhythmicity and adaptability, and the number of days an infant was born preterm was related to infant rhythmicity, intensity and mood.

Maternal depression is linked to maternal IDS, with depressed mothers displaying less pitch modulation in their IDS than non-depressed mothers (Kaplan et al., 2002). Furthermore, mothers with depression often exhibit less engagement in interactions and more negative affect, both factors known to be related to bell-shaped and sinusoidal contours (Kaplan et al., 2002; Papousek et al., 1991; Stern et al., 1982). Maternal depression has also been linked to the infant temperament. Depressed mothers perceive their infants as more difficult in temperament (Edhborg et al., 2000; McGrath et al., 2008). Maternal depression is a covariate in our results, and has been shown to be a predictor of infant temperament, but it is difficult to determine whether this is due to the perception of the mother influencing her judgement of infant temperament. And further, this study suggests that more research needs to investigate whether temperament is directly influenced by maternal depression, or whether maternal depression impacts temperament via the differences in IDS that occur in mothers who are depressed.

In terms of preterm status, studies that show preterm infants are perceived as less regular in body function by parents compared to those born to term (Langkamp et al., 1998). They are also perceived as having a more negative mood and being less adaptable (Langkamp et al., 1998). All of these temperament domains were related to the number of days preterm an infant was born in our study, with infants born more days preterm being perceived by their parents as more negative in mood, less adaptable, and more arrhythmic. Again, it is difficult to discern whether infant preterm status was directly impacting infant temperament, or whether the number of days an infant was preterm was influenced by the mothers' IDS which then influenced the infants' temperament. As such, future studies should take preterm status, and maternal depression, into consideration when investigating maternal IDS and infant temperament.

9.2 Limitations

Five general limitations of this study were 1) that the design was correlational, thus we cannot infer causation from our results, and 2) the IDS data were analysed during the interaction as a whole, and therefore we cannot view contingency, 3) depression data was available for only two of the three cohorts, 4) possible bias in our participants, and 5) this study focussed only on one aspect of prosody. These issues will be discussed in more detail in chapter 11. Limitations specific to the relationship between maternal pitch contours and infant temperament were 1) bias in parent-report, 2) lack of observational assessment, and 3) issues with the TTS profile scores.

The first limitation specific to our investigation of infant temperament and maternal IDS is that mothers rated their own infants' temperament. As such, the temperament data in this study is vulnerable to social desirability and recall bias. The evidence for the presence of social desirability bias is weak, as no mother in this study categorised their infant as having a socially-desirable ‘easy’ temperament profile, however, it is much harder to discern whether the mothers were influenced by recall bias. Recall bias occurs when participants do not remember previous events or experiences accurately, in this case their infant’s usual temperament. Parent-report questionnaires assessing temperament are still extremely valuable despite these biases though, as mothers typically spend a lot of time with their infant, and as such have a very good idea of their infant’s temperament (Rothbart & Goldsmith, 1985). Further, parent ratings of temperament encompass a wide variety of behaviours which would be difficult to observe in other situations, such as a novel laboratory setting, and are likely to be indicative of what an infant is normally like (Richardson & McCluskey, 1983). Bias associated with proxy and self-report can be mediated by observational measures of temperament administered by independent assessors. Thus, the second limitation of this section of our study was a lack of reliable observational measures that could be applied to our video recordings, and as such we did not include an observational measure of temperament in the current study. Of course, there are limitations with observational measures involving lack of context variability in which to observe an infant’s true temperament (Rothbart & Goldsmith, 1985). Studies have compared parent-rated questionnaires and observer rated assessments, and there are discrepancies between them, likely due to the different methods of measurement (Rothbart & Goldsmith, 1985). Despite the lack of cross-method consistency in temperament ratings, each method has advantages. An ideal study would encompass both a parent-rated temperament assessment, as well as an observation-based assessment, in order to provide a global temperament rating of the infant.

Another limitation was the lack of variability in TTS profile scores. No infants in our study were categorised by their mothers as *easy*. The majority (50% and 64.29%) of infants in the BLT-ID and SDPrem cohorts and a large portion (37.5%) of the infants in the BM cohort were rated as being *difficult* in temperament by their mothers. This leads to the question of whether the TTS is sensitive enough as a psychometric measure to capture the nuances in infant temperament. The data in our study seem to suggest that all of the infants tested were on the difficult end of the TTS scale. Perhaps, they were not actually more difficult, but instead the findings of the original study on TTS data by Fullard et al. (1984) are not comparable to our study. This may be because the study was conducted more than 30 years ago, or even that American definitions of temperament do not easily translate to Australia. One study found differences in temperament between American infants and Australian infants using the Carey temperament scales, although these differences were assessed when the infants were much younger than our sample, at 4-months of age (Oberklaid et al., 1984). Alternatively, due to our sampling approach, we may have a selection bias in our study for infants with higher predisposition for a more difficult temperament. The infants within the BLT-ID and SDPrem cohorts were subject to early life stress. The BLT-ID infants all had mothers with asthma, and exacerbations of asthma during pregnancy are common (Murphy, 2006). Further, infants who themselves display asthma symptoms, which is common in infants born to mothers with asthma, have been suggested to have different temperaments than their non-asthmatic peers (Priel et al., 1988). Similarly, all infants within the SDPrem cohort had been admitted to the NICU, also a stressful life event, and many had significant health problems early in life. Preterm birth as well as medical issues early in infancy have been linked to a more difficult temperament compared to infants born to term with no medical issues (Langkamp et al., 1998; Oberklaid et al., 1986). This explanation, however, does not account for the fact that none of the infants in any cohort in our study were rated as easy. Further, the BM cohort, which was a community sample, also had a considerably higher proportion of difficult infants when compared to normative data (12.3%; Fullard et al., 1984).

9.3 Summary and Future considerations

This study is the first to find relationships between the pitch contours used by mothers interacting with their 12-month-old infants, and their infant's temperament. This study extended the work of Woolard et al (2016), further investigating the relationship between maternal pitch contours and temperamental domains in infancy. We found three themes emerged from our study relating the way mothers use pitch contours with their infant's temperament. First, mothers use of rapidly-rising contours relate to their infant's mood. Mothers were using more of these contours if their infant was perceived as having a more negative mood. Second, mothers' use of slowly-falling contours were related to their infant's activity level. Mothers' would use fewer of these contours if infants were more active. And finally, mothers' use of bell-shaped contours were related to both infant activity and mood. Mothers would use more bell-shaped contours if their infant was more negative in mood and more active. Our results, along with previous research, suggest that mothers use these contours in a functional way, responding to their infant's temperament state. If infants are more negative in mood, mothers might try to change their behaviour with rapidly-rising contours or encourage positive affect with their bell-shaped contours. If infants are displaying more activity mothers might try to encourage interaction participation with bell-shaped contours, or if they are less active they might try to encourage that state of low arousal with their slowly-falling contours. It is clear from our results that the way mothers use pitch contours with their infants is related to their temperament, and thus more research needs to be conducted in order to tease apart the directionality within mother-infant interactions, and the way in which infant temperament could impact upon a mother's IDS, and vice-versa. Future studies may consider using real-time audio coding in conjunction with a recorded observation-based temperament assessment in order to detect contingency within interactions. This would allow for investigation into the bi-directionality that is suggested to encompass mother-infant interactions (Feldman, 2007; Thomas & Chess, 1986).Uncovering this bi-directionality within this relationship could lead to interventions to help improve both mother-infant interactions, and also enhance the outcomes of difficult infants.

Chapter 10: Discussion of the relationship between autism and maternal pitch contours

The second objective of this study was to examine the relationship between the pitch contours used by mothers, interacting with their 12-month-old infants, and symptoms of autism in infancy. In line with our aim, this study did find relationships between maternal pitch contours and symptoms of autism in infancy. Further, the results of this study indicated partial support for our hypothesis, that mothers of infants displaying more autism symptoms (indexed by the FYI and ADEC) would use more rapidly-falling and rapidly-rising contours, and fewer bell-shaped and sinusoidal contours during an interaction.

10.1 Interpretation of findings

Similar to the temperament section of this study, several themes emerged from our results. First, sinusoidal contours were related to parent-rated sensory regulation in infants. Second, utterances, not pitch contours, were related to parent-rated social communication, as well as total autism symptoms. Third, flat contours were related to parent-rated and observed autism symptoms in opposing ways. And lastly, that maternal depressive symptoms are related to both IDS and infant autism symptoms.

10.1.1 Sinusoidal contours The mothers in our study used fewer sinusoidal contours when their infants displayed more autism symptoms on the FYI (r_s=-.30, p=.004). This use of fewer sinusoidal contours within the interaction seemed to be more related to their infant displaying sensory regulation issues (r_s=-.31, p=002) than to overall FYI score, as they were not associated with social communication issues on the FYI (r_s=-.15, p=.14). Further, higher infant sensory regulation score (indicating more difficulty with sensory regulation) was associated with higher maternal depressive symptoms, fewer rising and sinusoidal contours, and lower infant score on the cognitive domain of the BSID-III (R^2=.20, p=.005).

Sinusoidal contours, as stated previously, are known to be associated with communicating positive affect, increasing arousal, and encouraging interactions and back-and-forth communication (Fernald, 1989; Papousek et al., 1991; Stern et al., 1982). Mother-infant interactions worsen as autism symptoms increase, with less enjoyment, coordination, responsivity and communication (Beurkens et al., 2013). Further, autistic infants and their mothers have less synchronous interactions (Steiner et al., 2018; Yirmiya et al., 2006). Mothers in our study were using fewer sinusoidal contours when interacting with infants showing more symptoms of autism, and therefore one explanation would be that the mother-infant interactions involving infants displaying more autism symptoms were less synchronous. The mothers of these infants may not have been engaging in as much back-and-forth interaction, a function of sinusoidal contours, and thus the mothers were using fewer sinusoidal contours (Papousek et al., 1991).

Sensory processing issues are suggested to affect up to 96% of autistic individuals (American Psychiatric Association, 2013; Hand et al., 2017; Schoen et al., 2009). Sensory regulation problems in infants include hyper-reactivity (intense, negative response to stimuli), hypo-reactivity (reduced or absent response to stimuli), unusual sensory interests (craving or seeking sensory stimuli), inaccurate perception of stimuli (misinterpretation of stimuli, e.g. volume or pitch of speech), and/or difficulties integrating multiple sensory stimuli (e.g. distinguishing speech in a distracting environment; Ben-Sasson et al., 2009; Hand et al., 2017). The mothers in our study may have been trying to overcome any sensory regulation issues their infants were displaying by using fewer sinusoidal contours, which are typically used to increase arousal (Fernald et al., 1989; Papousek et al., 1991; Stern et al., 1982). By decreasing the number of sinusoidal contours they may have been responding to their infant's behavioural responses to their perception of sensory stimuli or difficulties integrating sensory integrating sensory stimuli by not further increasing their arousal levels (Hand et al., 2017).

10.1.2 Number of Utterances Although the number of utterances the mothers spoke was not a primary variable of interest, it was related to autism symptoms (FYI total, r_S=-.29, *p*=004) and also emerged in our regression analysis as a significant predictor of the infants' FYI total score and social communication score (FYI). Higher FYI total score was significantly related to higher maternal depression scores, lower infant cognitive score, and the fewer number of maternal utterances (R^2=.34, p<.0001). A higher social communication (FYI) score, indicating more issues with social communication, was related to more maternal depressive symptoms and flat contours used, and fewer total number of maternal utterances (R^2=.28, p=.0003).

The scoping review in chapter 3 of this thesis found varied results regarding frequency of speech (in our case, operationalised by the number of utterances) towards infants diagnosed or later diagnosed with autism. Some studies found mothers speak more (Frank et al., 1976; Shizawa et al., 2012), others less (Cassel et al., 2014; Kay-Raining Bird et al., 2008), and one found no difference (Leezenbaum et al., 2014). Our study provides additional evidence that mothers speak *less* with infants displaying more early autism symptoms, and in particular social communication. Our explanation for this pertains to interaction quality. Mother-infant interactions may not be as synchronous between mothers and autistic infants (Steiner et al., 2018; Yirmiya et al., 2006), and the more autism symptoms an infant displays, the poorer the interaction quality with others (Beurkens et al., 2013). Successful and synchronous mother-infant interactions rely on cues from infants to their mother, that the mother then picks up on and responds to (Reyna & Pickler, 2009), and therefore the reduced quality of the interaction may mean the mothers have fewer cues with which to respond. Of course, as this is a correlational study, it could very well be the mother influencing and cueing the infant during the interaction, but this seems unlikely given these infants are displaying sensory regulation and social communication issues and are therefore likely to be displaying behaviours relating to said issues (Ben-Sasson et al., 2009; Hand et al., 2017).

10.1.3 Flat contours Mothers used *fewer* flat contours if their infant displayed more autism symptoms rated by an observer (ADEC, r_s=-.38, *p*=.04). Higher infant ADEC scores were also related to lower infant language scores on the BSID-III as well as fewer rising, bell-shaped, and flat contours and more complex contours used by the mother (R^2=.70, *p*<.0001). Paradoxically, as stated in the previous section, higher score on the parent-rated social communication domain (FYI) was predicted by *more* flat contours used by the mother, as well as more maternal depressive symptoms and fewer utterances (R^2=.28, *p*=.0003).

Flat contours are not typically used in IDS, however in this case flat contours were used less if the infant was rated by an independent observer as having more autism symptoms but used more if the infant was rated by their parent as having more social-communication issues. Flat contours do not engage infants as well as other pitch contours, such as sinusoidal or bell-shaped contours (Papousek et al., 1991). Perhaps infants with more social communication difficulties, a core symptom of autism, have poorer mother-infant interaction quality (Beurkens et al., 2013; Steiner et al., 2018; Yirmiya et al., 2006). Therefore, it is possible that the mothers used flat contours as they were not engaged in an interaction with the infant, and thus did not need to use the other contours shown to be more successful in back-and-forth interactions as they were not actively interacting (Papoušek et al., 1990). However, mothers using fewer of these contours with infants displaying more autism symptoms, as rated by an *observer*, may imply that they had to use other contours in order to either 1) keep their infant engaged, or 2) engage their infant in the first place, as we know infants with autism often have impaired social interactions with others (Deconinck et al., 2013; Wetherby et al., 2004).

These opposing results do suggest, however, that the parent-rated and observation-based assessment do not align. Parent-rated assessments of childhood autism (and frequently other developmental disorders in children) are often not correlated with ratings given by other people close to the child, like teachers (Thompson & Winsler, 2018). This is suggested to be due to different assessors observing different behavioural contexts that the child is in, and therefore giving different information on the child (Szatmari et al., 1994). The ADEC scores infants on symptoms observed during a ~10-minute play session, which is the same context in which the mothers' IDS is measured, and therefore may be picking up on different symptoms to the FYI, which can be seen as a more 'global' rating as it is rated by the parent on many more behavioural symptoms across more contexts (63 items vs. 16 items on the ADEC). In line with this, our study found that the ADEC and FYI scores were not correlated (r_s=-.09, *p*=.66), and therefore maternal ratings and observer-rated scores were independent.

10.1.4 Depression in mothers Depressive symptoms that mothers displayed were predictive of parent-rated autism symptoms. Higher infant score on the FYI (indicating more autism symptoms present) was significantly associated with higher maternal depression scores, lower infant cognitive score, and the fewer number of maternal utterances (R^2=.34, *p*<.0001). Higher infant sensory regulation score (indicating more difficulty with sensory regulation) was related to higher maternal depressive symptoms, fewer rising and sinusoidal contours, and lower infant score on the cognitive domain of the BSID-III (R^2=.20, *p*=.005). And finally, higher score on the FYI social communication domain (indicating more difficulty with social communication) was associated with more maternal depressive symptoms, fewer total number of utterances and more flat contours used by the mother (R^2=.28, *p*=.0003).

These results are in line with previous literature regarding maternal depression, frequency of speech, and infant cognitive and language deficits. Generally, mothers with depression speak less to their infants (Tronick & Reck, 2009). Parental depression has also been linked to the severity of their child's autism symptoms, and with the severity of the child's cognitive and language deficits (Bebko et al., 1987). Further, parents own broader autism phenotype is linked to depression (Ingersoll & Hambrick, 2011). Interestingly, these relationships between the parents' depression, their own broader autism phenotype, and the child's autism severity can be alleviated by social support for the family (Sharpley et al., 1997). Parental depression is also suggested to be a risk factor for autism diagnosis in children if parents are taking antidepressants (Croen et al., 2005; Rai et al., 2013). The predictive models within this study are in line with previous research on maternal depression and reinforce the importance of taking this factor into account when conducting research on autistic populations. As such, future studies should include maternal depression as a covariate, as we did. Infants and children with autism also display difficulty with language and cognition, and they should also be included in future studies investigating mother-infant interactions (American Psychiatric Association, 2013). Furthermore, these factors and the family as a whole are also important to consider when implementing interventions within autistic communities.

10.1.5 Interpretation of null findings Our hypotheses regarding the relationship between maternal rapidly-falling and rapidly-rising contours and infant autism symptoms were not supported. There are two explanations that we put forward for these null findings. First, it is possible that rapidly-rising and rapidly-falling contours are not related to autism symptoms. Rapidly-rising and rapidly-falling contours are prohibitive and increase infant arousal levels (Papousek et al., 1991; Stern et al., 1982). It could be that the most important aspect of pitch contours for infants displaying early autism symptoms is related to the functions that encourage interactions and positive affect, rather than increasing the arousal levels of infants. If this is the case, then it makes sense that only sinusoidal, bell-shaped and rising contours are related to autism symptoms as they promote interactions and the communication of affect, hence the reason mothers use them more frequently during interactions. A second possible explanation is that we did not gather sufficient observations to detect any relationship between rapidly-falling or rapidly-rising contours and infant autism symptoms. This is particularly pertinent of the ADEC assessment, which was only conducted on the SDPrem cohort. It may be the case that we need to observe mother-infant interactions in more contexts, or perhaps we need to include more infants in our sample with a higher representation of infants displaying early autism symptoms. Our samples did not differ in comparison to normative means, and actually scored below norms on the ADEC. This meant that our sample displayed fewer autism symptoms than the original normative studies, which may have led to our null findings regarding any other relationships between maternal pitch contours and autism symptoms because there weren't enough autism symptoms.

10.2 Limitations

One limitation for this section of the study was that only the infants in the SDPrem cohort were tested using the ADEC. Thus, they were the only infants to receive both a parent-rated and observational assessment of autism symptoms. The results pertaining to the observer rated autism assessment (ADEC), although highly significant, should be interpreted with the fact that there were only 26 observations in mind. The findings we demonstrated do line up with the literature, though, regarding the use of pitch contours within interactions, and the links between infant language and maternal depression and autism. Maternal pitch contours, along with infant cognitive scores, were found to be significantly strongly associated with infant scores on the ADEC. It is highly recommended that future studies extend upon this work in order to further understand this relationship.

10.3 Summary and future considerations

This study was the first to investigate the relationship between maternal pitch contours during an interaction and infant autism symptoms at 12-months of age. This study is the first to provide evidence that maternal pitch contours used during interactions are related to early autism symptoms, and further, sensory regulation issues. We also found evidence of the relationship between the number of utterances used during interactions with 12-month old infants, and their autism symptoms and social communication issues. Four themes emerged from our study on autism symptoms and pitch contours. First, sinusoidal contours were related to parent-rated sensory regulation in infants. Second, the number of utterances mothers used were related to parent-rated social communication, as well as total autism symptoms. Third, flat contours were related to parent-rated and observed autism symptoms in opposing ways, evidencing differences in the assessments. Future research should also consider using both an observational measure, as well as a parent-rated measure, as we found they may demonstrate different autism symptoms within different contexts. It is crucial to consider both in order to gain an accurate understanding of early symptoms. And lastly, that maternal depressive symptoms are related to both IDS and infant autism symptoms, and should be considered in future studies.

We recommend future research should extend upon this study. Our results suggest that not only is the quality of IDS (i.e. pitch contours used) important in early interactions with infants displaying autism symptoms, but also the quantity (i.e. the number of utterances). Infants who display autism symptoms have issues with interactions (Beurkens et al., 2013). Understanding the early mechanisms that influence interactions with these infants would lead to earlier diagnosis and improved intervention. Our study has evidenced that pitch contours may be an important mechanism within early interactions with infants displaying autism symptoms, and therefore more research needs to be undertaken in this area.

Chapter 11: General discussion and conclusions

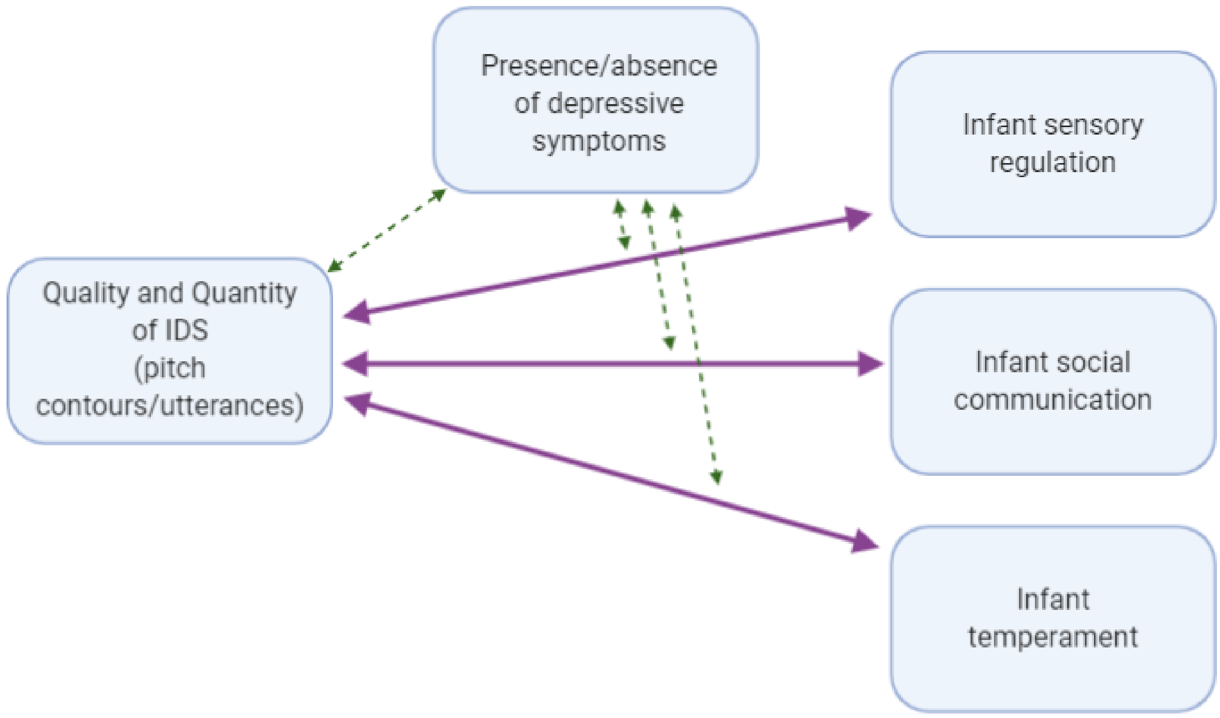
It is known that mothers and their infants influence each other during interactions, however the mechanisms and characteristics behind this influence are not well understood. IDS is crucial for many aspects of infant development and early interactions, therefore the current study aimed to determine if certain infant characteristics were related to pitch contours during interactions between mothers and their infants. We first conducted a scoping review on the literature to determine if parents speak differently to infants and children who are diagnosed, or later diagnosed, with autism. This review determined that the literature in this area is heterogeneous, however some differences in the IDS used in this population were apparent in the studies reviewed. The speech that these infants and children hear may be different in that, compared to typically developing peers, parents speaking to these infants use more exaggerated acoustic features, use more directive speech, and use more attention-bids during their speech. More research in this area was recommended. Our primary study was then conducted which attempted to address two aims. The first aim of this study was to determine whether maternal pitch contours during an interaction were related to infant temperament at 12-months. The second aim was to determine whether maternal pitch contours during an interaction were related to infant autism symptoms at 12-months. This study found evidence to support both aims, with several themes emerging which will be discussed below.

Three themes emerged in our results relating to the way mothers use pitch contours in relation to their infant's temperament. The first theme was that maternal rapidly-rising contours were related strongly to infant mood. Mothers would use more of these prohibitive contours, that are useful in increasing arousal and attention, with infants rated as having a more negative mood (Fernald, 1993; Papousek et al., 1991). The second theme was that slowly-falling contours were strongly related to infant activity. Mothers would use more of these soothing contours if infants were rated as less active. And finally, the third theme was that bell-shaped contours were related to infant mood and infant activity. Mothers used more of these positively affective and interactive contours if infants were rated as having a more negative mood and more activity. It is clear from our results that infant activity and mood are important temperament traits within interactions that may influence mothers. Maternal rapidly-rising, slowly-falling, and bell-shaped pitch contours are also significant factors in relation to infant temperament and interactions, and mothers are likely using these pitch contours in a functional way to influence their infant.

Several themes emerged from our results regarding our second aim, that maternal pitch contours used during an interaction were related to infant autism symptoms. First, sinusoidal contours were related to parent-rated sensory regulation in infants. Mothers would use fewer of the interactive sinusoidal contours with infants displaying more autism symptoms related to sensory regulation. The second theme was that utterances were related to parent-rated social communication, as well as total autism symptoms. Mothers used fewer utterances during the interaction with infants displaying more autism symptoms, particularly relating to social communication. The third theme was that flat contours were related to parent-rated and observed autism symptoms in opposing ways. Mothers used fewer flat contours if infants displayed more observation-based autism symptoms, and fewer if infants displayed more parent-rated social communication issues. And lastly, maternal depressive symptoms are related to both IDS and infant temperament and autism symptoms. Maternal depressive symptoms were associated with infant rhythmicity and adaptability. More maternal depressive symptoms were also related to more autism symptoms generally, as well as sensory regulation and social communication issues.

The themes that have emerged from this study indicate that there are several key pitch contours that are important in early interactions with infants. Rapidly-rising, slowly-falling, and bell-shaped contours seemed to be the key contours that were of importance in our findings regarding infant temperament. Sinusoidal and flat contours were of particular importance when mothers were interacting with infants displaying more symptoms of autism. Further, we found that maternal depression is related to not only autism symptoms, but also IDS generally *and* infant temperament. It is very likely that maternal depression has either a moderating or mediating effect on a mothers' IDS and in turn relates to infant outcomes (see Figure 5).

Figure 5. Maternal depression as a likely mediator/moderator within our key variables of IDS, infant temperament, and infant autism symptoms.



Given that maternal responsivity is linked to the development of communication skills in autistic children as well as language outcomes generally (Siller & Sigman, 2002; Yoder et al., 2015), the relationships found in this study between maternal pitch contours and infant temperament and autism symptoms are important factors to consider when investigating early mother-infant interactions. The results from this study suggest that a mother interacting with her infant is incredibly sensitive to cues the infant gives her; whether they be temperamental, or to do with socio-communicative abilities, or even to do with how they regulate the stimuli around them. This line of thinking proposes that the infant is a far more active participant in dyadic interactions than has been traditionally put forward. Our results, although correlational, provide evidence that infant characteristics are at the very least implicated in the way mothers speak to their infant. More research into the influence that the infant can have on the interactions around them might provide further insight into the facilitation of socio-communicative, sensory and emotional development during infancy.

11.1 General limitations of the study and future recommendations

There are four general limitations that pertain to this study that will be discussed, 1) the correlational design of the study, 2) the interaction design, 3) the maternal depression data only being available for two cohorts, 4) the possibility of volunteer bias within our participants, and 5) this study focussed only on one aspect of prosody. Firstly, the nature of this study is correlational. As such, interpretations made are inferred based on our results and on previous literature and cannot be interpreted as causational within our current design. This limitation relates to the second limitation, that the IDS data within the interactions were analysed as an aggregate total, and infant characteristics were correlated with the aggregate IDS data. In order to tease apart the influence that each partner has on the interaction, it is recommended that future studies focus on a temporal analysis of the interaction. This would mean time-stamping infant cues during mother-infant interactions (perhaps during an observational temperament assessment, or during the ADEC) in order to determine if the mother's use of pitch contours is a response or a catalyst for infant behaviour. This temporal analysis was not feasible for this study, however, now that relationships have been established between maternal pitch contours and infant temperament and autism symptoms, future studies should justifiably investigate this further.

The EPDS was only available for mothers within the BLT-ID and BM cohorts. As such, the mothers in the SDPrem cohort did not have data on depressive symptoms. This is a limitation which lessens the generalisability of the results of this study. We were unable to gain access to the mother's EPDS data within the SDPrem cohort because this study was already established before the PhD candidate started working on this project. Maternal depressive symptoms were a significant predictor the infants' FYI scores as well as their adaptability and rhythmicity TTS scores. Maternal mental health should therefore be considered in future studies investigating not only IDS but also infant outcomes.

The mothers recruited for this study were mostly on a volunteer basis. There is therefore the possibility of volunteer bias, which means that our sample may not be truly representative of the general population. Unfortunately, there is little we could do in the way of overcoming this issue, however future studies should keep this in mind and our results should be interpreted accordingly. Furthermore, the participants in our study all spoke Australian English during the interactions. This is the first study of this kind, however, in order to improve the generalisability of our results future studies should consider replicating our procedure with different languages.

Finally, another limitation of the study was that only pitch contours and the minimum, median, and maximum pitch were analysed in relation to our key variables of interest. Although, as stated previously, pitch contours are highly salient for infants, it would be interesting to determine if other characteristics of prosody in IDS (e.g. loudness or intensity) are related to infant characteristics. It is recommended that future studies investigate the other characteristics of prosody in IDS and whether they are related to infant characteristics such as temperament or autism symptoms.

11.2 Implications and conclusions

This study is the first to relate maternal pitch contours during an interaction and infant temperament and symptoms of autism. It is well established that the role the mother plays during interactions is substantial, however, this study provides evidence that the interactions that occur between mothers and their infants could indeed be *bidirectional*. Furthermore, we know that infants respond differentially to maternal IDS, however very little was known previously about how infant characteristics are related to maternal IDS (Stern et al., 1982). We now know, from the results of this study, that certain temperament domains are important to mother-infant interactions, and further, we know the pitch contours that are involved in these interactions in relation to infant temperament. Maternal pitch contours are crucial to many aspects of infant language, emotional, and socio-communicative development, and therefore it is essential to understand the different contexts in which they can be influenced.

Infant temperament is influential during early interactions, and we also know that temperamental domains are relatively stable (Bates et al., 1985; Fox & Henderson, 1999; Milliones, 1978). The influence that temperament can have on early interactions can significant implications not only for early relationships the infant makes with others, but also their development generally. If research can uncover more information on how infant temperament shapes and is shaped by maternal IDS, then interventions can be implemented that target parent-training in order to improve infant and parent experiences.

This study has also highlighted that maternal pitch contours and early symptoms of autism in infancy are related. This is the first study to do so, and as such the implications of this knowledge are great. We now know that certain pitch contours are more associated autism symptoms, and now more work needs to determine if these pitch contours associated with autism symptoms influence the behaviours of infants during interactions and whether this has longitudinal implications for their development. We have also contributed to the growing body of knowledge surrounding the use of IDS with infants displaying symptoms of (or are later diagnosed with) autism. Autism research has been focussing on early detection and intervention, which will ultimately lead to lessening the burden on health care systems and families affected by an autism diagnosis. It is of the utmost important to be able to assist in the improvement of early symptoms in order to improve functional outcomes of children with autism. The current study is a step in the right direction towards this outcome. If research can target the how pitch contours, that assist in language, attention, and socio-communicative development in infants, are influenced by autism symptoms, then perhaps interventions can be put in place that utilise this information. There are already many useful interventions for children with autism which focus on carers or parents responding appropriately and contingently to the child's interactive behaviours, and conceivably the results from this study can help inform such interventions which focus on the quality of IDS used with much younger children and infants (NICE, 2013).

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Appendix 1: Study protocol for BLT-ID 6-week appointment

BLT-ID **6 weeks**

Participant ID______________ Time start ________________	Date _____________________ Time end ________________ Researcher __________________
Before participants arrive: ☐ Collect 6 week parent questionnaire packet & pen ☐ Ensure room is set up, with materials/toys/mat for: - Parent-child interaction (with toys for 6 week old infants) ☐ Is the video camera set up and fully charged? ☐ Phones off **After participants arrive** ☐ Greet family in HMRI waiting room ☐ Bring them into allocated research room in research pod ☐ Give parent PIS and consent form ☐ Collect consent form ☐ Mother and infant happy to proceed with testing? ☐ Collect any completed questionnaires mailed beforehand	☐ Ask parent their sociodemographic info and medical history (10 mins) ☐ Invite mother to complete questionnaires at a desk (if not completed before?): - Infant/Toddler Sensory Profile (10 mins) - Carey Temperament Scale (20 mins) - Edinburgh PND Scale (10 mins) - Parenting Stress Index (20 mins) ☐ Collect questionnaires ☐ Explain process of recorded interaction ☐ Invite parent to play mat area to engage in spontaneous parent-child interaction with toys ☐ Press 'record' on camera and start timer for 15 mins ☐ Stop recording ☐ Conclude testing session and thank participants ☐ Show participants out of pod ☐ File consent form & questionnaires ☐ Clean/set up room

Appendix 2. Study Protocol for the BLT-ID study 6-month appointment

BLT-ID **6 months**

Participant ID______________ Time start ________________ Examiner _________________	Date _____________________ Time end _________________ Time baby last slept _________
Before participants arrive: ☐ Collect 6months parent questionnaire packet ☐ Ensure room is set up, with play mat and toys out, and testing kits accessible ☐ Set up video camera and test to ensure it is working and is fully charged **After participants arrive** ☐ Greet participant ☐ Get participant to sign consent form ☐ Phones off ☐ Collect any completed questionnaires that have been mailed to the participant beforehand	☐ Ensure mother and baby are settled and happy to proceed with testing ☐ Invite mother to complete questionnaires at a desk ☐ Administer Bayley scales -3 screener to child (30mins) ☐ Invite mother to the play mat area to engage in 15 minute spontaneous parent-child interaction ☐ Set timer for 15 minutes and press record on video camera ☐ Complete eye tracking (20mins)? ☐ Administer Test of Sensory Function in Infants (20mins) ☐ Conclude testing session and thank participants

Appendix 3. Study protocol for the BLT-ID study 12-month appointment

BLT-ID **12 months**

Participant ID______________	Date _____________________
Time start ________________	Time end ________________
	Researcher __________________

Before participants arrive:

☐ Collect 12 month parent questionnaire packet & pen

☐ Ensure room is set up, with materials/toys/mat for:

- Parent-child interaction (with toys for 12 month old infants)
- Bayley Scales
- Test of Sensory Function in Infants

☐ Is the video camera set up and fully charged?

☐ Phones off

After participants arrive:

☐ Greet family in HMRI waiting room

☐ Bring them into allocated research room in research pod

☐ Mother and infant happy to proceed with testing?

☐ Give parents consent form

☐ Collect consent form

☐ Collect any completed questionnaires mailed beforehand

☐ Complete Bayley Scales with child (1 hour)

**Feel like we need to break these down into more steps, but need to know more about them!*

☐Ask parent updated infant medical history

☐ Ask parent updated their medical history (including medical health hx) (5 mins)

☐ Invite parent to complete questionnaires at a desk (if not completed before?):

- Infant/Toddler Sensory Profile (10 min)
- Carey Temperament Scale (20 mins)
- Macarthur Communication Development Inventory (20 mins)
- First Year Inventory (10 mins)
- ASEBA (30 mins)
- Parenting Stress Index (20 mins)
- Brief

**Might be better to break up all these Qs with parent-child interaction/sensory measure? Or parents complete while conducting Bayley Scales?*

☐ Collect questionnaires

☐ Invite parent to play mat area to engage in spontaneous parent-child interaction with toys

☐ Press 'record' on camera and start timer for 20 mins

☐ Stop recording

☐ Show participants out of pod

☐ Complete test of sensory function on infant, using parent's help (20 mins) ☐ Conclude testing session and thank parents	☐ File consent, questionnaires and record forms for Bayley & Test of Sensory Function ☐ Clean/set up room for next participant

Appendix 4. Study Protocol for the BM cohorts

Age	**Questionnaire Measures***	**Lab Assessment Measures**
6 weeks	About the infant: Infant Toddler Sensory Profile (10 mins) Carey Temperament Scales (20 minutes) About the parent: Sociodemographic (postcode) & medical history Questionnaire, including mental health history (10 mins) Edinburgh Post-Natal Depression Scale (10 minutes) Parenting Stress Index – Short Form (10 minutes) Achenbach System for Empirically Based Assessment (ASEBA) – adult (30 minutes) Behaviour Rating Inventory of Executive Functions – Adult (10 minutes) Adult ADHD Self-Report Scale (ASRS-v1.1) Symptom Checklist (5 mins) **Total Questionnaire Completion Time = ~1 hr 45 minutes**	Parent-infant interaction (15 minute video of spontaneous interaction with parent) **Total Lab Assessment Time = ~15 mins**
6 months	About the infant: Infant Toddler Sensory Profile (10 mins) Carey Temperament Scales (20 minutes) Social-Emotional and Adaptive Behaviour Questionnaire (20 minutes) Updated infant medical history (5 minutes) About the parent: Updated medical history including mental health history (5 minutes) Achenbach System for Empirically Based Assessment (ASEBA) – adult (30 minutes) Parenting Stress Index – Short Form (10 minutes)	Bayley Scales-3 Screener (30mins) Parent-infant interaction (15 minute video of spontaneous interaction with parent) – including audio for linguistics/acoustics analysis; play assessment; parent-child interaction assessment Eye tracking protocol (20 minutes) Test of Sensory Function in Infants (15 minutes)

	Behaviour Rating Inventory of Executive Functions – Adult (10 minutes) **Total Questionnaire Completion Time = ~1 hr 50 mins minutes**	**Total Lab Assessment Time = ~ 1.5 hours**
12 months	About the infant: Infant Toddler Sensory Profile (10 mins) Carey Temperament Scales (20 minutes) Macarthur Communication Development Inventory (OZI – Australian English Version) (20 mins) First Year Inventory (10 mins) Social-Emotional and Adaptive Behaviour Questionnaire (20 minutes) Updated infant medical history (5 mins) About the parent: Updated medical history including mental health history (5 mins) ASEBA – adult (30 minutes) Parenting Stress Index – Short Form (10 minutes) Behaviour Rating Inventory of Executive Functions – Adult (10 minutes) **Total Questionnaire Completion Time = ~2.5 hrs**	Bayley Scales-III (1 hour) Parent-infant interaction (15 minute video of spontaneous interaction with parent) Eye tracking protocol (20 minutes) Test of Sensory Function in Infants (15 minutes). Autism Detection in Early Childhood Assessment (10-15 minutes) **Total Lab Assessment Time = ~2 hrs**

Appendix 5. Study protocol for the SDPrem cohort

Participant ID____________	Date ____________
Time Start ____________	Time End ____________
Room ____________	Researcher____________
Before participants arrive: ☐ Take out assessment form package for 12 month olds, place on table ☐ Ensure room is set up, with pens, tissues and other materials/toys/mat: • Bayley-III full assessment • Test of Sensory Function in Infants ☐ Phones on silent ☐ Wash hands **After participants arrive:** ☐ Greet family in HMRI waiting room ☐ Bring them into allocated research room in research pod ☐ Seat mother in assessment room, give brief instructions for assessment procedures ☐ Give parent consent form and answer all questions before proceeding ☐ Collect consent form ☐ Caregiver and infant happy to proceed with testing? ☐ Collect any completed questionnaires mailed beforehand ☐ Administer Bayley-III with child (1 hr) ☐ Administer Test of Sensory Function with infant with mum's help (20 mins) ☐ Conduct Interaction:	• If there are any siblings/other family members, direct to waiting room • Any extra toys will need to stay in the pram *"We will now ask you to interact with your child as naturally as possible, like you do would do in your own home. This play session will run for 15 minutes and will be videotaped and audio recorded. During the first half, there will be no toys involved. Halfway into the session, we will quietly come in and place a bucket of toys in reaching distance for you and your child to use. We would like you to use the toys to engage with you child, in any way you see fit. Do you have any questions before we begin?"* ☐ Turn on audio recording equipment and calibrate the equipment to mums voice *"I will now attach the microphone to you which will record any sound during the interaction. (turn ON and attach microphone; make sure it is NOT on mute). Tell the mother that we need to adjust the microphone settings to suit her voice"* Ask mother to recite the alphabet, then press record when calibrated ☐ Turn on video recording equipment and press record *"I will now ask you to sit on the play mat with your infant and to stay within the boundary of the mat, but feel free to move around on the mat."* **Comments:**

"We will now leave and return after 15 minutes, remember that we will bring toys in halfway through the session." • Leave room and start timer: Record for 15 mins. • At 7.5 minutes go to lab room and place toys next to mother within reaching distance, trying not to interact with the dyad: LITTLE PHONE, PLANE and TRUCK ☐ Re-enter and conclude interaction at 15 mins. ☐ Ask participant if they would like to conduct eye-tracking and questionnaires for the BabyMinds Study • If yes, show participants down to EEG room, have them sign consent for BabyMinds and explain the eye-tracking procedure ☐ Conclude testing session and thank participants: *We have now finished testing for today and we thank you for your time. Do you have any comments or questions?* ☐ Show participants out of pod **After participants leave:** ☐ Sterilise toys, equipment, table, and chairs ☐ File consent form, Bayley, TSFI and questionnaires ☐ Prepare room for next participant: take out bin and re-wash hands.	

Appendix 6. Participant information statement for the BLT-ID study

<u>How will your privacy be protected?</u>

Any information you provide for this study will be confidential. Only the research team will have access to your or your child's information. We will allocate all children a study code so that they are not easily identifiable. Details that identify you or your child will be removed when the study is complete.

The results of this study will be collated and communicated to the scientific community. They may also be compared to results from other studies. Individual participants will not be identifiable in any report.

<u>What choice do you have?</u>

It's up to you! Participation in this study is entirely voluntary. If you decide that you do not want your child to participate in the study this will not affect the health care you or your child receive. If at a later date you wish to withdraw your child from the study you are free to do so without having to give a reason.

If you decide to withdraw from the study all the information collection about you and your child will be destroyed. An exception to this is in the case of an adverse event where data needs to be retained for regulatory reporting. Importantly, your decision on participating or not in this follow-up study will not impact on your participation in the overall BLT project.

<u>What do you need to do to participate?</u>

If you have further questions or would like to participate please phone the study team on 02 4042 0130.

We may contact you later on to assess your child's progress or to invite you to participate in further follow-ups.

We would like to thank you for your interest in this study, even if you decide not to participate.

<u>What if I have a complaint about the study?</u>

This research has been approved by the Hunter New England Human Research Ethics Committee of the Hunter New England Local Health District, Reference number [15/05/20/4.05]

Should you have concerns about your rights as a participant in this research, or you have a complaint about the manner in which the research is conducted, it may be given to the researcher, or, if an independent person is preferred, to Dr Nicole Gerrand, Manager, Research Ethics and Governance Unit, Hunter New England Human Research Ethics Committee, Hunter New England Local Health District, Locked Bag 1, New Lambton NSW 2305, Ph (02) 4921 4950. Email: <u>hnehrec@hnehealth.nsw.gov.au</u>.

Find us on facebook (www.facebook.com/breathingforlifetrial)

Information for Parents/Guardians

Breathing for Life Trial

The Breathing for Life Trial - Infant Development: A follow-up study investigating infant and childhood development subsequent to maternal asthma intervention.

We would like to invite you and your infant to participate in our *Infant Development* follow-up study

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Why is the research being done?

Previous studies have suggested that children whose mothers have asthma have a higher likelihood of having developmental delay. There is a lack of robust research in this area, however. This study aims to provide a detailed profile of the development in the first year of life of infants whose mothers have asthma. Clinicians may be able to use the information from this study to plan appropriate clinical services to meet the developmental needs of these infants.

Who can participate?

- **Mothers who participated in the Breathing for Life Trial (BLT), and their infants**

What does the study involve?

If you agree to participating, you will be asked to sign the Parent/Guardian Consent form. We will invite you and your baby to a developmental assessment session at 6 weeks, 6 months and 12 months of age. We will also look at your own wellbeing in your role as a parent.

At 4-6 weeks of age

We will ask you complete a set of questionnaires regarding your child's temperament and response to sensations such as touch or sound We will also assess your own parenting experience so far, including how you think you are coping and how you are currently feeling. We will do this since parenting stress and mental health has been found to impact child outcomes. The questionnaires will take about 1.5 hours to complete and you can do this in the comfort of your own home. We will also ask you to take part in a 15-minute videoed interaction with your infant. This session will. coincide with the lung function test of the BLT and be held at HMRI

At six months of age We will again ask you to complete questionnaires regarding your child's development and about your own mental health. The questionnaires will take about 1.5 hours to complete. You can complete these questionnaires prior to your arrival or at the appointment. At this session we will assess developmental milestones in your child. This involves the child sitting on your lap or lying on a play mat. The researcher will present your child with different objects or sounds and observe how the child reacts to them. An eye-tracking study will be used to further assess their mental development. During this assessment your child will sit on your lap whilst watching visual scenes of objects and people on a computer screen. The eye gaze of your child will be recorded using a camera. Finally, a 15-minute interaction between you and your child with and without toys will be videoed. We expect the session to take approximately 1.5 - 2 hours depending on your child (if they are tired or need a feed we will take breaks as appropriate). This session will coincide with your appointment for the BLT at HMRI.

At 12 months of ageThe set-up is almost identical to the six-month session but might take a bit longer depending on your child since they are able to complete more tasks at this age. The additions are a more thorough assessment of language development and also a parental questionnaire about your child's behaviours. This assessment will be scheduled at your convenience around the time of your final appointment with the BLT follow up team, but will be separate to the other assessments to ensure that your child is not tired. It will take place at HMRI.

Are there risks and benefits of participating?

Note that all members of the BLT Infant Development research team have a background in psychology or occupational therapy. The team is headed by a registered Psychologist (Dr Linda Campbell) and registered Occupational Therapist (A/Prof Alison Lane). All persons participating in the assessments are experienced in assessments and have a "Working with Children Check".

None of the assessments should incur any risks to you or your child. However, your child may become tried; if your child needs a nap or a feed that is fine. If you feel that any of the questions about your own wellbeing have caused distress, we can offer you an initial assessment by a registered Psychologist and referral to your local community mental health service for further assessment. Alternatively the number for Lifeline is 13 11 14 and they can provide immediate telephone counselling. If your child shows any signs of developmental delay, we will discuss this with you and refer to any appropriate service provider in your area for follow-up.

While we intend that this research study furthers knowledge of development of children whose mothers have asthma, it will not be of direct benefit to your child. **We will provide you with your child's developmental test results subsequent to participation**. Participation in this study will not cost you anything, nor will you or your child be paid.

Parent/Guardian Consent Form

The Breathing for Life Trial - Infant Development

A follow-up study investigating infant and childhood development subsequent to maternal asthma intervention.

Investigators: Dr Linda Campbell, Dr Vanessa Murphy, Associate Professor Alison Lane, Dr Titia Benders, Associate Professor Frini Karayanidis.

I, ... [name of parent/guardian]

of ....[address],

Parent/Guardian of …………………………………………………………………….. [name of child]

have read and understand that the study will be conducted as described in the Information Statement, a copy of which I have retained.

- I have been made aware of the procedures involved in the study, including any known or expected inconvenience, risk, discomfort or potential side effect and of their implications as far as they are currently known by the researchers.
- I understand that I can withdraw myself and/or my child at any time without providing a reason.
- I understand that my own and my child's personal information will remain confidential to the researchers.
- I have had the opportunity to have questions answered to my satisfaction.
- I understand that information from the BLT and the BLT-follow-up study will be linked to the current information.

I hereby agree to my own and my child's participation in this research study. **YES** **NO**

In addition (please circle as appropriate)

I consent to be contacted about further studies, in the next five years, investigating my child's progress or follow-up studies **YES** **NO**

I consent for information from the current study to be used in future studies by the research team. **YES** **NO**

I consent to be contacted about future studies, in the next five years **YES** **NO**

I consent to the use of my own de-identified information being shared with other researchers for additional studies **YES** **NO**

I consent to the use of my child's de-identified information being shared with other researchers for additional studies **YES** **NO**

NAME OF PARENT/GUARDIAN: ______________________________

SIGNATURE: ______________________________

DATE: ______________________________

Declaration by person conducting the consent process

I, the undersigned, have fully explained this research to the patient named above.

NAME: ______________________________

SIGNATURE: ______________________________

The Breathing for Life Trial - Infant Development

A follow-up study investigating infant and childhood development subsequent to maternal asthma intervention.

Investigators: Dr Linda Campbell, Dr Vanessa Murphy, Associate Professor Alison Lane, Dr Titia Benders, Associate Professor Frini Karayanidis.

I, ... [name of parent/guardian]

of ....[address],

Parent/Guardian of ……………………………………………………………….. [name of child]

hereby give my consent for video taping, filming and/or photographing of myself and my child for the purposes indicated below (initial all appropriate).

_______ For the purposes of data analysis carried out by the research team and consistent with the aims of the Breathing for Life: Infant Development study

_______ For the press and or publication to be used at the researchers' discretion; to be published in newspapers, magazines or shown on television to the public.

_______ For professional use or teaching; including publication in a medical or scientific journal or presented at a meeting of health care professionals.

I understand that my name will be kept confidential regardless of the use of this photograph, film, or videotape.

Signature:___________________________ Staff: ____________________________

Witness: ___________________________

Appendix 8: Poster for the BM study

BabyMinds: A Study of Infant Development and Parental Well-Being

Now recruiting research participants

Learn more about your baby's development by participating in this study!

Researchers at the University of Newcastle are carrying out a new study to gain a better understanding of babies' development in the first year of life.

Who can participate?

Parents and their babies between the ages of 6 weeks and 13 months of age.

What does the study involve?

Three sessions (1-3 hours depending on the child's age), completing a parent-baby play interaction, various assessments of baby development and parent well-being. We will also video the eye gaze of your baby while s/he watch objects/people on a computer screen.

What will you receive for participating in the study?

- Close tracking of your baby's development with feedback from experts, including a brief report at 6 and 12 months.
- A 'graduation' picture of your child after completing the study.

Privacy

Confidentiality and privacy are of utmost concern for us. Please be assured that, whatever your decision about the study, it will have no effect on the care that you receive from Child and Family Health Nursing (CFHN), John Hunter Children's Hospital or any other health care provider now or in the future.

Appendix X: Participant information statement for the BM study

Information for Parents/Guardians V2, date 12/02/2018

Baby Minds

Sign up for research

If you would like more information, or wish to register your interest in participating;

Call Carly Mallise (PhD candidate), on (02) 4985 4565 or send an email to babymindsstudy@gmail.com

Alternatively, you can complete the attached contact consent form and return it in the reply-paid envelope either by posting it or giving it to the Child and Family Health nurse.

Sessions will be carried out either at the Hunter Medical Research Institute or the Ourimbah Campus of the University of Newcastle, as agreed with each participant.

Appendix 9. Participant information statement for the BM study

We would like to invite you and your baby to participate in our study of infant development and parental well-being!

Baby Minds

We are investigating how infant development across the first year of life is shaped by parental health and well-being.

You can participate either at the Hunter Medical Research Institute in Newcastle or at the Ourimbah Campus of the University of Newcastle.

If you are interested read this information and contact us.

Principal Investigators:
Dr Linda Campbell
A/Professor Alison Lane A/Professor
Frini Karayanidis
Dr Titia Benders

Contact Person:
Ms Carly Mallise
A: Psychology Building, The University of Newcastle, University Drive, Callaghan, NSW 2308
Ph: (02) 4985 4565
E: babymindsstudy@gmail.com

Why is the research being done?

There is increasing evidence that a child's temperament, sensory processing, and their parents' well-being can affect a child's development.

In this study, we profile infant development in the first year of life to explore relationships between infant developmental patterns and parental health and wellbeing. We aim to identify factors that influence infant development and can help clinicians plan appropriate services to meet infants' needs.

Who can participate?

Parents of infants aged 6 weeks, 6 months, and 12 months are invited to participate. If you are interested, please contact us before your infant reaches these ages, or while you or your partner are still pregnant.

What does the study involve?

If you agree to participate and sign the Parent/Guardian Consent form, you and your baby will be invited attend testing at 6 weeks, 6 months and 12 months of age. We will complete a developmental assessment of your baby and assess your wellbeing in your role as a parent. This study is run at the Hunter Medical Research Institute, Newcastle and at the Ourimbah campus of the University of Newcastle.

Some tests are identical across the three testing sessions. Others differ, as your baby becomes able to achieve more tasks.

Session 1: 6 weeks of age
This session will include:

- A short videotaped play session with your baby (15min).
- A set of questionnaires about your baby's temperament and your health and well-being which you can complete prior to, or after, your visit. The whole set takes 1.5 – 2 hours, but can be done at your own pace.

Session 2: 6 months of age
This session will include:

- A short videotaped play session with your baby (15min).
- A set of questionnaires about your baby and yourself, which you can complete during the visit or at home. Some of the questionnaires will ask questions related to mental health and drug & alcohol consumption. Again, the whole set takes 1.5 – 2 hours, but can be done at your own pace.
- An assessment of your baby's developmental milestones. While your baby sits on your lap or lies on a mat, the researcher will:
    - examine your baby's response to different objects or sounds.
    - measure your baby's ability to track objects presented on a computer screen with their eyes.

The session takes approximately 1.5 - 2 hours. The exact time will depend on your baby (if they are tired or need a feed, we will take breaks as appropriate).

Session 3: 12 months of age
This session is almost identical to the 6 month session. However, as your baby is older and can complete more tasks, it may take a bit longer (e.g., we can complete a more thorough assessment of language development). We estimate it will take 1.5-2.5 hours.

Are there risks and benefits of participating?

All researchers of the Baby Minds team have a background in psychology or occupational therapy. The team is headed by a registered Psychologist (Dr Linda Campbell) and registered Occupational Therapist (A/Prof Alison Lane). All persons participating in the assessments are experienced in assessments and have a "Working with Children Check".

The assessments do not carry any risks to you or your child. If your child becomes tired or needs a nap or a feed, we can take a break or complete testing another time.

While this research will help us understand whether there is any relationship between parental factors and infant development, there is no direct benefit for your baby. However, you will be given the option of receiving the results of your infant's developmental tests. If these results suggest any cause for concern (e.g., signs of developmental delay), we will discuss this with you and refer you to an appropriate service provider in your area for follow-up.

You will also be given the choice of having a photo taken of your baby after they 'graduate' from our testing session for you to keep, complete with a graduation certificate and graduation gown! If you consent, after viewing the image, we can even share this on our social media platforms without any other identifying information.

Some questions are quite personal, asking about substance use and negative thoughts. It is known that parental stress and mental health may affect child outcomes. Therefore, we need to take these into account when looking at parental factors and infant development. However, you do not have to answer any questions that make you feel uncomfortable. If you do feel any distress, we can offer you an initial assessment by a registered Psychologist and referral to your local community mental health service for further support. Alternatively, you can contact your GP for an assessment and referral, or call Lifeline on 13 11 14 for immediate telephone counselling. If it become known to the researcher that a child is at risk of significant harm, that is if there are current concerns regarding the safety, welfare or well-being of the child, we will report this to the appropriate authorities.

You are encouraged to share and discuss the information provided within this flyer with other people prior to signing our consent form. In addition, potential participants are able to bring an interpreter, relative or friend with them as support during the consenting procedure.

Participation in this study will not cost you anything. Parking at HMRI and Ourimbah is also free for participants.

How will my privacy be protected?

Any information you provide for this study will be de-identified (that is, you and your child will be allocated a study code and your names will be removed) and kept confidential. The exception to this is if we are required, by law, to report information related to child protection. The link between the study code and you or your child will be removed when the study is complete, unless you choose to be contacted for follow-up studies.

De-identified data will only be accessible by the research team and be used for scientific theses / publications / presentations and may be compared to results from other studies. If you consent, your de-identified video data may be shared with the scientific community (e.g., scientific presentations), shared with other researchers for research purposes, and/or used for educational purposes.

If you consent to have your child's 'graduation' photos posted on our social media platforms and/or used in scientific presentations, we will not use it with any other identifying information pertaining to you or your child. The photos may be posted on our website www.findlab.net.au or on our study specific Instagram, Facebook or Twitter accounts. In addition, with your consent, we may include the de-identified picture in scientific presentations when we discuss our study.

What choice do I have?

It's up to you! Participation is entirely voluntary. If you decide not to participate in the study, this will not affect your access to health care or any other related services. If you consent to participate, you can change your mind and withdraw from the study without having to give a reason. In this case, you can withdraw all your data from the study. The only exception involves data related to an adverse event, which need to be retained for regulatory reporting.

What do I need to do to participate?

If you have any questions or would like to participate, please call or email our recruitment officer, Ms Carly Mallise, on 4985 4565, or babymindsstudy@gmail.com.

Alternatively, if you are the father, and your baby is participating in this study, we will contact you via a letter with an invitation to participate. If you choose to participate in our study, we will send you a few questionnaires regarding some sociodemographic information, your everyday functioning and your attentional abilities.

As part of the consent process, we will ask your permission to contact you with information about follow-up studies. If you consent to be contacted in the future for follow-up studies, this by no means obligates you to participate. We thank you for taking the time to consider this study.

What if I have a complaint about the study?

This research has been approved by the Hunter New England Human Research Ethics Committee reference number [17/12/13/4.01]. If you want any information about your rights as a research participant, or if you have a complaint about the manner in which the research is conducted, you can contact Dr Nicole Gerrand, Manager, Research Ethics and Governance Unit, Hunter New England Human Research Ethics Committee, Locked Bag 1, New Lambton NSW 2305, Ph (02) 4921 4950. Email: hnehrec@hnehealth.nsw.gov.au.

BabyMinds: A Study of Infant Development and Parental Well-Being

Investigators: Dr Linda Campbell, A/Prof Alison Lane
Professor Frini Karayanidis

Baby Minds

and

I, ... [name of parent/guardian]

of .... [address],

Parent/Guardian of ……………………………………………………….. [name of child]

have read and understand that the study will be conducted as described in the information provided.

I hereby register my interest in participating in this study and consent for the research team to contact me. I understand that I will be provided with more information before deciding if I would like to participate in the study. I understand that by signing this form I am not committed to participate in this study. I also understand that participation is voluntary.

NAME OF PARENT/GUARDIAN: ______________________________

CHILD'S D.O.B: ______________________________

BEST CONTACT NUMBER: ______________________________

BEST EMAIL ADDRESS: ______________________________

PARENT/GUARDIAN SIGNATURE: ______________________________

DATE: ______________________________

Please return this part of the form in the reply paid envelope.
You can either post it or give it to the Child and Family Health nurse.

Consent for Video Taping, Filming and/or Photography

Baby Minds:

A study of infant development and parental well-being.

Investigators: Dr Linda Campbell, A/Prof Alison Lane and A/Prof Frini Karayanidis.

I, ... [name of parent/guardian]

of ……………………………………………………………………………………………………[address],

Parent/Guardian of …………………………………………………………………….. [name of child]

hereby give my consent for videotaping, filming and/or photographing of myself and my child, for the purposes indicated below (**initial all appropriate**).

_______ For data analyses carried out by the research team, consistent with the aims of this study.

_______ For data analyses carried out by the research team, alongside data from other studies.

I understand that, in all cases, my name and my child's name will be kept confidential. Video data obtained from this research study will only be accessed by enrolled students and investigators on the study. This video data will be used by researchers to code infant temperament and attachment styles.

In addition (please circle as appropriate)

1. I consent for video data to be shared with the scientific community **YES / NO**
2. I consent for photography of my child to be shared on social media sites that the research team is affiliated with **YES / NO**

SIGNATURE: ______________________________

DATE: ______________________________

Declaration by person conducting the consent process

I, the undersigned, have fully explained this research to the participant named above.

NAME: ______________________________

SIGNATURE: ______________________________

Baby Minds

Dear Participant,

In order to promote our research and to disseminate the findings from the study, we regularly develop recruitment materials such as posters and fliers, post on our website and social media account, undertake community, educational and scientific presentations and write theses and articles (both scientific and community based) about our research.

In order to develop appropriate materials, it is really useful to have images illustrating what we do in the study. Hence, we seek your consent to take photos of you and your child in today's session and to use them in the promotion of our research of early child development.

If you consent, you will be provided with an opportunity to view the images and confirm your consent. Any images you do not feel comfortable sharing, will be deleted immediately. The images will not be used with any identifying information, such as name, without your explicit consent.

Kind regards

BabyMinds research team

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

HMRI Hunter Medical Research Institute

NSW GOVERNMENT Health Hunter New England Local Health District

Image consent form

Name ______________________________

Address ______________________________

Phone ______________________________

Email ______________________________

I have been given the opportunity to view the images (please tick): ☐

This consent form authorises the researchers to publish/disseminate the images via electronic and/or other form, to be shown in public via promotion materials, newspaper, magazine, internet, scientific presentations, theses, educational materials or other means.

I acknowledge that I assign all rights, title and interest including copyright to our research team, and acknowledge that our research team is not obliged to use the multi-media material if it so chooses.

I consent for the images to be used as required and without restriction

Signature: ______________________ Date: ______________

For the purposes described below:

____

____

For distribution/public as described below:

____

____

Signature: ______________________ Date: ______________

Re: Invitation to participate in a research study Characteristics and Moderators of Sensory Modulation in Preterm Infants, in the First Year of Life

I am writing to invite you to consider participating in a research study on 12 month old infants.

Participation would involve completing four caregiver questionnaires, and attending a 2 hour appointment with your child at the Hunter Medical Research Institute.
At this visit, you will be required to complete the questionnaires whilst researchers administer a series of measures relating to overall development as well as their response to a range of sensory experiences (touch, visual etc). Please find enclosed a Participant Information Sheet on the study that will provide you with more details about the project.

Participation in the study is voluntary. If you would like more information, or wish to register your interest in participating, please do not hesitate to contact PhD student Alix Woolard on *4033 9160 or 0414 697 710* or email alix.woolard@uon.edu.au. Please note a follow up phone call will be conducted if we have not heard from you within 2-4 weeks of the date of this letter.

Please be assured that, whatever your decision about the study, it will have no effect on the care that you receive from John Hunter Children's Hospital now or in the future.

Thank you for considering this invitation. Yours sincerely,

Dr. Larissa Korostenski
Neonatologist
Neonatal Intensive care
John Hunter Children's Hospital

Characteristics and moderators of sensory modulation in preterm infants, in the first year of life.

INFORMATION FOR PARTICIPANTS

Introduction

You are invited to take part in a research study into the *sensory modulation of preterm and full term infants at 12 months of age*. Sensory modulation occurs when our central nervous system takes in and responds to sensory information from our environment. Children can over-respond (e.g. covering ears to a loud, unexpected sound) and under-respond (e.g. not showing a reaction to pain) to many different types of sensory information. This research is being undertaken by PhD student Miss Alix Woolard from the University of Newcastle, Australia, under the supervision of Associate Professor Alison Lane from the University of Newcastle. This research is being completed in conjunction with Ms Michelle Jackman and Dr. Larissa Korostenski from the John Hunter Children's Hospital.

Why is this research being done?

Previous studies have identified that babies and infants born early can respond differently to certain sensory experiences (e.g. being aversive to certain touch or sounds) compared to other children their age. Research has also found that there is a higher risk of developmental delay in infants born preterm. However, there is a lack of robust research in this area. This study aims to understand any differences between the sensory modulation of preterm and full term infants, and whether these differ based upon experiences such as admission to the Neonatal Intensive Care Unit (NICU) in the first year of life. This study will also explore whether there is any association between sensory modulation differences and risk for developmental disorders including autism. Clinicians may be able to use information from this study to plan appropriate services to meet the needs of preterm infants in their care.

Who can participate?

- Infants born at John Hunter Children's Hospital who were admitted to the Neonatal Intensive Care Unit (NICU) at birth, and are aged between 10 and 14 months, at the time of testing.
- Infants who were born at the John Hunter Children's Hospital who were not admitted to the NICU at birth, and are aged between 10 and 14 months, at the time of testing

What does the study involve?

If you agree for your child to participate in this study, you will be asked to contact our research assistant Jordan Tait to register your interest in this project, and arrange an appointment time. At the appointment you will be asked to sign a Parent/Guardian Consent Form indicating you agree to participate. We invite you to have a friend and/or a relative present when you attend the testing session. You and your child will then be invited to participate in a clinical assessment whereby you will complete a few questionnaires that will ask questions about how your child responds to sensory events in their typical environment, their typical behaviours and temperament, as well as a sociodemographic questionnaire asking questions about your family. At this session, we will also present your child with different sensory experiences and observe how they react to them. Examples of these include massaging your child's tummy, and watching a puppet. We will also invite you to complete a 15-minute interaction video, where we record you and your baby playing as you would do so at home. We will then complete assessments of overall development including a brief autism screen by presenting your child with a range of play activities. We expect the session to take approximately 1.5-2 hours.

You will be asked to complete the following questionnaires during the test appointment:

- Sociodemographic questionnaire: this will ask questions about the ethnicity, education and financial status of you and your family.
- Toddler Sensory Profile 2 (TSP2): this will ask questions about how your child responds to sensory events in their typical environment. E.g. how they respond to a loud noise, certain materials or smells.
- Toddler Temperament Scale: this will ask you questions about your child's behavior that relates to their temperament, E.g. how they respond to meeting other children or adults.
- First Year Inventory (FYI): this will ask you about your child's behavior, E.g. typical play with toys.

During the testing appointment we will complete the Test of Sensory Function in Infants. This will be administered to your child and involves administering 24 items to examine the infant's ability to modulate sensory information. For example, massaging their tummy, or watching a puppet.

The Bayley Scales of Infant and Toddler Development (Bayley-III) will also be administered by a member of the research team. The Bayley-III is an observational tool used to evaluate general development in young children 1-42 months of age. This tool examines cognition, expressive and receptive communication, fine and gross motor skills.

The Autism Detection in Early Childhood (ADEC) will be used to screen for autistic tendencies, and will be administered by a member of the research team. The ADEC is an observational tool used to examine social communication, play, sensory motor and regulation skills in children aged 12months – 3 years.

Cases of developmental delay and autism in premature babies are still relatively rare and, while it is unlikely, if your child shows any signs of developmental delay or risk for autism, we will discuss this with you and refer you to any appropriate service provider in your area for follow-up.

The 15-minute interaction video will be recorded by a member of the research team in order to see how you and your baby interact. We will leave you and your baby to play alone for 7.5 minutes, and then we will bring in some toys for your child to play with for the remaining 7.5 minutes.

The expected duration of the appointment will be 1.5-2 hours. In the event that we are unable to complete all of the assessments at the initial session, a second session will be scheduled at your next convenience.

Risks
All members of the research team are registered occupational therapists or psychology students, as well as Dr. Larissa Korostenski who is a staff specialist from the John Hunter Children's Hospital NICU. All persons participating in the research are experienced in clinical assessments and have a current "Working with Children Check".

There are no known risks to your child in participating in this study as none of the assessments should incur any harm to you or your child. However, your child may become tired or require feeding, in which case this is perfectly okay. We also acknowledge the potential for you to experience stress and anxiety when answering the questionnaire. If you have any concerns arising from the questionnaires, you may contact A/Prof Alison Lane on Ph. (02) 4921 5004. Alternatively, the number for Lifeline is 13 11 14 and they can provide immediate telephone counselling.

Benefits

We cannot guarantee or promise that you or your child will receive any direct benefits from this research; however the results of this research will help us better understands the needs of young infants with a history of early birth.
At the end of the study, we will provide you with a short summary of your child's results based on the developmental testing during the appointment.

Costs

Participation in this study will not cost you anything, nor will you be paid.

Voluntary Participation

Participation in this study is entirely voluntary. You do not have to take part in it. If you do take part, you can withdraw at any time without having to give a reason.
Whatever your decision, please be assured that it will not affect your routine care, relationship with professional staff or relationship with the John Hunter Children's Hospital.

Confidentiality

All the information collected from you for the study will be treated confidentially, and only the researchers named above will have access to it. The study results may be presented at a conference or in a scientific publication, but individual participants will not be identifiable in such a presentation, unless they have given consent for video data to be shared. All data files will be kept in restricted access storage for 10 years after the completion of the study, after which they will be destroyed.

Further Information

If you would like to know more at any stage, please feel free to contact Jordan Tait, jordan.tait@uon.edu.au, 0413 337 892. This information sheet is for you to keep.
Ethics Approval and Complaints
This study has been approved by the Hunter New England Research Ethics Committee. Any person with concerns or complaints about the conduct of this study should contact the Executive Officer (HNELHD) on (02) 4921 4950 and quote protocol number 16/05/18/4.11.

Appendix 13: Consent to contact form for the SDPrem study

Characteristics and Moderators of Sensory Modulation in Preterm Infants, in the First Year of Life

Researchers from the University of Newcastle and John Hunter Children's Hospital are conducting a study to understand how sensory factors in the first year of life influence a child's development up to 12 months of age.

Participation in this study is completely voluntary, and would involve completing four caregiver questionnaires, and attending an appointment with your child at the Hunter Medical Research Institute. At this visit, you will be required to complete the four questionnaires regarding your child, whilst researchers administer a series of measures relating to overall development. We will also invite you to record an interaction video with your child. We will also measure your child's response to a range of sensory experiences (touch, visual etc) at this appointment.

If you would like more information, or wish to register your interest in participating, please complete one of the following actions.

- Phone research assistant Jordan Tait 0*413 337 892.*
- Email: Jordan.tait@uon.edu.au
- Sign and return the consent to contact form, and a member of the research term will be in contact with you to arrange an appointment time.

Please be assured that, whatever your decision about the study, it will have no effect on the care that you receive from John Hunter Children's Hospital now or in the future.

Parent/Guardian Consent Form

Characteristics and moderators of sensory modulation in preterm infants, in the first year of life.

Investigators: Associate Professor Alison Lane, Professor Shelly Lane, Dr. Larissa Korostenski, Ms Michelle Jackman & Miss Alix Woolard.

I, ...[name of parent/guardian]

of ....[address],

Parent/Guardian of …………………………………………………………..[name of child]

have read and understand that the study will be conducted as described in the information provided..

I hereby register my interest in participating in this study, or wish to receive more information,

and consent for the research team to contact me.

YES **NO**

NAME OF PARENT/GUARDIAN: ________________________________

CHILD'S D.O.B: ________________________________

BEST CONTACT NUMBER: ________________________________

PARENT/GUARDIAN SIGNATURE: ________________________________

DATE: ________________________________

Appendix 14. Consent forms for the SDPrem study

Parent/Guardian Consent Form

Characteristics and moderators of sensory modulation in preterm infants, in the first year of life.

Investigators: Associate Professor Alison Lane, Professor Shelly Lane, Dr. Larissa Korostenski, Ms Michelle Jackman & Miss Alix Woolard.

I, ...[name of parent/guardian]

of ....[address],

Parent/Guardian of ……………………………………………………………[name of child]

have read and understand that the study will be conducted as described in the Information Statement, a copy of which I have retained.

- I have been made aware of the procedures involved in the study, including any known or expected inconvenience, risk, discomfort or potential side effect and of their implications as far as they are currently known by the researchers.
- I understand that I can withdraw my child at any time without providing a reason.
- I understand that my own and my child's personal information will remain confidential to the researchers.
- I have had the opportunity to have questions answered to my satisfaction.
- I understand that information from the John Hunter Children's Hospital, such as my child's medical records, will be linked to the current information.

I hereby agree to my own and my child's participation in this research study. **YES** **NO**

In addition (please circle as appropriate)

I consent to be contacted about further studies, in the next five years, investigating my child's progress or follow-up studies **YES** **NO**

I consent for information from the current study to be used in future studies by the research team. **YES** **NO**

I consent to be contacted about future studies, in the next five years **YES** **NO**

I consent to the use of my own de-identified information being shared with other researchers for additional studies **YES** **NO**

I consent to the use of my child's de-identified information being shared with other researchers for additional studies **YES** **NO**

NAME OF PARENT/GUARDIAN: ______________________________

SIGNATURE: ______________________________

DATE: ______________________________

Declaration by person conducting the consent process

I, the undersigned, have fully explained this research to the patient named above.

NAME: ______________________________

SIGNATURE: ______________________________

Characteristics and Moderators of Sensory Modulation in Preterm Infants, in the First Year of Life

I, ... [name of parent/guardian]

of ....……[address],

Parent/Guardian of …………………………………………………………………….. [name of child]

hereby give my consent for videotaping, filming and/or photographing of myself and my child, and for the data analyses carried out by the research team, consistent with the aims of this study.

In addition, I consent to (initial all appropriate):

_______ For research or teaching purposes, including publication in scientific journals or presented at scientific conferences.

_______ For the press and/or publications at the researchers' discretion, including newspapers, magazines or shown on television.

I understand that, in all cases, my name and my child's name will be kept confidential. Video data obtained from this research study will only be accessed by enrolled students and investigators on the study.

In addition (please circle as appropriate)

3. I consent for video data to be used in research presentations at the researcher's discretion **YES / NO**

SIGNATURE: ________________________________

DATE: ________________________________

Declaration by person conducting the consent process

I, the undersigned, have fully explained this research to the participant named above.

NAME: ________________________________

SIGNATURE: ________________________________

Appendix 15. Sociodemographic questionnaire

						Date:	Data entry:
ID Number						Assessor:	Data checked:

Infant Demographics

First name	**Middle Name**	**Surname**

Infant's Date of Birth:____/ _/____
(dd/mm/yyyy)

Visit attended by: ☐ Mother ☐ Father ☐ Guardian ☐ Other

Parent / Primary Caregiver Contact Details:

Parent / Primary Caregiver:

Address:____

Suburb:___________________________________Post Code:___________

Phone (HOME):___________________________(include area code)

Phone (WORK):__________________________(include area code)

Mobile:____________________

Email: ____

Remove this page and file in Demographic folder with completed consent forms.

The following is a questionnaire that will ask questions about basic socio- demographics related to you, your partner, and your child. All information in this questionnaire is confidential and will onlybe used for research purposes.

Personal Details

1. What is *your* date of birth (DD/MM/YYYY):____/___/_____	2. What is your country of birth? (please state):

Infant Information

Infant's given name(s): ____

3. Infant's gender (please tick): Male Female

4. Infant's date of birth (DD/MM/YYYY):____/___/_____

5. Was your child born preterm (earlier than 37 weeks' gestation)? ☐ Yes ☐ No

If you answered "Yes" to question 5, how many weeks early? ____________

6. At which hospital was your child born?_______________________________

Was your child admitted to the Neonatal Intensive Care Unit (NICU)?☐Yes ☐No

If yes, how long did your child stay in the NICU? ______________________

Was your child admitted to the Special Care Nursery ?☐Yes ☐No

If yes, how long did your child stay in the Nursery? ______________________

7. What was your estimated date of delivery (due date)?_____/____/________

8. Is your current partner the father of your child? (please tick) ☐No ☐Yes

9. Do any siblings live with your child? (if yes, please state how many):

☐No ☐Yes____________

Sibling 1: Age:___Sex: M/F (Please circle)
Sibling 2: Age:___Sex: M/F
Sibling 3: Age: Sex: M/F
Sibling 4: Age: Sex: M/F
Sibling 5: Age: Sex: M/F
Sibling 6: Age: Sex: M/F

10. Does anyone speak to your child in a language other than English? ☐Yes ☐No

If yes, which language(s) and for how many hours per week?

Language ________________________ Hours per week ________________
Language ________________________ Hours per week ________________

						Date:	Data entry:
						Assessor:	Data checked:
	ID Number						

Education and Occupation Information

10. What is the highest level of education **you** have **completed**? (E.g. School Certificate, Higher School certificate, TAFE Diploma, Bachelor's degree): ____________________________________ 11. What is **your** current occupational status? (please circle all that apply): Employed: Full-time / Part-time / Casual Unemployed Job searching Stay at home parent On maternity leave Student Retired	12. What is the highest level of education **your partner** has **completed**? (E.g. School Certificate, Higher School certificate, TAFE Diploma, Bachelor's degree): ____________________________________ 13. What is **your partner's** current occupational status? (circle all that apply): Employed: Full-time / Part-time / Casual Unemployed Job searching Stay at home parent On maternity leave Student Retired

14. Which of the following best characterises your net annual **household** income? (before tax):

☐ $0-$18,200 ☐ $18,201- $37,000 ☐ $37,001 - $80,000
☐ $80,001 – $180,000 ☐ $180,001 and over

Family History

*Please respond about **your biological** mother, father, brothers, and sisters* 15. What is their highest level of education? Mother: Father: 16. What is/was their occupation? Mother: Father:	17 Do **you** have brothers and/or sisters? ☐ No ☐ Yes If yes, how many? _____

						Date:	Data entry:
						Assessor:	Data checked:
ID Number							

18. Does you suffer from any of the following:

☐ Speech or language disorder ☐ Learning or behaviour problems
☐ Depression ☐ Bipolar disorder
☐ Schizophrenia ☐ Other (please specify):

The following questions relate to the child's biological father,

19.Is your **current partner** the child's biological father? ☐ Yes ☐ No

20.What is the **child's biological father**'s date of birth?____/___/____

Please respond about ***your child's biological father*** *- his mother, father, brothers, and sisters*

21. What is their highest level of education?
Mother:
Father:

22.What is/was their occupation?
Mother:
Father:

23. Does he have brothers and/or sisters? ☐ No ☐ Yes
If yes, how many?

Comments

If you have any comments, please write them below:

Appendix 16: First Year Inventory

fyi First Year Inventory

Version 2.0

The University of North Carolina at Chapel Hill

NO TWO BABIES ARE ALIKE. We are interested in some of the behaviors that make your baby unique. There are no right or wrong answers to these questions. They are just descriptions of the range of behaviors we find in one-year-olds. Please answer each question as it applies to your baby within the week before or after your baby's first birthday. Please answer every question and give the most accurate answer you can. Again, we are not looking for any particular answer. We just want to know how your baby behaves and responds in various ways.

Date filled out: ______/______/______ (Month / Date / Year)

Baby's birth date: ______/______/______ (Month / Date / Year)

Baby's due date: ______/______/______ (Month / Date / Year)

Baby's gender: ❑ Male ❑ Female

Birth order: _____ of _____ children born to this mother

Baby's weight at birth: ______________

Baby's Mother
Race/Ethnicity: (check 1 or more)
❑ White
❑ Black/African-American
❑ Hispanic/Latino
❑ Asian
❑ American-Indian /Alaskan Native
❑ Native Hawaiian/Pacific Islander

Highest grade completed
or degree obtained: ________________

Baby's Father
Race/Ethnicity: (check 1 or more)
❑ White
❑ Black/African-American
❑ Hispanic/Latino
❑ Asian
❑ American-Indian /Alaskan Native
❑ Native Hawaiian/Pacific Islander

Highest grade completed
or degree obtained: ________________

The person filling out this form is the (check one):
❑ Mother
❑ Father
❑ Both
❑ Other (specify): ____________________________

For the following questions, check the ONE BOX that best describes how frequently this behavior occurs—Never, Seldom, Sometimes or Often.	Never	Seldom	Sometimes	Often
1. Does your baby turn to look at you when you call your baby's name?				
2. Does your baby seem bothered by loud sounds?				
3. Does your baby seem overly sensitive to your touch (for example, fuss or pull away when you touch him or her)?				
4. During familiar games like "I'm gonna get you," does your baby get excited because he or she knows what will happen next?				
5. Does your baby seem to have trouble hearing?				
6. When you and your baby are facing each other, does your baby turn his or her eyes to avoid looking at you?				
7. In new or strange situations, does your baby look at your face for comfort?				
8. Does your baby ignore loud or startling sounds?				
9. Does your baby spit out certain textures of foods, such as lumpy or chunky pieces?				
10. When you point to something interesting, does your baby turn to look at it?				
11. Is your baby content to play alone for an hour or more at a time?				
12. Does your baby look at people when they begin talking, even when they are not talking directly to your baby?				
13. Does your baby rock his or her body back and forth over and over?				
14. Does your baby look up from playing with a favorite toy if you show him or her a different toy?				
15. Does your baby get upset when you need to switch your baby from one activity to another one?				
16. Is it easy to understand your baby's facial expressions?				
17. Does your baby forcefully press his or her face, head, or body against people or furniture?				
18. Does your baby smile while looking at you?				
19. Does your baby try to get your attention to show you something interesting?				
20. Does your baby try to get your attention to play games like peek-a-boo?				
21. Does your baby try to get your attention to obtain a favorite toy or food?				
22. Does your baby try to get your attention to play physical games, like swinging, tickling, or being tossed in the air?				
23. When your baby is awake and you pick him or her up, does your baby's body feel loose or floppy?				
24. Does your baby copy or imitate you when you make sounds or noises with your mouth?				
25. Does your baby copy or imitate your actions, like sticking out your tongue, clapping your hands, or shaking your head?				
26. Does your baby copy or imitate you when you do something with a toy or object, like shaking a rattle or banging a spoon on the table?				
27. Is it difficult to calm your baby once he or she becomes upset?				
28. Are your baby's sleeping and waking patterns regular from day to day?				
29. Does your baby try to get your attention by making sounds and looking at you at the same time?				
30. Does your baby get stuck doing a simple activity over and over?				
31. Does your baby seem interested in other babies his or her age?				
32. Does your baby babble by putting sounds together, such as 'ba-ba', 'ga-ga-ga', or 'ba-dee'?				
33. Does your baby enjoy staring at a bright light for long periods of time?				
34. Does your baby use gestures such as raising arms to be picked up, shaking head, or waving bye-bye?				
35. When you say "Where's (a familiar person or object)?" without pointing or showing, will your baby look at the person or object named?				
36. Does your baby use the first finger and tip of the thumb to pick up a very small object like a raisin or a Cheerio?				
37. Does your baby seem to get stuck on playing with a part of a toy (such as an eyeball, label, wheel or tag), instead of the whole toy?				
38. Does your baby communicate with you by using his or her finger to point at objects or pictures?				
39. Do you get the feeling that your baby plays or communicates with you less now than in the past?				
40. Do your baby's eyes line up together when looking at an object?				
41. Are your baby's feeding patterns regular from day to day?				
42. Does your baby enjoy rubbing or scratching toys or objects for long periods of time?				
43. Does your baby seem to get his or her body stuck in a position or posture that is hard to move out of?				
44. Does your baby enjoy making objects spin over and over in the same way?				
45. While lying down, does your baby enjoy kicking his or her feet over and over for long periods of time?				
46. Does your baby stare at his or her fingers while wiggling them in front of his or her eyes?				

For the following questions, please circle the ONE ANSWER that best describes your baby.

47. Which of the following best describes your baby's typical play with a favorite toy?
    a. Uses the toy in more or less the same way all the time.
    b. Occasionally finds a new way to play with the toy.
    c. Often explores new ways to play with the toy.

48. Which of the following describes your baby's interest in toys on a typical day?
    a. Plays with one or two special toys most of the time.
    b. Plays with a small number of toys (3-5).
    c. Plays with a large number of toys (6 or more).

49. When you introduce your baby to a new game (peek-a-boo, so-big, patty-cake, etc.) how does your baby respond?
    a. Almost always joins in immediately without any help.
    b. Usually joins in, with a little help.
    c. Joins in only with a lot of help
    d. Doesn't seem very interested in new baby games.

50. What do you typically have to do to get your baby to look up from playing with a favorite toy?
    a. Just show him or her different toy.
    b. Move, shake or make a noise with the different toy.
    c. Take the favorite toy away and give your baby the different toy.

51. What is your baby's usual reaction to somewhat painful experiences, like bumping his or her head?
    a. Doesn't seem to notice.
    b. Reacts a little but gets over it quickly.
    c. Seems very sensitive or cries for a long time.

52. What do you typically have to do to get your baby to turn towards you?
    a. Simply say your baby's name.
    b. Say your baby's name several times.
    c. Say your baby's name loudly or use other means, such as clapping.
    d. Your baby doesn't do this yet.

53. What do you typically have to do to get your baby to smile or laugh at you?
    a. Smiling and laughing is enough.
    b. Usually need to touch and tickle.
    c. Usually need to swing and bounce.
    d. Your baby doesn't do this yet.

54. On a typical night, how many hours does your baby sleep?
    a. 12 or more.
    b. 10-11.
    c. 8-9
    d. 7 or fewer.

55. On a typical night, how many times does your baby wake up?
    a. 0 times.
    b. 1-2 times.
    c. 3 or more times.

56. Which of the following best describes your baby's skill level?
    a. Walks independently.
    b. Walks with hand(s) held, holding a push-toy, or holding onto furniture.
    c. Pulls up to stand but doesn't walk yet.
    d. Does not pull up to stand yet.

57. Which of the following best describes your baby's typical day?
   a. Almost never gets upset.
   b. Gets upset and needs to be calmed 1-3 times.
   c. Gets upset and needs to be calmed 4-6 times.
   d. Gets upset and needs to be calmed 6 or more times.

58. If you start a game by copying or imitating a sound your baby makes, what does your baby typically do?
   a. Doesn't seem to notice the sound.
   b. Looks at you, but doesn't make the sound.
   c. Looks at you and makes the sound.
   d. Plays the game, making the sound several times.

59. When your baby is awake and not eating, does your baby keep a toy or object in his or her mouth?
   a. Almost never keeps a toy or object in his or her mouth.
   b. Sometimes keeps a toy or object in his or her mouth.
   c. Often keeps a toy or object in his or her mouth.
   d. Almost always keeps a toy or object in his or her mouth.

60. Which of the following best describes the way your baby coordinates his or her eyes and hands while playing with a toy?
   a. Almost always looks at the toy that he or she is physically handling.
   b. Sometimes looks at the toy that he or she is physically handling.
   c. Rarely looks at the toy that he or she is physically handling.
   d. Almost never looks at the toy that he or she is physically handling.

61. Please circle all of the following sounds you've heard your baby use in babble, word approximations, or words:

p b t d k g m n w y h s

62. Do you or others (grandparents, doctor, babysitter) have any concerns about your baby's development in any area? If yes, please describe.

63. Does your baby have any unusual physical or medical characteristics? If yes, please describe.

Thank you for taking the time to respond to this questionnaire.
The information you have given us about your baby will help us understand more about how babies are different from one another, and will help us advise parents who may be concerned about their baby's development.
Please return the questionnaire to us in the self-addressed envelope provided.

Appendix 17: Edinburgh Postnatal Depression Scale

The Edinburgh Postnatal Depression Scale (EPDS)

(J L Cox, J M. Holden, R Sagovsky – 1987)

BLACK DOG INSTITUTE

This 10 item self report measure is designed to screen women for symptoms of emotional distress during pregnancy and the postnatal period.

The EPDS is not a diagnostic tool and must always be used in conjunction with clinical assessment.

The EPDS includes one question (Item 10) about **suicidal thoughts** and should be scored before the woman leaves the office in order to detect whether this item has been checked. Further enquiry about the nature of any thoughts of self-harm is required in order for the level of risk to be determined and appropriate referrals made where indicated to ensure the safety of the mother and baby.

As it reflects the woman's experience of the last 7 days, the EPDS may need to be repeated on further occasions as clinically warranted.

BLACK DOG INSTITUTE

EDINBURGH POSTNATAL DEPRESSION SCALE

Today's Date: _____ / _____ / _____ Weeks pregnant: _____ or weeks postnatal: _______

Surname: ____________________________ Given Name(s): ______________________ TOTAL SCORE [ ]

INSTRUCTIONS:

Please colour in one circle for each question that is the closest to how you have felt in the **PAST SEVEN DAYS.**

1. I have been able to laugh and see the funny side of things:

{ As much as I always could
{ Not quite as much now
{ Definitely not so much now
{ Not at all

2. I have looked forward with enjoyment to things:

{ As much as I ever did
{ Rather less than I used to
{ Definitely less than I used to
{ Hardly at all

3. I have blamed myself unnecessarily when things went wrong:

{ Yes, most of the time
{ Yes, some of the time
{ Not very often
{ No, never

4. I have been anxious or worried for no good reason:

{ No, not at all
{ Hardly ever
{ Yes, sometimes
{ Yes, very often

5. I have felt scared or panicky for no very good reason:

{ Yes, quite a lot
{ Yes, sometimes
{ No, not much
{ No, not at all

6. Things have been getting on top of me:

{ Yes, most of the time I haven't been able to cope at all
{ Yes, sometimes I haven't been coping as well as usual
{ No, most of the time I have coped quite well
{ No, I have been coping as well as ever

7. I have been so unhappy that I have had difficulty sleeping:

{ Yes, most of the time
{ Yes, sometimes
{ Not very often
{ No, not at all

8. I have felt sad or miserable:

{ Yes, most of the time
{ Yes, quite often
{ Not very often
{ No, not at all

9. I have been so unhappy that I have been crying:

{ Yes, most of the time
{ Yes, quite often
{ Only occasionally
{ No, never

10. The thought of harming myself has occurred to me:

{ Yes, quite often
{ Sometimes
{ Hardly ever
{ Never

NB: If you have had ANY thoughts of harming yourself, please tell your GP or your midwife <u>today</u>

Comments

____

____

* Murray and Cox 1990 * Cox, Holden & Sagovsky 1987

Appendix 18. Coding script used through Praat to segment utterances and then classify utterances into contour types

```
#TITIA BENDERS, 2011
#UPDATE: TITIA BENDERS & ALIX WOOLARD, 2017


#FORM TO SELECT TRANSCRIBER, PROJECT, AND FILE
beginPause ("Inventory")
    choice ("transcriber", 1)
        option ("AW")
        option ("TA")
        option ("TB")
    choice ("project",1)
        option ("BLTID")
         comment: "This is the data folder (including the
age!)"
    word ("folder", "D:\BLT-ID\Participants\6mths\")
         comment: "This is the folder with settings files"
    word ("settingsFolder", "D:\CodingScriptsIDS\settings\")
    sentence ("name", "AVE4126m")
endPause ("OK", 1)


#CHECK WHICH FILES ALREADY EXIST
readWav=fileReadable("'folder$''name$'\'name$'.WAV")

if readWav=1

 readGrid1 =
fileReadable("'folder$'/'name$'/'name$'_1fraseAuto.TextGrid")
 readGrid2 =
fileReadable("'folder$'/'name$'/'name$'_2fraseHand.TextGrid")
 readGrid3 =
fileReadable("'folder$'/'name$'/'name$'_3checkPitch_'transcrib
er$'.TextGrid")

 if readGrid1*readGrid2*readGrid3=0
  sound = Read from file... 'folder$'\'name$'\'name$'.wav
 endif

 if readGrid1 = 0
  execute 1fraseAutoSelectSpeech.praat 'sound' "'name$'"
'folder$' 'project$'
 endif

 if readGrid2 = 0
  execute 2fraseHand.praat 'sound' "'name$'" 'folder$'
'project$'
 endif
```

```
 if readGrid3 = 0
  execute 3pitchCheck.praat 'sound' "'name$'" 'folder$'
'settingsFolder$' 'project$' 'transcriber$'
 endif

endif
form NameOfLargeFile
    real sound 0
    sentence name 00_test
    word folder
/Users/alixwoolard/Desktop/Audio_processing/CodingScriptsIDS/
    word project BLTID
endform


####################################
#### VARIABLES
####################################
    #What is the duration (in sec) of each fragment that is
used in the phrase detector.
    #30 is reasonable.
    cutLength=30
    #These are all variables for the silence detector
    minimumPitch=75
    timeStep=0.02
    silenceThreshold = -40
    minSilInt=0.25
    minSoundInt=0.1

####################################
#### SCRIPT PROPER
####################################

scriptName$="1fraseAuto"
readGrid =
fileReadable("'folder$''slash$''name$''slash$''name$'_'scriptN
ame$'.TextGrid")

if readGrid = 0
 if sound=0
  sound = Read from file...
'folder$''slash$''name$''slash$''name$'.wav
 else
  select sound
 endif
 nowarn To TextGrid (silences)... minimumPitch timeStep
silenceThreshold minSilInt minSoundInt "" M
```

```
 Save as text file...
'folder$''slash$''name$''slash$''name$'_'scriptName$'.TextGrid
endif

form NameOfLargeFile
    real sound 0
    sentence name 00_test
    word folder
/Users/alixwoolard/Desktop/Audio_processing/CodingScriptsIDS/
    word project BLTID
endform

#####################
### VARIABLES
#####################

scriptPrev$="1fraseAuto"
scriptName$="2fraseHand"

viewDur = 10
overlapDur  = 2.5
startInt = 0
endInt = overlapDur

clicked = 3

playAutomatically = 0
#####################
### END VARIABLES
#####################


### READ IN NEW OR TEMPORARILY SAVE GRID
 readGridTemp =
fileReadable("'folder$''slash$''name$''slash$''name$'_'scriptN
ame$'_Temp.TextGrid")
 if readGridTemp = 0
  grid = Read from file...
'folder$''slash$''name$''slash$''name$'_'scriptPrev$'.TextGrid
  Rename... 'name$'_'scriptName$'_Temp
  Insert interval tier: 1, "hand"
 else
  grid = Read from file...
'folder$''slash$''name$''slash$''name$'_'scriptName$'_Temp.Tex
tGrid
 endif

### READ IN SOUND AND VIEW WITH GRID
 if sound=0
```

```
  sound = Read from file...
'folder$''slash$''name$''slash$''name$'.wav
 else
  select sound
 endif
 soundDur = Get total duration
 plus grid
 Edit

while endInt < soundDur and (clicked = 2 or clicked = 3)
 ### UPDATE VARIABLES
 if clicked = 3
  startInt = endInt - overlapDur
 endif
 endInt = startInt + viewDur
 startIntNext = endInt - overlapDur

 ### VIEW IN THE EDITOR
  editor TextGrid 'name$'_'scriptName$'_Temp
   Zoom... startInt endInt
   if playAutomatically
    Play... startInt endInt
   endif
  endeditor

  ### INTERFACE
  beginPause: "Stuffxxx"
   real: "startInt", startInt
   comment: "Change the values below for your next window"
   real: "startIntNext", startIntNext
   real: "viewDur", viewDur
   real: "overlapDur", overlapDur

  clicked = endPause: "Cancel","SaveStay", "SaveNext",3

  ### SAVE THE TEMPORARY TEXT GRID
  if clicked = 2 or clicked =3
   select grid
   Write to text file...
'folder$''slash$''name$''slash$''name$'_'scriptName$'_Temp.Tex
tGrid
  endif

  ### THIS IS THE EXIT CHECK
  if endInt >= soundDur
    ### if we seem to be at the end, check whether the coder
is ok to go out
    beginPause: "ConfirmClosure"
     comment: "You've reached the end of the file"
```

```
     comment: "If you don't change anything, you will exit
this stage"
     comment: "If you change here which start time you want to
go to, you'll go there"
     comment: "but ONLY if startInt < 'soundDur'-'viewDur'"
    real: "startInt", startInt
   clickedConfirm = endPause: "CONFIRM", 1
  endif

  ### THIS IS A LITTLE HACK TO MAKE SURE USER CAN CONTROL THE
START OF THE INTERVAL
  endInt = startIntNext + overlapDur
endwhile

if clickedConfirm = 1
 select grid
 Write to text file...
'folder$''slash$''name$''slash$''name$'_'scriptName$'.TextGrid
 filedelete
'folder$''slash$''name$''slash$''name$'_'scriptName$'_Temp.Tex
tGrid
endif

plus sound
Remove
###TODO
### select intervals
### cancel needs to get us out of everything

form NameOfLargeFile
    real sound 0
    sentence name 00_test
    word folder
/Users/alixwoolard/Desktop/Audio_processing/CodingScriptsIDS/
    word settingsFolder
/Users/alixwoolard/Desktop/Audio_processing/CodingScriptsIDS/s
ettings
    word project BLTID
    word transcriber AW
endform

#####################
### VARIABLES
#####################

scriptPrev$="2fraseHand"
scriptName$="3checkPitch"

toyNoToy = 1
```

```
playAutomatically = 0

### Read in the contour names
contourList = Read Table from tab-separated file...
'settingsFolder$''slash$'contourList_'project$'.txt
nContour = Get number of rows
for contour to nContour
 contour'contour'$ = Get value... contour contourName
endfor

### Read in the exclusion names
exclusionList = Read Table from tab-separated file...
'settingsFolder$''slash$'exclusionList_'project$'.txt
nEx = Get number of rows
for ex to nEx
 ex'ex'$ = Get value... ex exclusionName
endfor

### Read in the exclusionReason names
exclusionReasonList = Read Table from tab-separated file...
'settingsFolder$''slash$'exclusionReasonList_'project$'.txt
nExr = Get number of rows
for exr to nExr
 exr'exr'$ = Get value... exr exclusionReasonName
endfor

### Read in the column names
Read Table from tab-separated file...
'settingsFolder$''slash$'columnList_'project$'.txt
nCol = Get number of rows
for col to nCol
 col'col'$ = Get value... col colName
endfor


#####################
### END VARIABLES
#####################

### READ IN NEW OR TEMPORARILY SAVE GRID
### READ IN OR CREATE TABLE TO SAVE INFO IN

 readGridTemp =
fileReadable("'folder$''slash$''name$''slash$''name$'_'scriptN
ame$'_Temp_'transcriber$'.TextGrid")
 if readGridTemp = 0
  grid = Read from file...
'folder$''slash$''name$''slash$''name$'_'scriptPrev$'.TextGrid
  Rename... 'name$'_'scriptName$'_Temp_'transcriber$'
```

```
  gridTmp = Extract one tier: 1
  settingsTableTmp = Down to Table: "no", 6, "no", "no"
  settingsTable = Extract rows where column (text): "text",
"is equal to", "M"
  for col to nCol
   col$ =  col'col'$
   Append column: "'col$'"
  endfor
  Formula: "name", """'name$'"""
  Formula: "seen", """0"""
  nRow = Get number of rows
  for row to nRow
   startInt = Get value: row, "tmin"
   endInt = Get value: row, "tmax"
   select grid
   int = Get interval at time: 1, (startInt+endInt)/2

   select settingsTable
   Set numeric value: row, "row", row
   Set numeric value: row, "int", int
   Set numeric value: row, "startInt", startInt
   Set numeric value: row, "endInt", endInt
  endfor
  Remove column: "tmin"
  Remove column: "tmax"
  Remove column: "text"
  row = 1
 else
  grid = Read from file...
'folder$''slash$''name$''slash$''name$'_'scriptName$'_Temp_'tr
anscriber$'.TextGrid
  settingsTable = Read from file...
'folder$''slash$''name$''slash$''name$'_'scriptName$'_Temp_'tr
anscriber$'.txt
  nRow = Get number of rows
  row = Search column: "seen", "0"
  row = if row = 0 then 1 else row endif
 endif

 if sound=0
  sound = Read from file...
'folder$''slash$''name$''slash$''name$'.wav
 else
  select sound
 endif

 plus grid
 Edit
```

```
### LOOP THROUGH INTERVALS WITH M
while row <= nRow
  select settingsTable

  startInt = Get value: row, "startInt"
  endInt = Get value: row, "endInt"

  editor TextGrid 'name$'_'scriptName$'_Temp_'transcriber$'
   Zoom... startInt-1.5 endInt+1.5
   Select... startInt endInt
   if playAutomatically
    Play... startInt endInt
   endif
  endeditor

  call updateSettingsFillTable

  row = nextRow

  if row > nRow
    ### if we seem to be at the end, check whether there is
unseen rows
    ### if you get a 0 back, it's really done
    select settingsTable
    row = Search column: "seen", "0"
    row = if row=0 then nRow+1 else row fi
  endif

  if row > nRow
   beginPause: "ConfirmClosure"
    comment: "All utterances have been coded"
    comment: "If you don't change anything, you will exit the
script"
    comment: "If you change here which row you want to go to,
you'll go there"
    real: "row", row
   clickedConfirm = endPause: "CONFIRM", 1
  endif


endwhile


if clickedConfirm = 1
  select settingsTable
  Save as tab-separated file...
'folder$''slash$''name$''slash$''name$'_'scriptName$'_'transcr
iber$'.txt
```

```
  select grid
  Write to text file...
'folder$''slash$''name$''slash$''name$'_'scriptName$'_'transcr
iber$'.TextGrid

  filedelete
'folder$''slash$''name$''slash$''name$'_'scriptName$'_Temp_'tr
anscriber$'.txt
  filedelete
'folder$''slash$''name$''slash$''name$'_'scriptName$'_Temp_'tr
anscriber$'.TextGrid
endif

#############################################
### UPDATE SETTINGS FILL TABLE - START
#############################################

procedure updateSettingsFillTable

 ### If seen before, read in the values already set
 ### Table is already selected
 seen = Get value: row, "seen"
 if seen
  contour$ = Get value: row, "contour"
  exclusion$ = Get value: row, "exclusion"
  exclusionReason$ = Get value: row, "exclusionReason"
  pitchMin = Get value: row, "pitchMin"
  pitchMax = Get value: row, "pitchMax"
  octaveCost = Get value: row, "octaveCost"
  octaveJumpCost = Get value: row, "octaveJumpCost"
  nextRow = row+1
 endif

 clicked = if seen then 3 else 2 endif

 while clicked = 2 or clicked=3

  if clicked = 2
   ### Default Settings
    nextRow = row+1
    pitchMin = 100
    pitchMax = 500
    octaveCost = 0.01
    octaveJumpCost = 0.35
    contour$ = ""
    exclusion$ = "'ex1$'"
    exclusionReason$ = "'exr1$'"
  endif
```

```
  ### Find the numbers associated with selected/default
contour / exclusion / exclusionReason
  select contourList
  contourNr = Search column: "contourName", "'contour$'"
  select exclusionList
  exclusionNr = Search column: "exclusionName", "'exclusion$'"
  select exclusionReasonList
  exclusionReasonNr = Search column: "exclusionReasonName",
"'exclusionReason$'"

  ### INTERFACE
  beginPause: "UpdateSettings"
   if seen
    comment: "this is an OLD utterance"
   else
    comment: "this is a NEW utterance"
   endif

   real: "row", row
   real: "nextRow", nextRow

   real: "pitchMin", pitchMin
   real: "pitchMax", pitchMax
   real: "octaveCost", octaveCost
   real: "octaveJumpCost", octaveJumpCost

   choice: "Contour", contourNr
    for contour to nContour
     contour$ = contour'contour'$
     option: "'contour$'"
    endfor

   optionMenu: "Exclusion", exclusionNr
    for ex to nEx
     ex$ = ex'ex'$
     option: "'ex$'"
    endfor

   optionMenu: "ExclusionReason", exclusionReasonNr
    for exr to nExr
     exr$ = exr'exr'$
     option: "'exr$'"
    endfor

   optionMenu: "ToyNoToy", 'toyNoToy'
    option: "NoToy"
    option: "Toy"

  clicked = endPause: "Cancel","Defaults", "Apply","DONE", 3
```

```
  ###UPDATE SETTINGS IN EDITOR
  if clicked = 3 or clicked = 4
   editor TextGrid 'name$'_'scriptName$'_Temp_'transcriber$'
    Pitch settings: 'pitchMin', 'pitchMax', "Hertz",
"autocorrelation", "automatic"
    Advanced pitch settings: 0, 0, "no", 15, 0.03, 0.45,
'octaveCost', 'octaveJumpCost', 0.14
   endeditor
 endif

 endwhile

 ### UPDATE INFORMATION IN THE TABLE
 if clicked = 4
  select settingsTable
  Set numeric value: row, "seen", 1
  Set string value: row, "contour", "'contour$'"
  Set string value: row, "exclusion", "'exclusion$'"
  Set string value: row, "exclusionReason",
"'exclusionReason$'"
  Set string value: row, "toyNoToy", "'toyNoToy$'"
  Set numeric value: row, "startInt", 'startInt'
  Set numeric value: row, "endInt", 'endInt'
  Set numeric value: row, "pitchMin", 'pitchMin'
  Set numeric value: row, "pitchMax", 'pitchMax'
  Set numeric value: row, "octaveCost", 'octaveCost'
  Set numeric value: row, "octaveJumpCost", 'octaveJumpCost'

  Save as tab-separated file...
'folder$''slash$''name$''slash$''name$'_'scriptName$'_Temp_'tr
anscriber$'.txt
  select grid
  Write to text file...
'folder$''slash$''name$''slash$''name$'_'scriptName$'_Temp_'tr
anscriber$'.TextGrid

 endif

endproc

#############################################
### UPDATE SETTINGS FILL TABLE - END
#############################################
```

Appendix 19. Scatterplots of significant associations between infant TTS scores and maternal pitch contours during 15-minute interaction

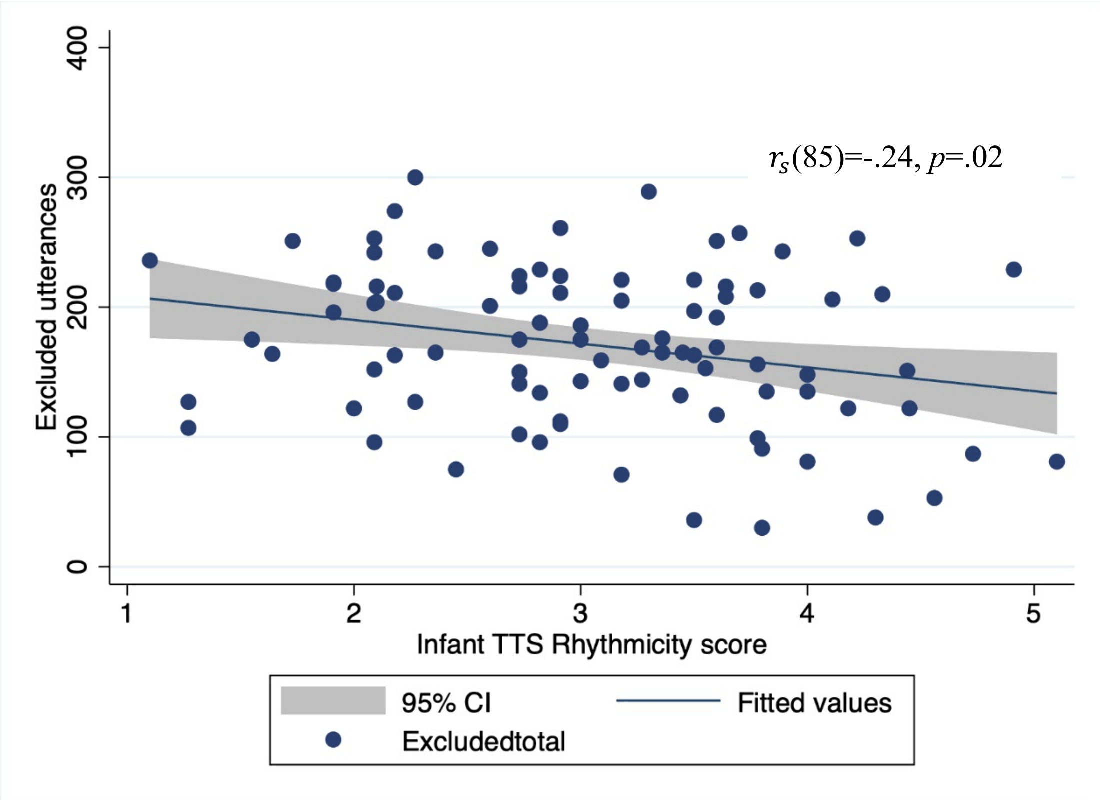

Figure 6. Scatter plot of infant TTS rhythmicity score and maternal excluded utterances

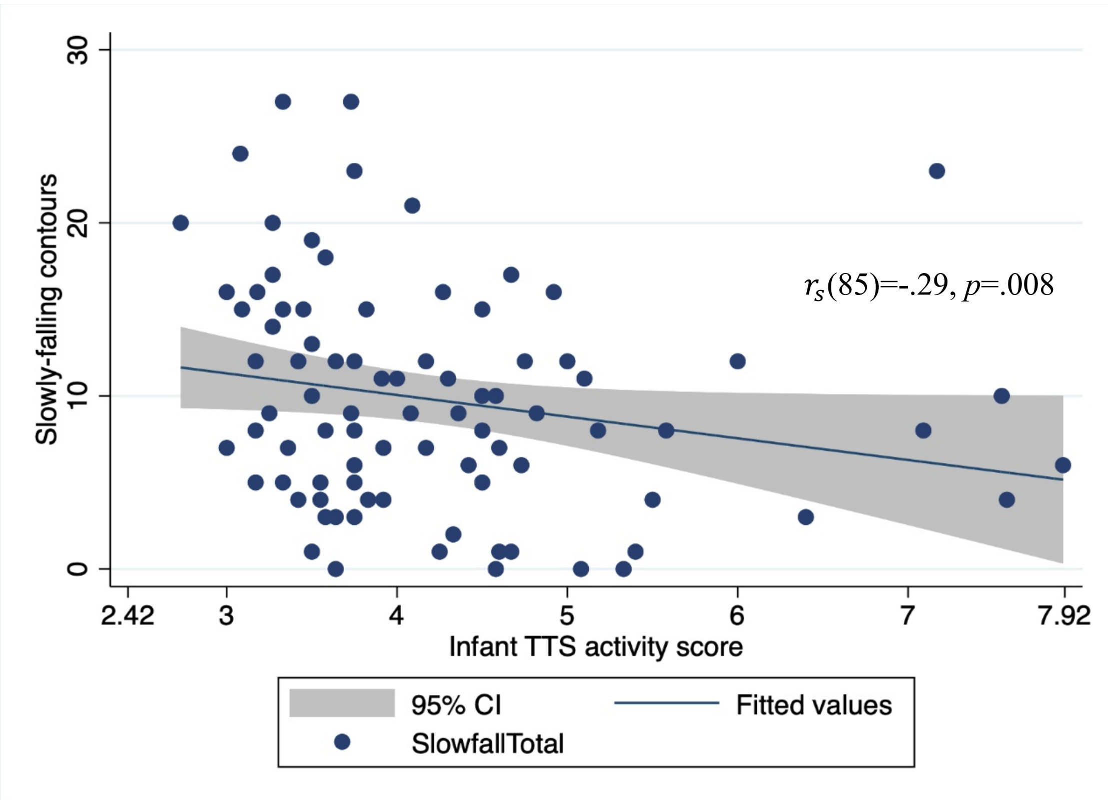

Figure 7. Scatter plot of infant TTS activity score and maternal slowly-falling contours

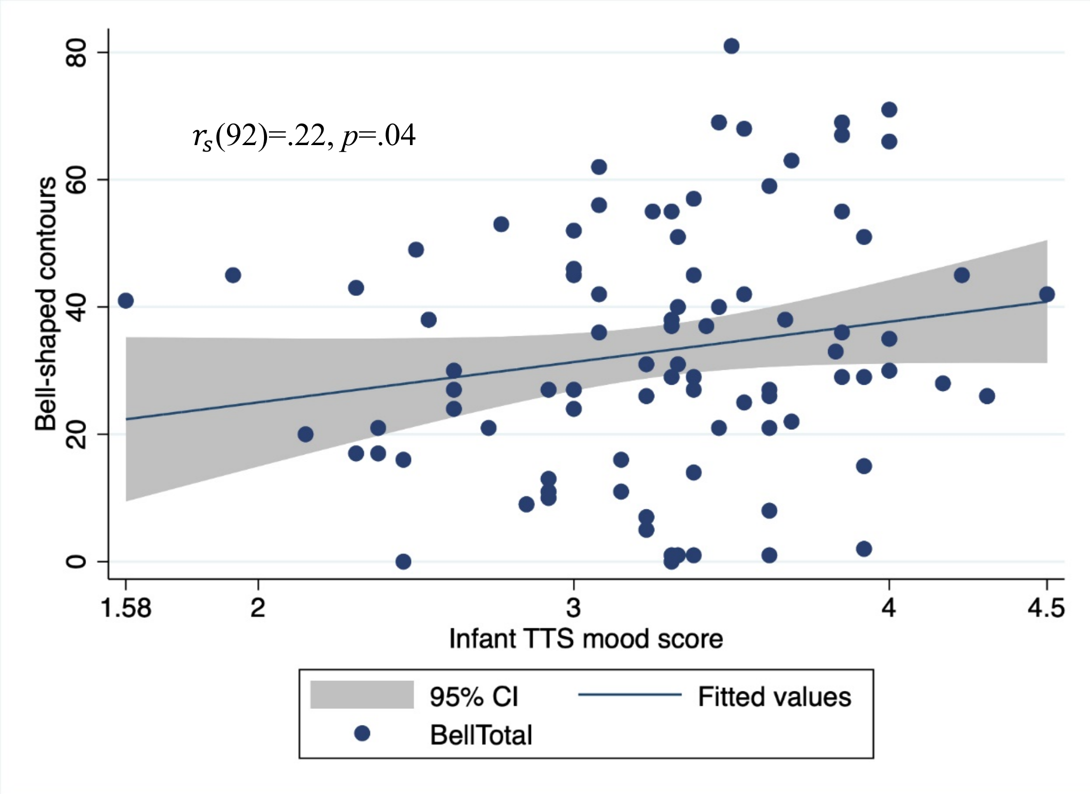

Figure 8. Scatter plot of infant TTS mood score and maternal bell-shaped contours

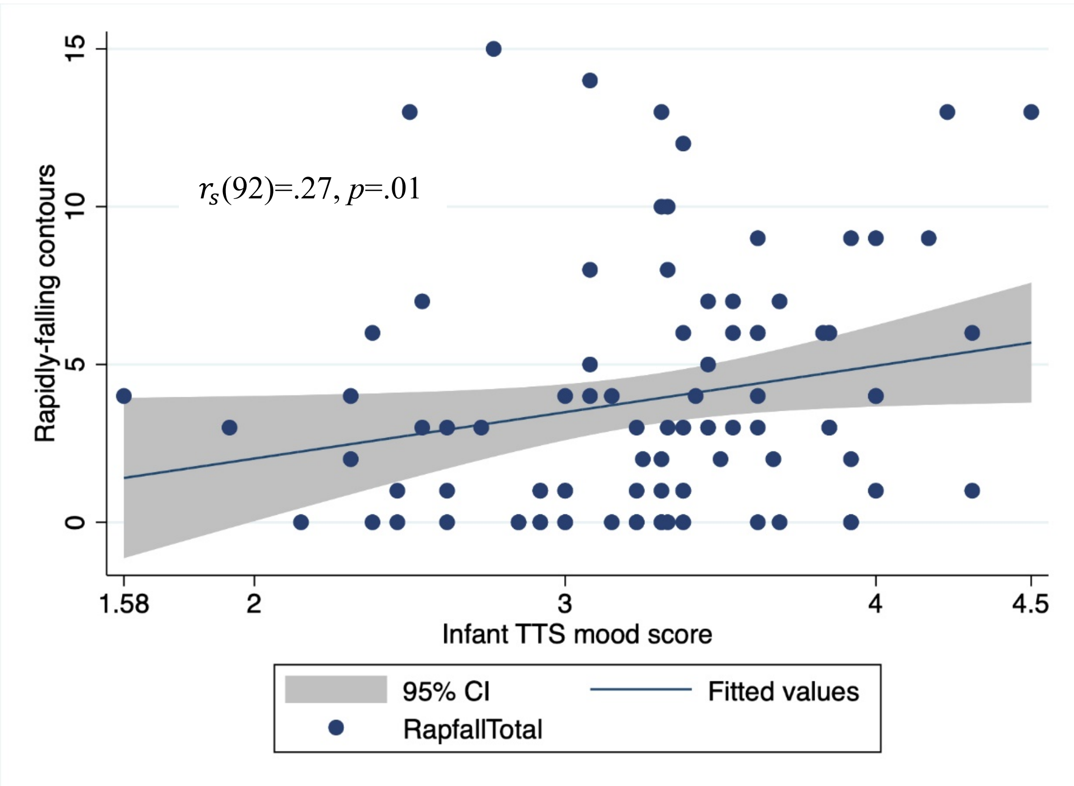

Figure 9. Scatter plot of infant TTS mood score and maternal rapidly-falling contours

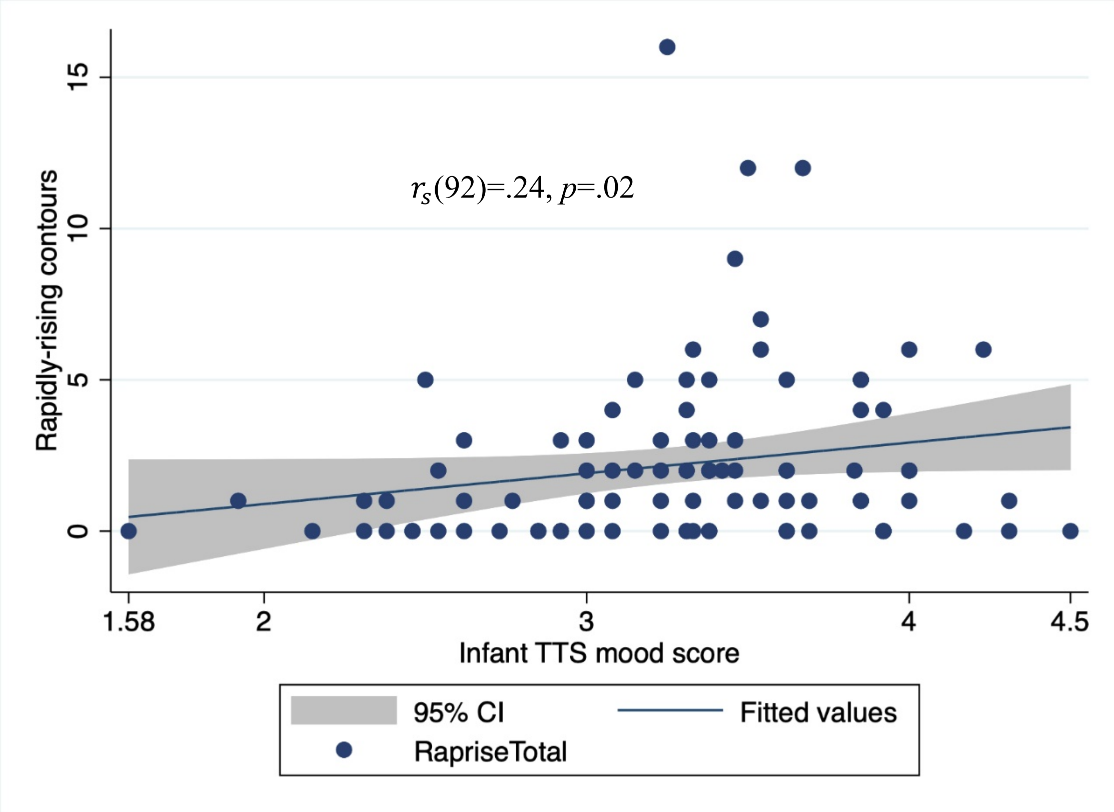

Figure 10. Scatter plot of infant TTS mood score and maternal rapidly-rising contours

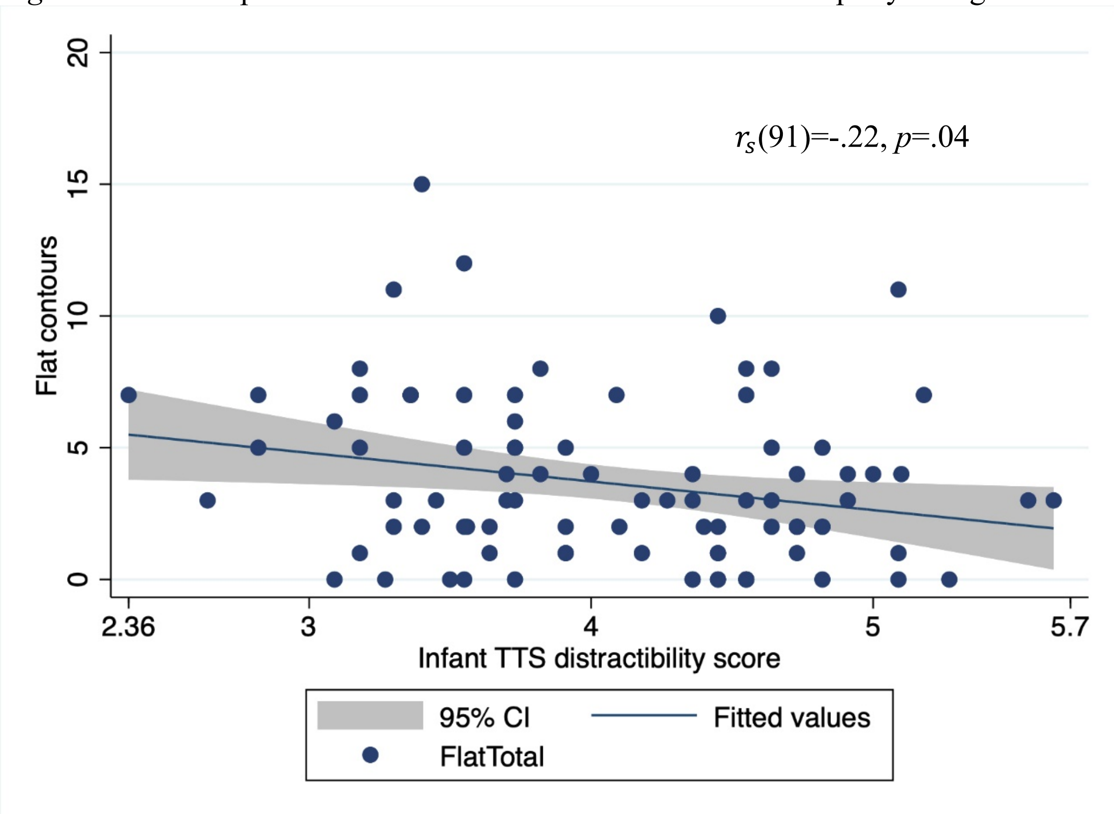

Figure 11. Scatter plot of infant TTS distractibility score and maternal flat contours

Appendix 20. Scatterplots of significant correlations between infant autism assessment scores and maternal utterances during 15-minute interaction

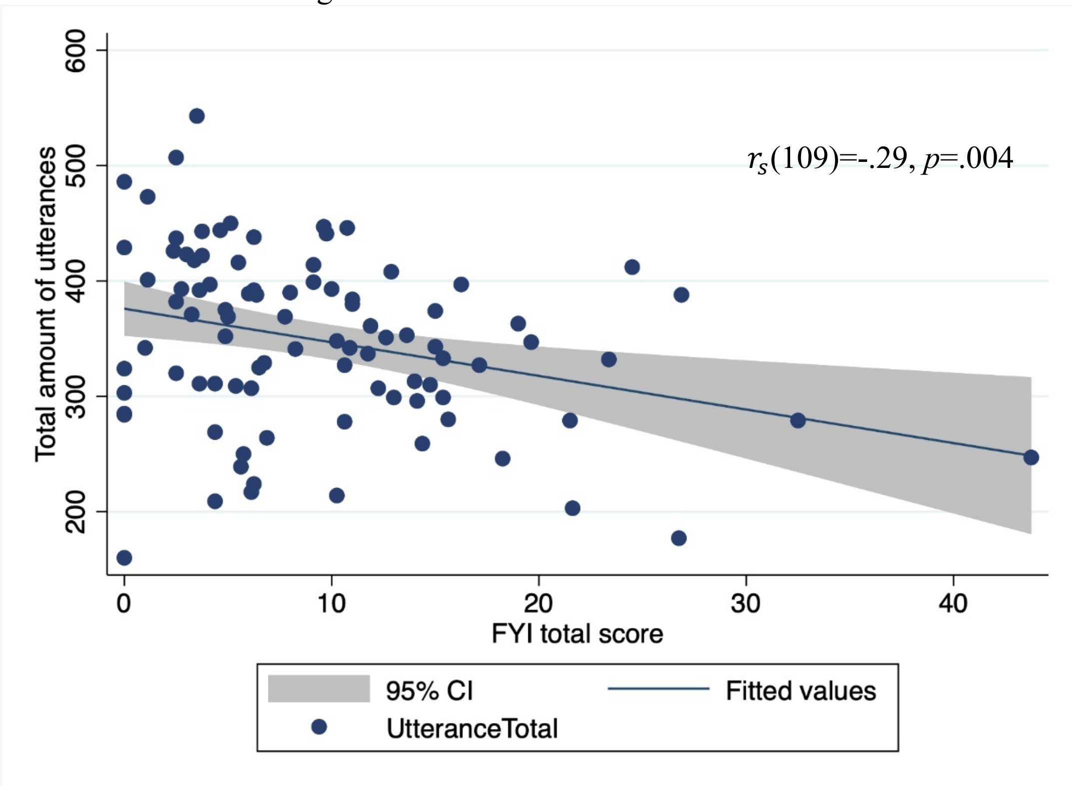

Figure 12. Scatter plot of infant FYI total score and maternal utterances

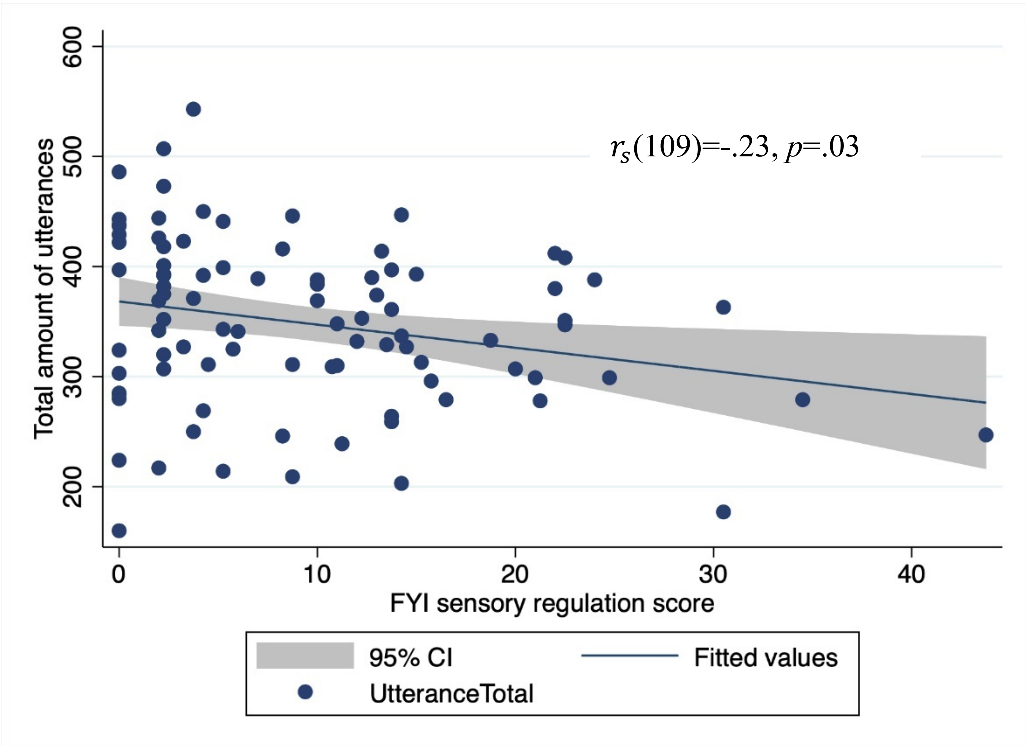

Figure 13. Scatter plot of infant FYI sensory regulation score and maternal utterances

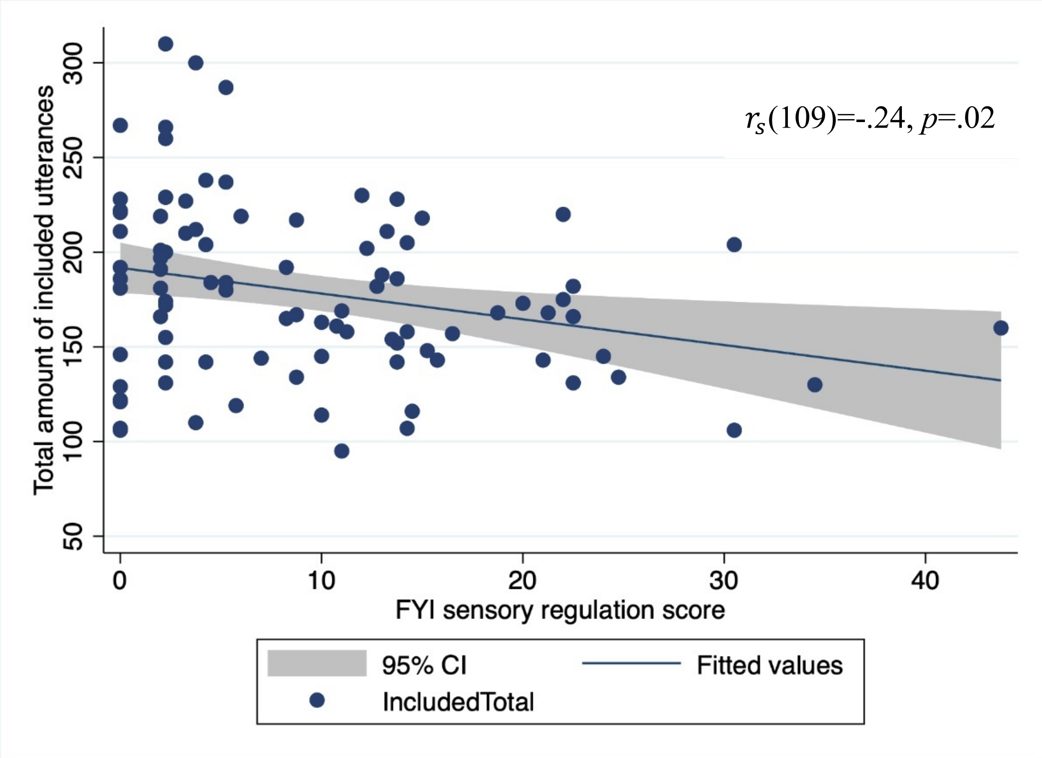

Figure 14. Scatter plot of infant FYI sensory regulation score and maternal included utterances

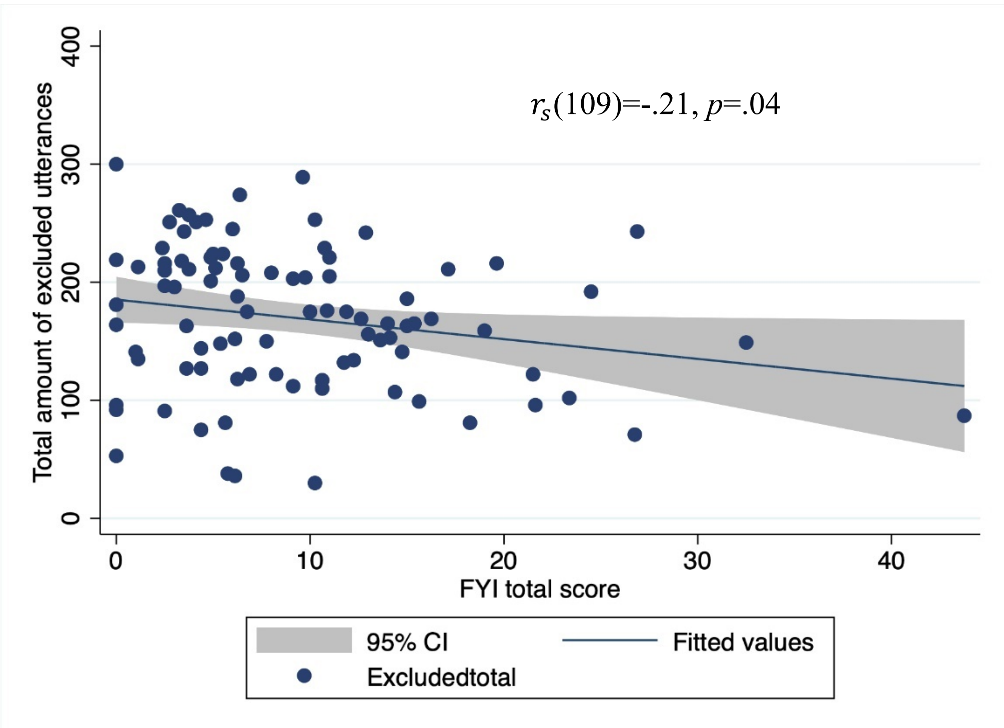

Figure 15. Scatter plot of infant FYI total score and maternal excluded utterances

Appendix 21. Scatterplots of significant correlations between infant autism assessment scores and maternal pitch contours during 15-minute interaction

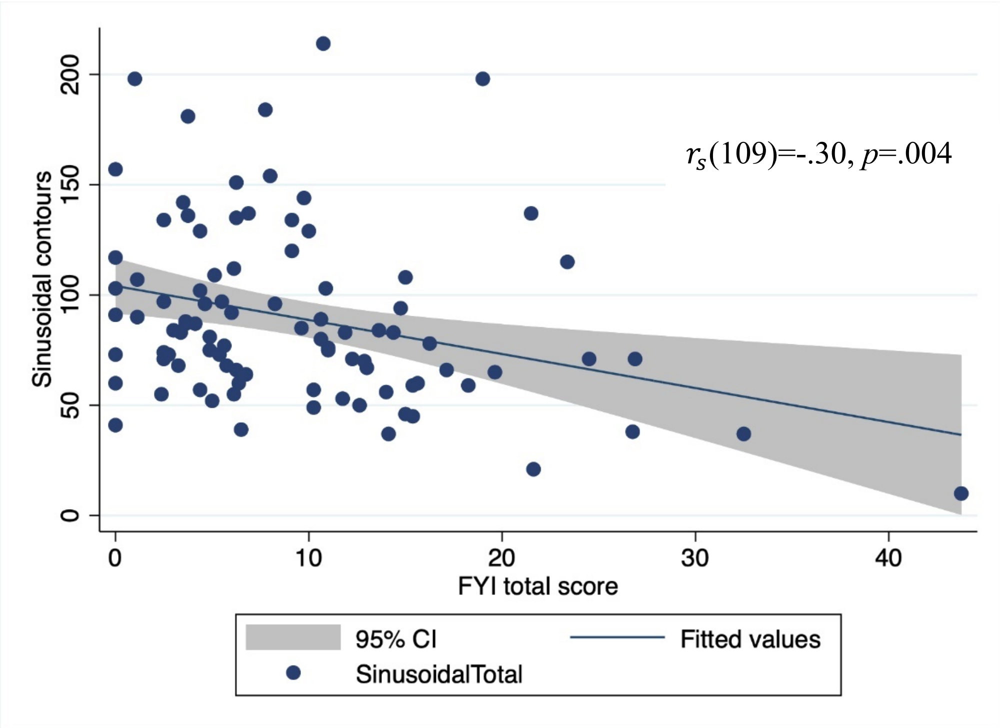

Figure 16. Scatter plot of infant FYI total score and maternal sinusoidal contours

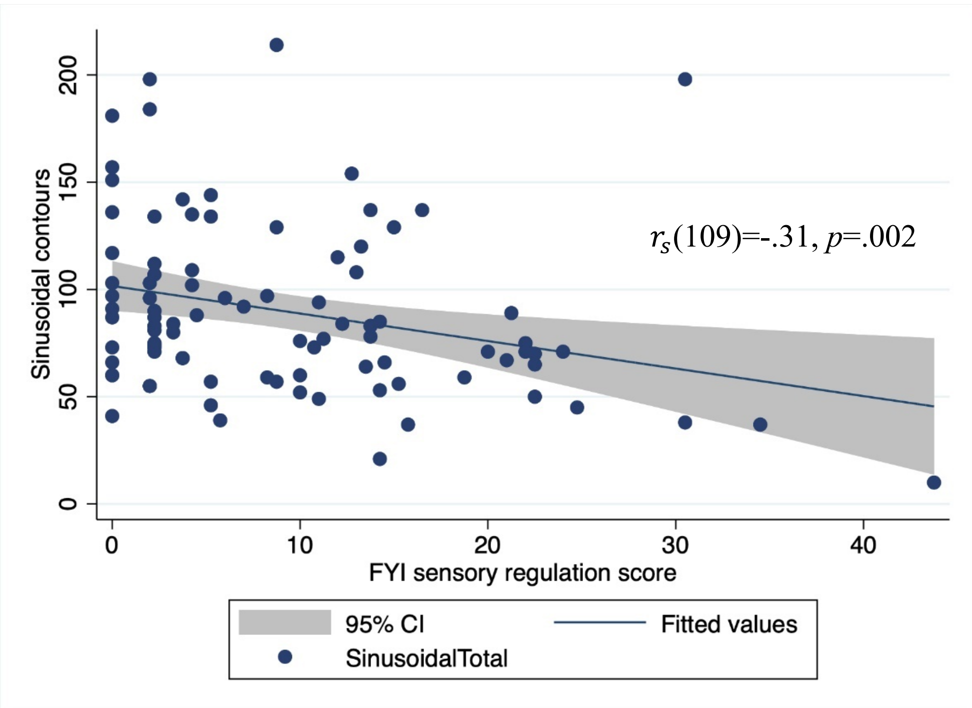

Figure 17. Scatter plot of infant FYI sensory regulation score and maternal sinusoidal contours

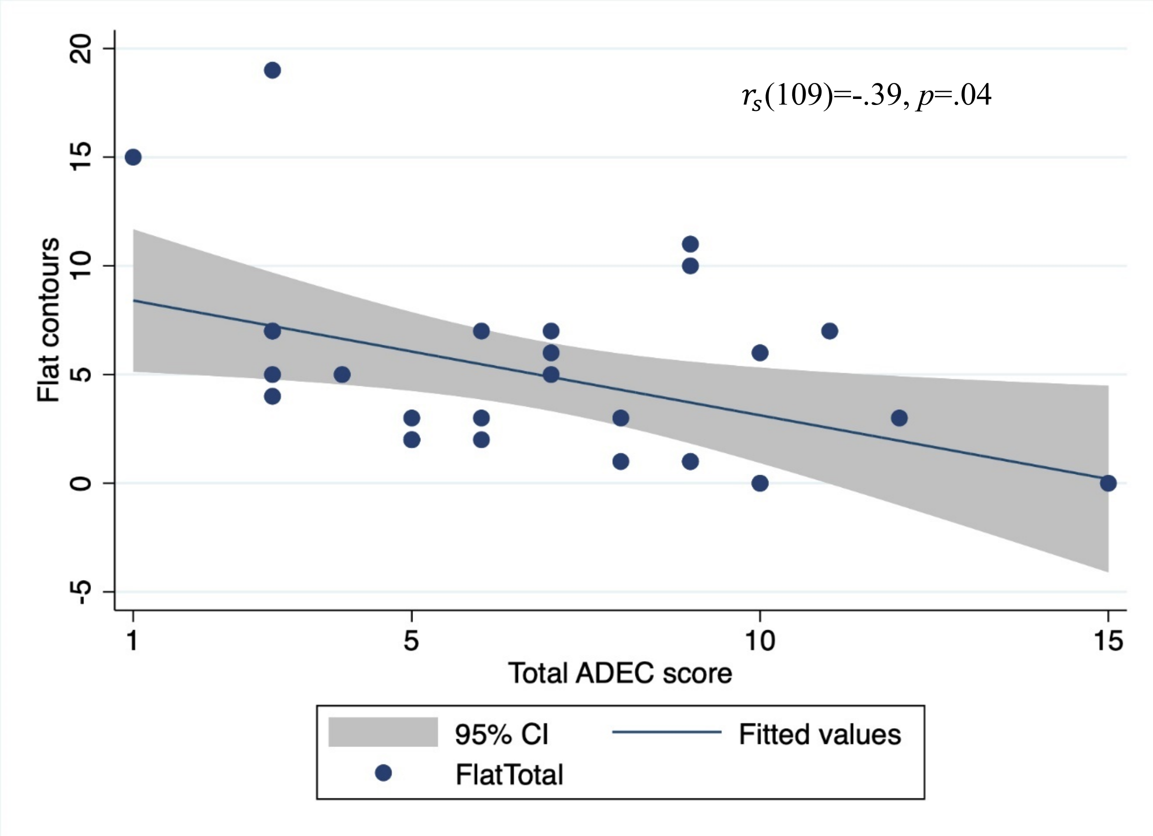

Figure 18. Scatter plot of infant ADEC score and maternal flat contours

Appendix 22. Normality checks for temperament variables

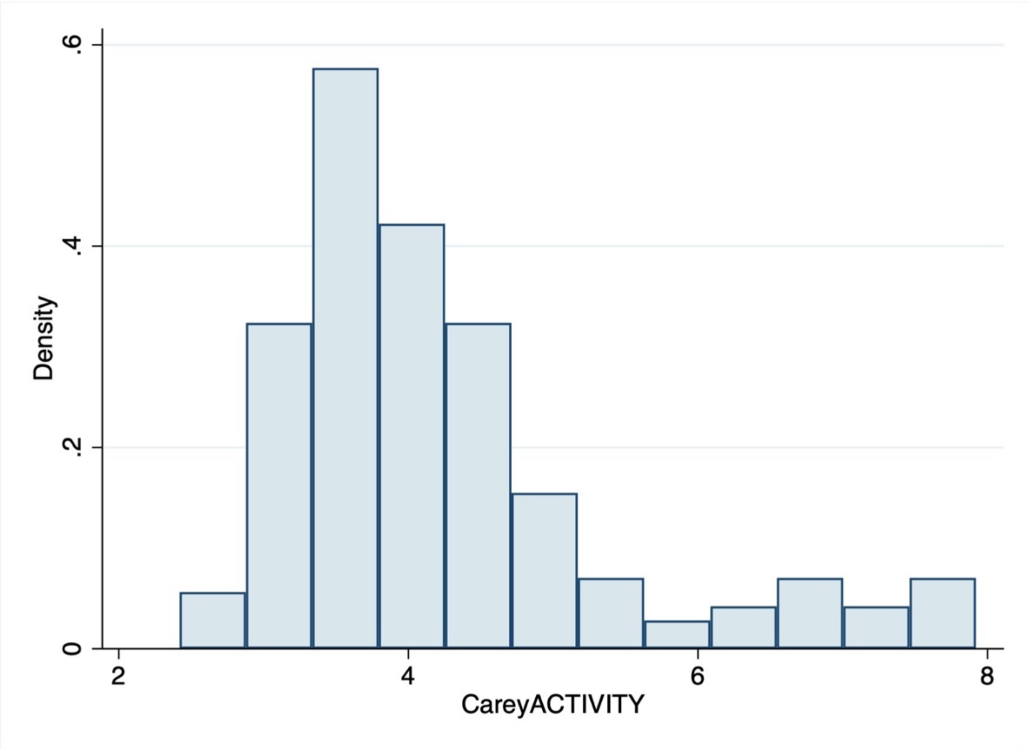

Figure 18. Histogram of infant TTS activity scores

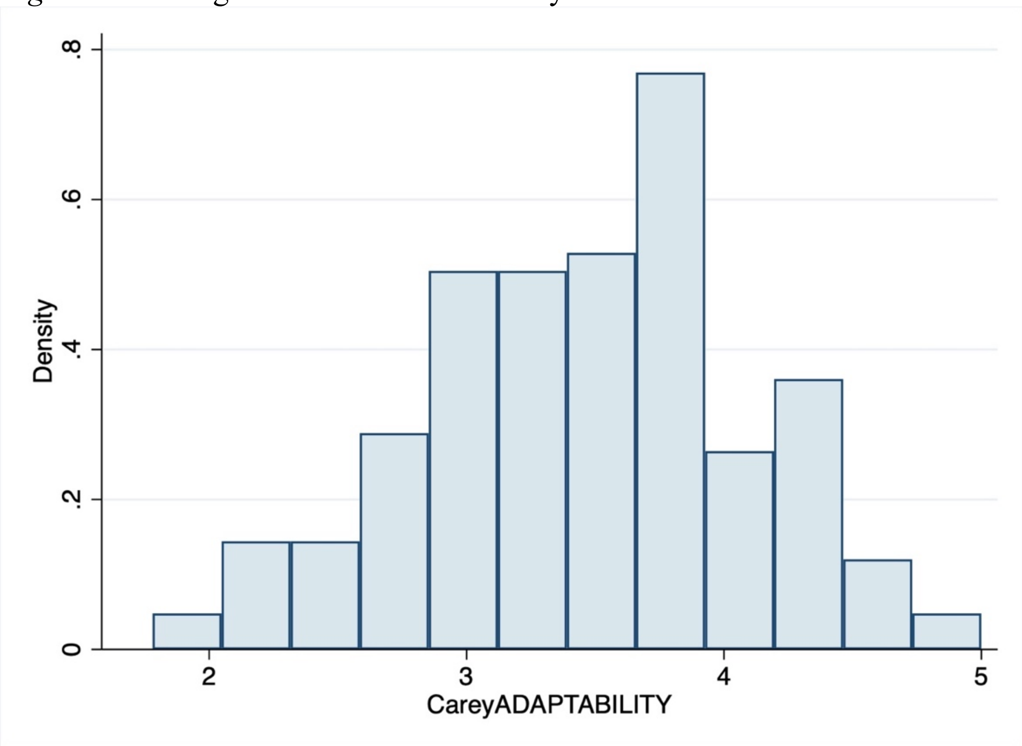

Figure 19. Histogram of infant TTS adaptability scores

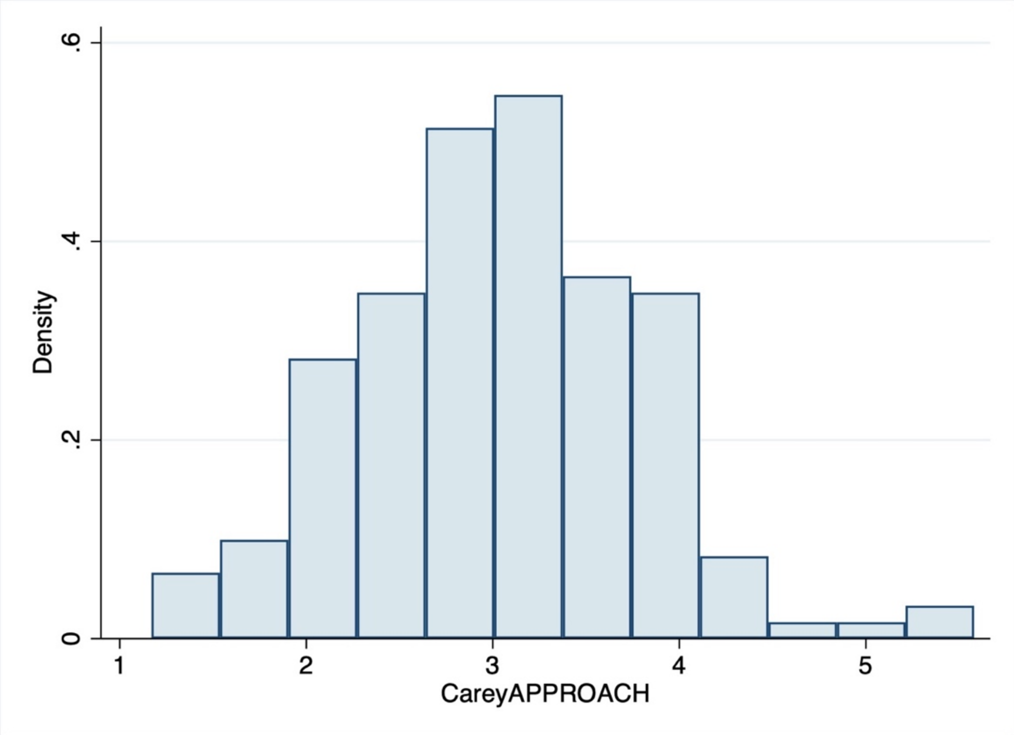

Figure 20. Histogram of infant TTS approach scores

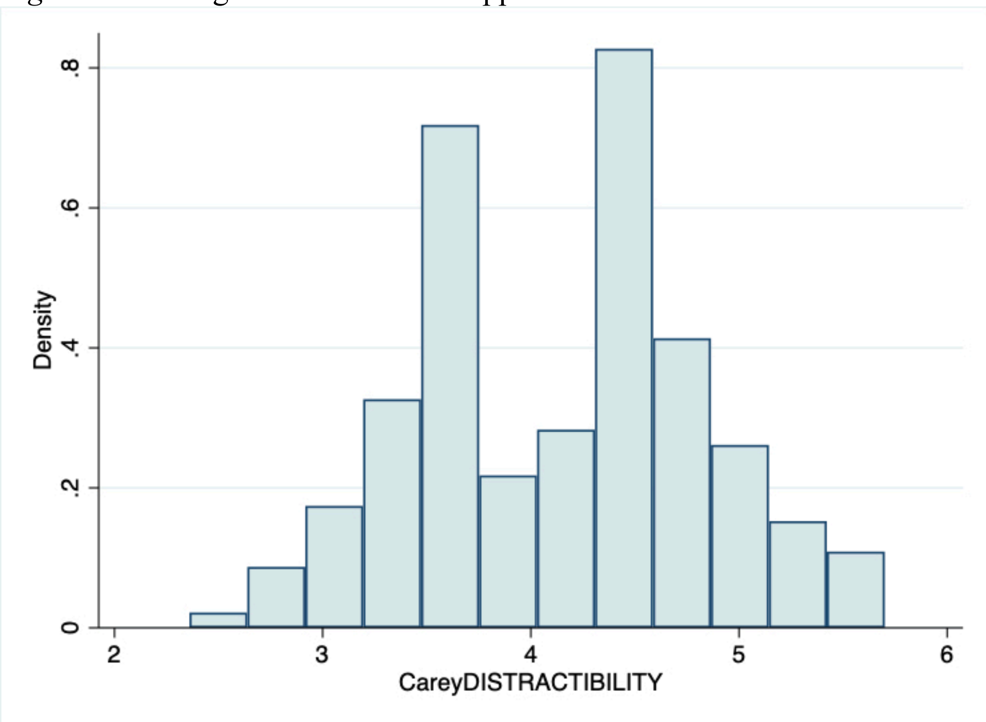

Figure 21. Histogram of infant TTS distractibility scores

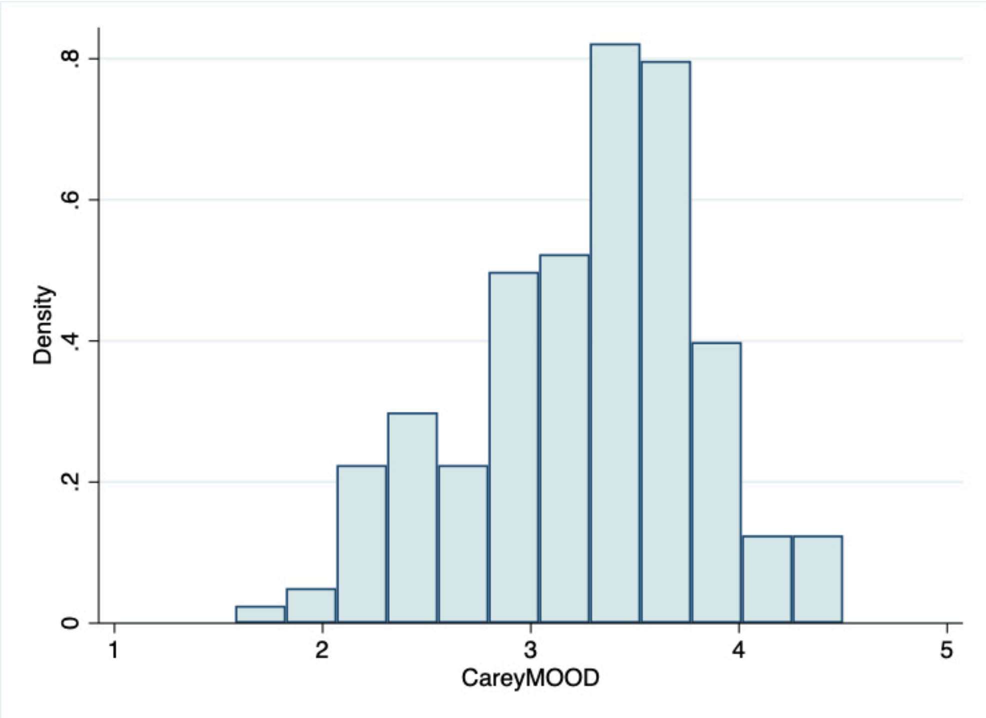

Figure 22. Histogram of infant TTS mood scores

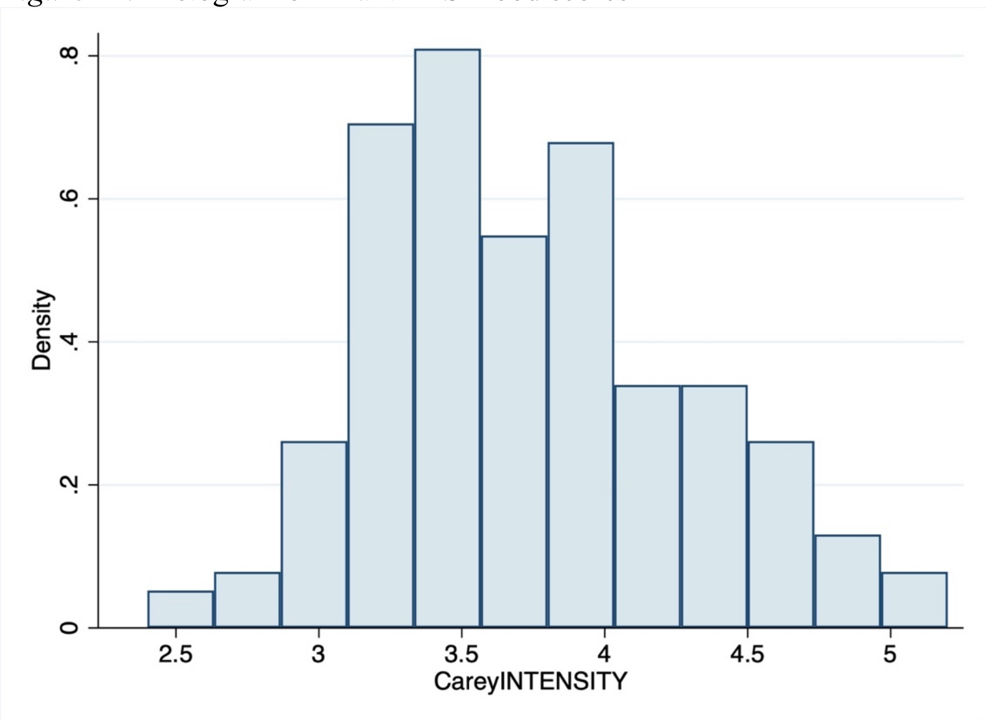

Figure 23. Histogram of infant TTS intensity scores

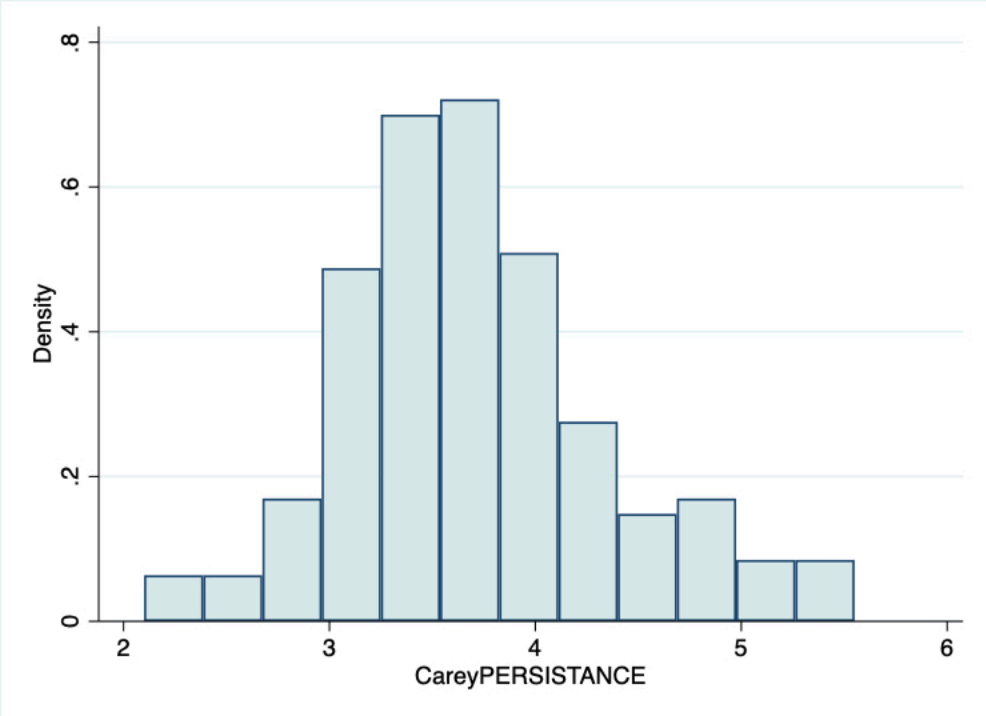

Figure 24. Histogram of infant TTS persistence scores

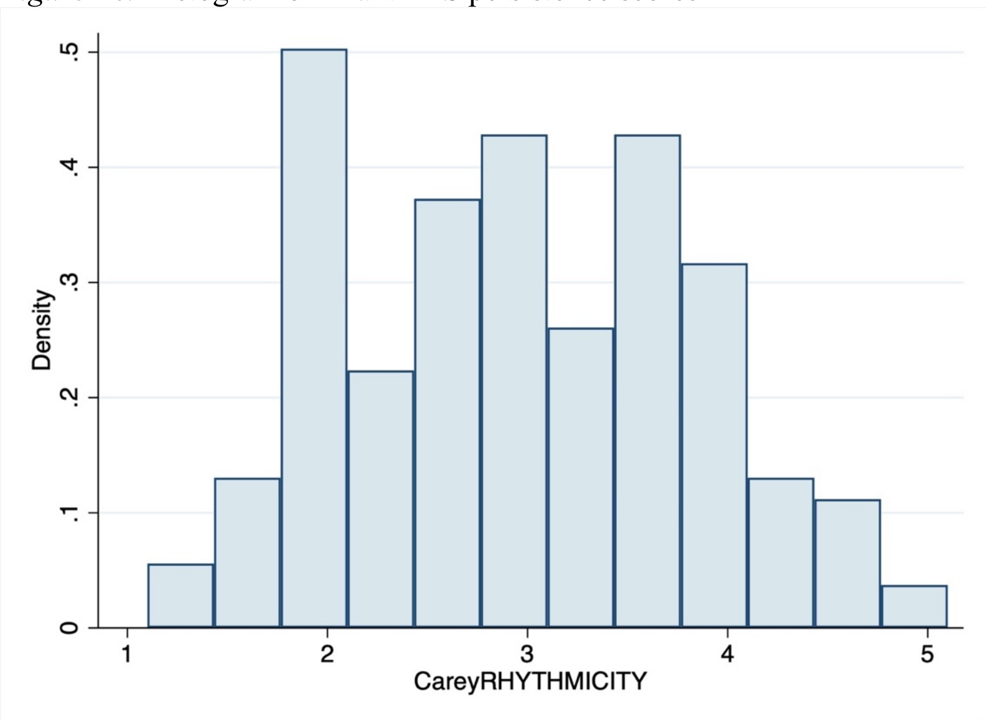

Figure 25. Histogram of infant TTS rhythmicity scores

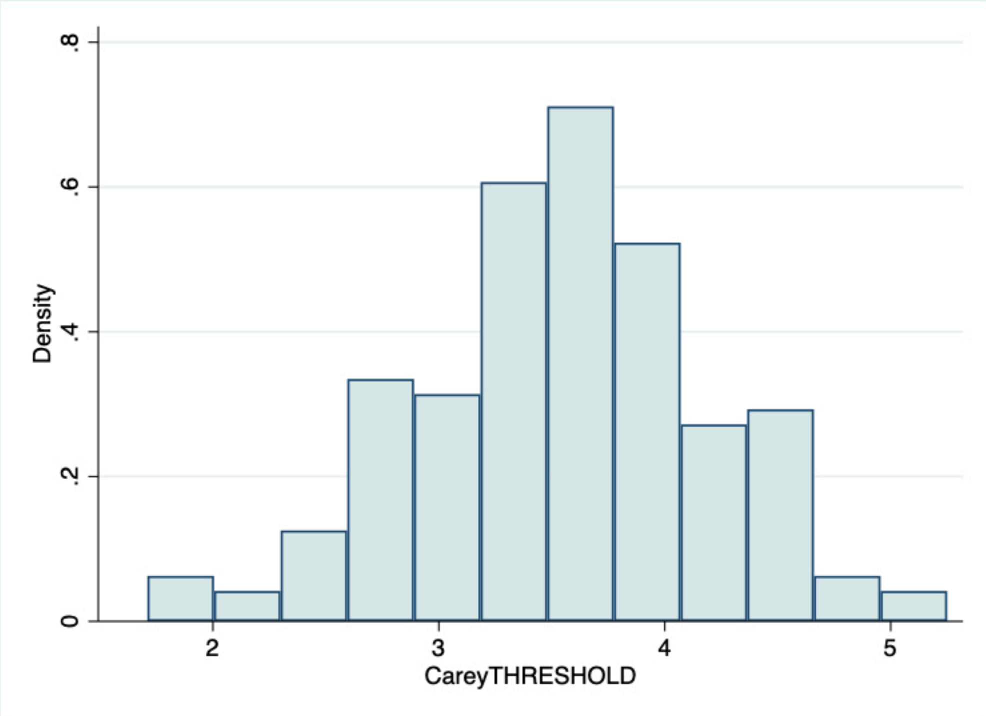

Figure 26. Histogram of infant TTS threshold scores

Appendix 23. Normality checks for autism variables

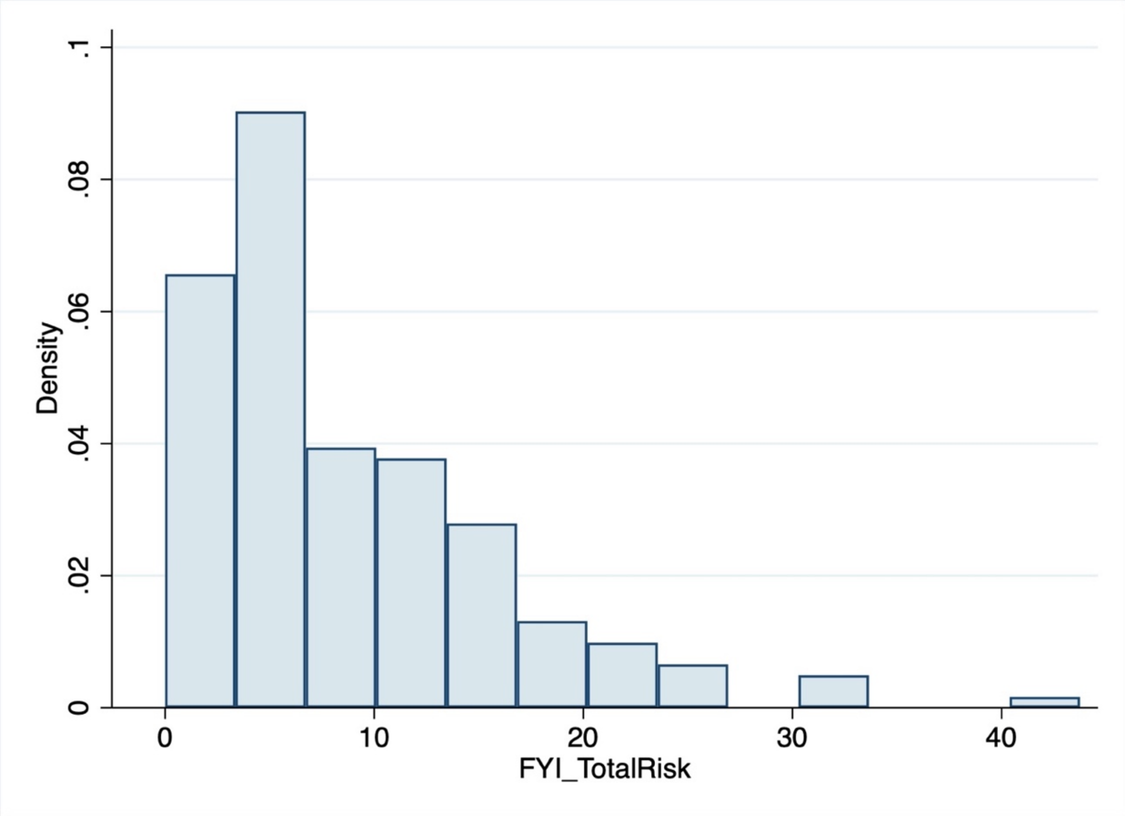

Figure 27. Histogram of infant FYI total scores

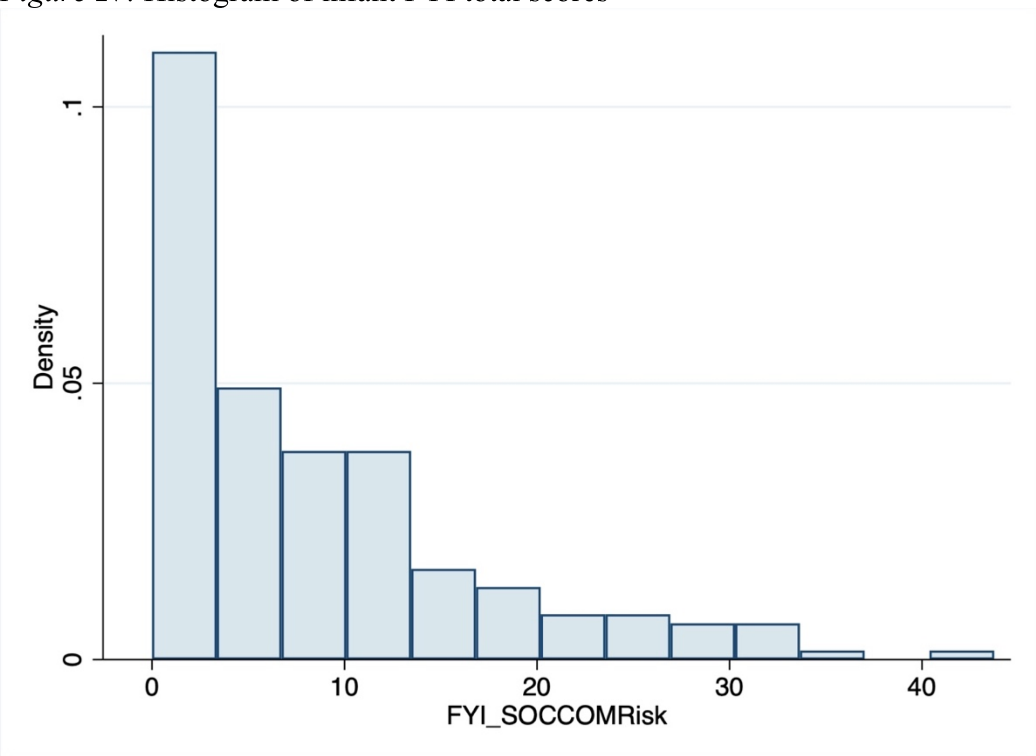

Figure 28. Histogram of infant FYI social communication scores

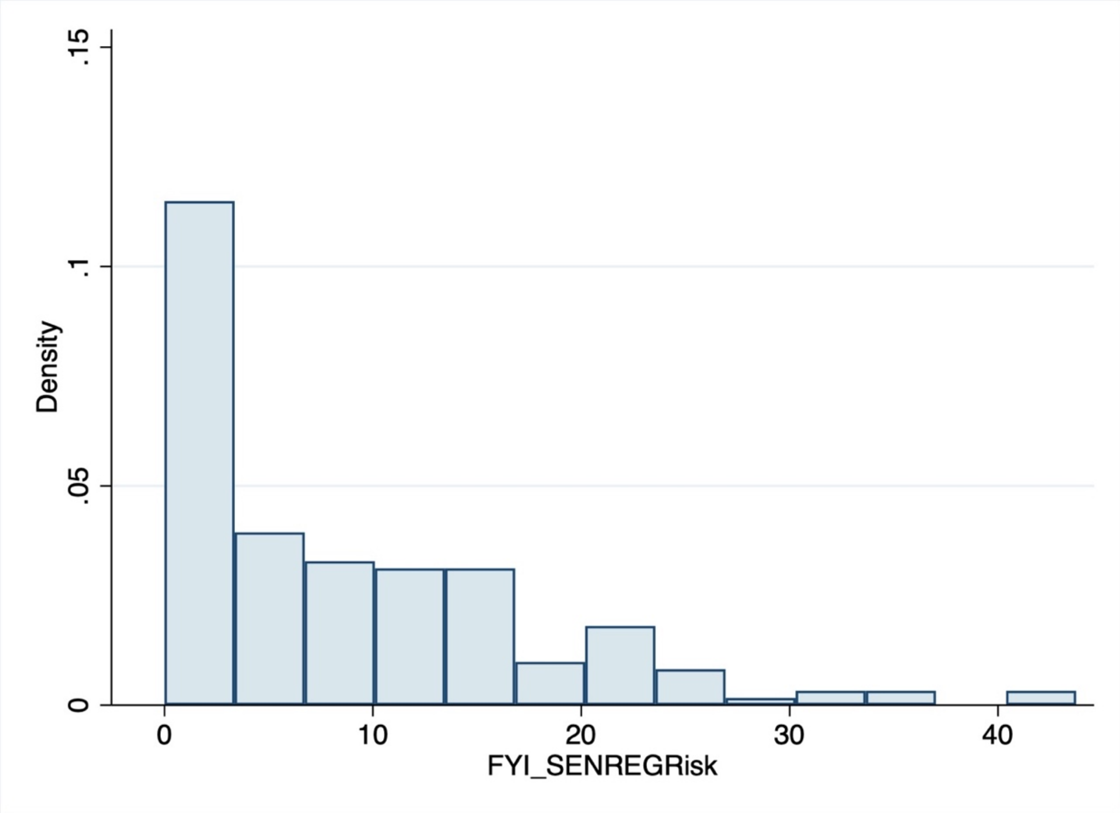

Figure 29. Histogram of infant sensory regulation scores

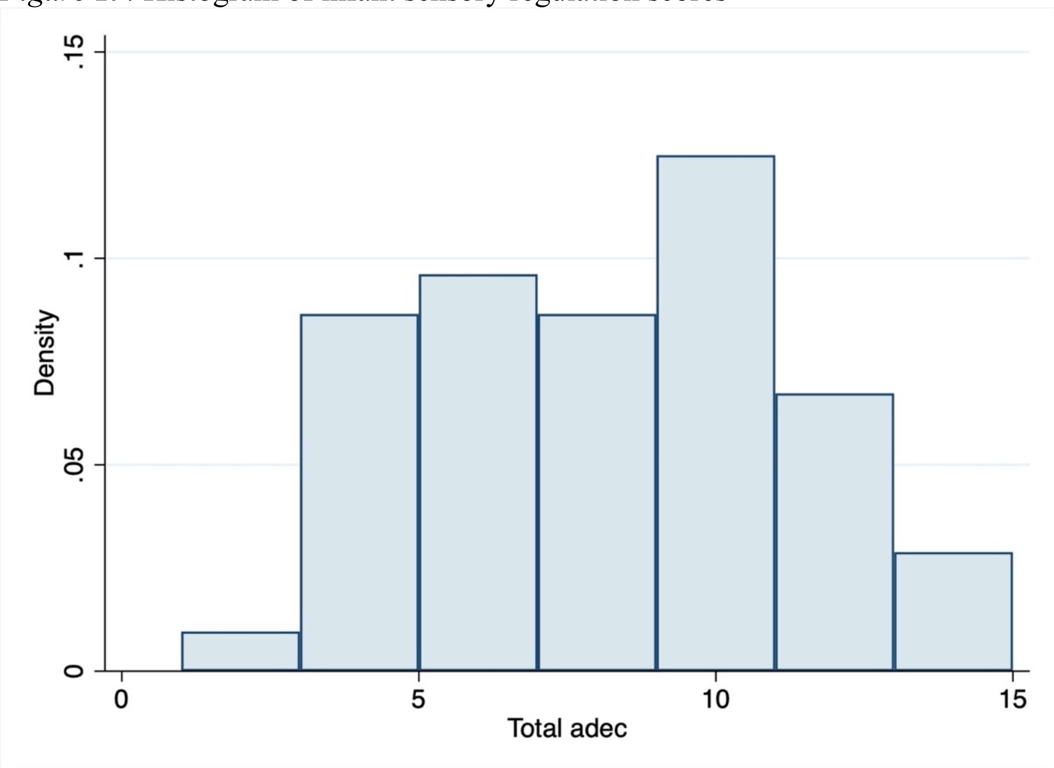

Figure 30. Histogram of infant ADEC scores

Appendix 24. Correlation matrix (r^2) for infant ADEC and TTS scores

TTS domain	ADEC
Activity	.32
Rhythmicity	.15
Approach	-.00
Adaptability	-.23
Intensity	-.02
Mood	-.05
Persistence	.08
Distractibility	-.10
Threshold	.14

Appendix 25. Correlation matrix (r^2) for maternal EPDS scores and maternal utterances

	Maternal EPDS scores
Utterance total	**-.29***
Included utterance total	-.24
Excluded utterance total	-.18

*Note: *indicates significance at the α<0.05 value*

Appendix 26. Correlation matrix (r^2) for maternal EPDS scores and maternal pitch values

	Maternal EPDS scores
Pitch minimum	.05
Pitch median	-.00
Pitch maximum	-.01

Appendix 27. Correlation matrix (r^2) for maternal EPDS scores and maternal pitch contours

Pitch contour	Maternal EPDS scores
Rising	.02
Bell-shaped	-.03
Sinusoidal	**-.27***
U-shaped	-.09
Flat	.16
Complex	-.08
Rapidly-falling	-.06
Rapidly-rising	**-.28***
Slowly-falling	.19

*Note: *indicates significance at the* α*<0.05 value*

Appendix 28. Correlation matrix (r^2) for infant BSID-III and TTS scores

TTS Domain	Cognitive composite	Language composite	Motor composite
Activity	.09	.10	.02
Rhythmicity	-.12	-.02	-.10
Approach	-.01	.02	-.13
Adaptability	-.05	-.13	-.02
Intensity	-.15	-.17	-.03
Mood	-.18	-.09	-.08
Persistence	-.09	-.06	-.02
Distractibility	-.04	.02	.07
Threshold	-.07	-.17	-.11

Appendix 29. Correlation matrix (r^2) for infant BSID-III and maternal pitch contours

Pitch contour	Cognitive composite	Language composite	Motor composite
Rising	.03	-.11	-.07
Bell-shaped	-.02	.00	-.08
Sinusoidal	.06	.17	.15
U-shaped	-.07	-.06	-.08
Flat	-.10	-.07	-.17
Complex	.16	.01	.08
Rapidly-falling	-.11	-.16	**-.21***
Rapidly-rising	.06	-.12	-.07
Slowly-falling	-.08	-.15	-.13

*Note: *indicates significance at the α<0.05 value*

Appendix 30. Correlation matrix (r^2) for infant BSID-III and ADEC scores

BSID-III composite domain	ADEC score
Cognitive	-.17
Language	-.46**
Motor	-.04

*Note: *indicates significance at the α<0.05 value, ** indicates significance at the α<0.01 value*

Appendix 31. Correlation matrix (r^2) for infant BSID-III and FYI scores

FYI Domain	Cognitive composite	Language composite	Motor composite
Total score	-.24*	-.18	-.16
Social communication	-.19	-.17	-.08
Sensory regulation	-.24*	-.12	-.20

*Note: *indicates significance at the α<0.05 value*

Appendix 32. Correlation matrix (r^2) for infant number of days born preterm and infant TTS domain scores

TTS domain	Days born preterm
Activity	-.09
Rhythmicity	**.45*** **
Approach	.16
Adaptability	-.09
Intensity	**.37** **
Mood	**-.26***
Persistence	-.20
Distractibility	**-.35** **
Threshold	.09

*Note: *indicates significance at the α<0.05 value, ** indicates significance at the α<0.01 value, ***indicates significance at the α<0.001 value*

Appendix 33. Correlation matrix (r^2) for infant number of days preterm and infant FYI domain scores

	Days born preterm
FYI total	-.09
FYI social-communication total	-.01
FYI sensory-regulation total	-.10
ADEC score	.16

Appendix 34. Correlation matrix (r^2) for maternal number of utterances and infant TTS profile scores

	TTS Profile
Utterance total	-.05
Included utterance	-.06
Excluded utterance	.03

Appendix 35. Correlation matrix (r^2) for maternal pitch values (Hz) and infant TTS scores

TTS domain	Pitch minimum	Pitch median	Pitch maximum
Activity	.05	.13	.10
Rhythmicity	.08	-.01	.08
Approach	-.00	.07	.05
Adaptability	-.05	-.12	-.19
Intensity	-.02	.03	-.12
Mood	.13	.17	.07
Persistence	.08	-.03	.02
Distractibility	-.12	-.20	-.16
Threshold	.13	.10	.05

Appendix 36. Correlation matrix (r^2) for pitch contours and infant TTS clinical profiles

Pitch contour	TTS clinical profile
Rising	-.16
Bell-shaped	-.01
Sinusoidal	.08
U-shaped	-.12
Flat	-.02
Complex	-.03
Rapidly-falling	-.03
Rapidly-rising	.18
Slowly-falling	-.09

Appendix 37. Correlation matrix (r^2) for pitch values and infant FYI and ADEC scores

	Pitch minimum	Pitch median	Pitch Maximum
FYI total score	.01	-.12	-.01
FYI social communication score	.00	-.07	-.15
FYI sensory regulation score	.01	-.06	-.01
ADEC score	.01	-.30	-.34

Appendix 38. *Correlations (r_s) between maternal utterances during the 15-minute interaction and infant ADEC score.*

	Total ADEC score
Utterance total	-.23
Included utterance total	-.03
Excluded utterance total	-.20

*Note: *indicates significance at the α<0.05 value, ** indicates significance at the α<0.01 value*