The Influence of Sensory Processing Patterns on Infant Directed Speech

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BPsychSc (Hons)

This thesis is presented in partial fulfilment of the requirements for the degree of Master of Clinical Psychology, School of Psychology, University of Newcastle, Australia.

October, 2020

Acknowledgements

To my primary supervisor Linda, thank you for your hard work, expertise, thorough feedback, guidance, and support over the past two years. Your passion for the field, and child and developmental research is infectious and I have learnt so much working under you for this project. You were able to steer the ship and keep me on task and I would not have finished this without your leadership.

To my secondary supervisor Alix, thank you for all your generosity with your time. You helped teach me all of the coding (which there was a lot), went through any process with me that I was unsure of, and looked over countless drafts. You fell out of the sky just when I needed you the most, and the fact that you agreed to stay a part of this process to support me has made all the difference.

Thank you to all of the Baby Lab team for teaching me the ropes, teaching me how to do all the testing, and helping me understand the immense data set.

To all the parents and babies who took the time to participate in this study. We would have nothing without you. Thank you for making this all possible.

To my loving wife Nicole. You sacrificed so much in moving across the country to allow me to follow my dream. I cannot put into words how thankful I am to you and hope that this goes a long way into supporting our family for years to come. You have kept me sane, encouraged me, listened to me vent, and held down the fort on all my long days and busy nights.

Finally to my family and friends back in Adelaide. Thank you for all your gift packages and support from afar. While we have been separated by distance, your support has been felt in full force and has allowed me to get through.

Declarations

Statement of Originality

This thesis contains no material which has been accepted 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 in the text. I give consent to this copy of my thesis, when deposited in the University Library*, being made available for loan and photocopying subject to the copyright Act 1968.

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Acknowledgement of Collaborations

I hereby certify that the work embodied in this thesis has been done in collaboration with other researchers. I have included as part of this thesis a statement clearly outlining the extent of collaboration, with whom and under what auspices. I contributed to the implementation of some of the assessments and data coding for new participants, contributed to the development of the research questions, undertook and interpreted the statistical analyses, and wrote the body of the work with editing provided by my primary supervisor, Dr Linda Campbell and secondary supervisor, Dr Alix Woolard. Research team members over the past few years from the Baby Lab project completed assessments and data coding for some of the participants used within this project, however their theses focused on different areas with them focusing on alternative data analyses for their respective studies. Both Dr Linda Campbell and Dr Alix Woolard contributed to the development of the research question, the formulation of the methodology, and the editing of the manuscript.

Statement of Authorship

I hereby certify that the work embodied in this thesis contains a manuscript of which I am a joint author. I have included as part of the thesis a written statement, endorsed by my supervisor, attesting to my contribution to the joint work.

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Formatting Style Used in This Thesis

This thesis is formatted according to the *Publication Manual of the American Psychological Association, sixth edition.* The manuscript was formatted for submission to the Journal of Autism and Developmental Disorders, in line with the submission guidelines and instructions for authors which are contained in Appendix A.

Running head: SENSORY PROCESSING AND INFANT DIRECTED SPEECH

The influence of Sensory Processing Patterns on Infant Directed Speech.

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Declarations

The authors declare no conflicts of interest.

Ethics Approval

Approval was obtained from the ethics committee of the University of Newcastle

Consent to Participate

Informed consent was obtained from all individual participants included in the study, or their legal guardians.

Abstract

Sensory processing abilities influence how we respond to our environments. Patterns of processing lie on two continuums: high/low thresholds for respond, and seeking/avoiding tendencies. These patterns can influence early interactions which play an important part in infant development. Infant directed speech (IDS) has been shown to be an effective tool for caregivers to interact with their infants. This study explored whether caregivers were able to pick up on early infant sensory processing patterns and were adjusting their speech accordingly. Data from 149 caregiver-infant dyads was collected when the infants were six- and 12- months old and were analysed both cross-sectionally and longitudinally. Evidence found weak relationships between sensory processing and IDS but suggested infant temperament better explained IDS overall.

Keywords: Sensory processing, infant directed speech, temperament

The influence of Sensory Processing Patterns on Infant Directed Speech.

How the brain integrates sensory information from the environment is key to how humans see the world. Effective integration promotes the development of social, emotional, and physical skills, leading to adaptive behaviours (Baranek et al., 2008; Miller, Anzalone, Lane, Cermak, & Osten, 2007). How the brain takes in and processes information from external stimuli is called sensory processing. Sensory processing measures how individuals respond and interact with their environments (Williams, 2017). Atypical sensory processing have been shown to occur in up to 16% of people in the general population (Ahn et al., 2004; Ben-Sasson et al., 2009), and commonly occur in neurodevelopmental conditions such as autism (Baranek et al., 2006). Sensory deficits have also been shown to impact on how people interact with others (Interdisciplinary Council on Developmental and Learning Disorders, 2012). Conversely, effective sensory processing has been shown to be a key contributor to learning and the development of motor functioning and emotions (Ahn et al., 2004). Variations in the development of sensory processing can be observed as early as the first few months of life (Iarocci, & McDonald, 2006; Mulligan, & White, 2012), have been shown to become stable by the time children are school aged (Dunn, 2001), and remain persistent across the life span (Leekam, Nieto, Libby, Wing, & Gould, 2007). The longevity of these processes make it important to understand how they develop in early life

In an effort to categorise response patterns Dunn (1997) proposed a model of sensory processing which will form the basis of the approach in this paper. The model argues that humans move along two continuums for sensory input. The first is a continuum of neurological thresholds of sensory input needed before we are able to process and respond (e.g., high and low thresholds). The second continuum is a behavioural response in which we either avoid or seek sensory stimulation as a form of self-regulation. Four possible patterns of sensory processing emerge depending on where the individual places on the two continuums: low registration, sensation seeking, sensation avoidance, and sensory sensitivity (see Table 1 for a summary of sensory processing patterns). Dunn emphasises the fluidity of these patterns and states that individuals may present with any of the four across the sensory systems as well as within different interactions (Dunn, 1997). For example, an individual may require low levels of stimulation in order to process auditory information paired with a tendency to try and avoid it, whereas have a similar low level of stimulation required for processing visual stimuli but instead seek this out. Additionally, the same individual who avoids auditory stimulation may in fact seek out low frequency tones but avoid sounds with higher frequencies.

(Place Table 1 here)

The ability to attend to stimuli has been highlighted as a key component for effective sensory processing. Ayres' (1972) sensory integration theory (SIT) outlines that active attention is crucial for one to be able to process sensory information. Infants need to have developed the ability to select what information to attend to, as well as sustain their attention to that stimuli to effectively process the information (Petersen & Posner, 2012). Based on Dunn's model, infants with avoidance tendencies may lack the ability to initially select where to put their attention. Infants with a higher registration threshold may be able to initially choose where to direct their attention, particularly for sensation seeking patterns, but have difficulties sustaining their attention for long enough to have the information processed sufficiently. This in turn can make interactions with caregivers more difficult, with infants who experience challenges with sensory processing not being able to pick up communication cues or develop joint attention skills as effectively as other children. The majority of research to date however has focused on sensory processing in response to environmental stimuli with little investigation about the ways in which sensory processing patterns may influence interactions themselves.

Caregiver-Infant Interactions

Parent-child interactions early in life play a crucial role in the development and well-being of infants (Hollenstein, Tighe & Lougheed, 2017; Saint-Georges et al., 2013). These interactions are reciprocal in nature where the attention, emotional experience, and behaviour of one interactional partner is influenced by the actions of the other (Katz, Cohn & Moore, 1996). Caregivers who are sensitive and responsive to the needs of their child have been shown to promote better language and attention skills, and healthier psychological wellbeing (Bentenuto, Perzolli, de Falco, & Venuti, 2020). When looking specifically at sensory processing abilities, Little, Dean, Tomcheck, and Dunn (2017) suggest that when children are seen to respond in certain ways to sensory stimulation, parents begin to change how they engage with the child to accommodate for their sensory aversions and preferences. For example, infants with a sensation avoidance response pattern may present as less responsive to their caregiver and less interested in exploring their environment resulting in caregivers speaking less to them (DeGangi et al., 1997). Infants with low registration response patterns on the other hand may appear as inattentive and unresponsive resulting in caregivers speaking more frequently or with higher volume and pitch properties in order to have the information register with the child.

One of the most useful ways caregivers can modify their interactions with infants is through their speech. Indeed, infant directed speech (IDS) refers to a unique speech register that adults use to communicate with infants (Fernald, 1989; Soderstrom, 2007). Infant Directed Speech can be differentiated from adult directed speech (ADS) by its unique linguistic, acoustic, and prosodic properties which include slower rates of speech, higher intensity, specific pitch contours (the visual representation of how the pitch of an utterance varies over time), and both higher and more variable pitch (Fernald & Simon, 1984; Kitamura & Burnham, 2003; Snow & Ferguson, 1977; Spinelli, Fasolo, & Mesman, 2017).

The acoustic and prosodic features present in IDS are arguably the most salient in early infancy as they regulate emotion and attention, which are more important early on as the ability to understand word meanings typically emerges at around 9 months of age (Kitamura & Burnham, 2003). While there is some evidence that infants may begin to understand basic and commonly used words in their environments from around 6 months of age (Bergelson, & Swingley, 2012), language recognition is still formative at this point thus placing a higher emphasis on sound tones. The acoustic and prosodic features of IDS assist in conveying emotion and directing infant attention, which are important early on for infant social and communicative development (Fernald, 1989). They are also able to be imitated more easily by infants emphasising and providing ways in which they can learn to direct interactions themselves (Gratier & Devouche, 2011; Papoušek & Papoušek, 1989). Variations in pitch contours generally take the form of one of the following eight categories, each with their own specific purpose in communication: rising and rapidly-falling/rising (attention gaining); bell-shaped, u-shaped, and sinusoidal (attention maintaining); slowly-falling (comforting distress); flat, or complex (limited function and infrequently studied) (Fernald, 1989; Gratier & Devouche, 2011; Papoušek et al., 1991; Stern et al., 1982). See Table 2 for a summary of contour functions. The different functions of each contour allows for the effective regulation of an infant's attention and suggest that IDS may play a contributing factor in the development of attention long-term.

(Place Table 2 here)

Despite research linking both sensory processing with attention abilities, and IDS with the acquisition of attention skills, there are no studies to date investigating the impact of infant sensory profiles on IDS in caregivers. Dunn, Saiter, and Rinner (2002) argue that parents may modify the qualities of pitch in their interactions with infants depending on their sensory processing thresholds. IDS in particular serves the function of gaining infant attention. It may be possible that caregivers are able to pick up on early signs of sensory processing styles and adjust their speech accordingly. Some factors, however, have been studied in relation to the impact on IDS. Caregiver mental health specifically has been shown to modify IDS with maternal depression specifically being found to reduce overall vocalisations as well as pitch means and ranges when speaking to infants (Brookman et al., 2020; Lam-Cassettari, & Kohloff, 2020; Porritt, Zinser, Bachorowski, & Kaplan, 2014). Temperament has also shown evidence to impact on IDS with caregivers responding to different temperamental traits, such as more negative moods or less likely to approach novel stimuli, with differing proportions of pitch contours (Woolard et al., 2016).

The aim of this study was to explore whether infant sensory sensitivity was related to the use of IDS from caregivers in an attempt to better understand the bidirectional relationship of early social interactions, specifically if caregivers are able to pick up on early signs of sensory processing difficulties within infants. Due to a lack of research within this area it was unclear as to whether any potential relationships would be observed cross-sectionally or longitudinally. As such, it was thought best to include analysis for both in an exploratory capacity in order to gain a good understanding of any effects. To achieve this aim, pitch contours and frequencies were measured from parents during a free play interaction with their babies at both six and 12 months of age and compared with infant sensory processing profiles. These time points were selected primarily as there was an available pool of data present from a pre-existing and larger study that had already been conducted. Despite no direct studies looking at this relationship, links to attention for both sensory processing and IDS lead to the theory that caregivers may modify their pitch and use specific contours aimed at regulating attention in response to their infants' sensory processing sensitivities. Initially data was explored cross-sectionally across the cohort at both six and 12 months to test the following hypotheses:

1. Caregivers of infants with higher scores on the registration variable (higher threshold of sensory input needed) at six months and 12 months will display higher overall pitch frequencies and more use of contours with attention purposes (rising, rapidly-falling, rapidly-rising, bell, u-shape, and sinusoidal) cross-sectionally.

2. Caregivers of infants with higher scores on the sensitivity variable (lower threshold of sensory input needed) at six months and 12 months will display lower overall pitch frequencies and fewer contours with attention purposes (rising, rapidly-falling, rapidly-rising, bell, u-shape, and sinusoidal) cross-sectionally.

Longitudinal analysis was also conducted to test the following hypotheses.

3. Caregivers of infants with higher scores on the registration variable at six months will display higher overall pitch frequencies and more use of contours with attention purposes at 12 months.

4. Caregivers of infants with higher scores on the sensitivity variable at six months will display lower overall pitch frequencies and fewer contours with attention purposes at 12 months.

To gain a better understanding of any links between sensory processing patterns and IDS, additional exploratory research questions were also asked:

1. Are IDS pitch properties related to sensation seeking/avoiding patterns as reflected in the seeking and avoiding variables?
2. Are sensory processing patterns related to the range of pitch used by caregivers when interacting with their infants?

Included within the scope of the study were measures postnatal depression and infant temperament which aligns with previously highlighted evidence of links with IDS. These were screened for covariates to ensure any links between IDS and sensory processing were independent of other factors. Infants' general development and social, emotional, adaptive behaviours as well as parental stress were also included as covariates within the study. With no established research links between these were all exploratory in nature to investigate whether they impact on IDS themselves or contribute to any links between IDS and sensory processing.

Method

Design

The current study was exploratory using a longitudinal design utilising data from the University of Newcastle Baby Lab research projects. Maternal pitch contours and frequencies, measured at both six and 12 months of infant age, were used as outcome variables. Sensory processing abilities, at six and 12 months of infant age, as measured by the quadrant scores of the Infant and Toddler Sensory Profile were used as the predictor variables.

Participants and Recruitment

Potential participants were identified at local antenatal clinics and asthma clinics or recruited through advertisements located in the John Hunter Hospital, community and social media, as well as being mentioned to women during their antenatal and six-week post-natal appointments. After contacting the research team, potential participants were provided with study information. An overall pool of 404 caregiver-infant dyads was present in the Baby Lab data however, only those with complete audio recordings of parent-child interactions were included in this study, leaving 149 dyad participants. Of these 149, only 24 dyads completed testing at both time points. Selection criteria required 1) all caregivers to be over 18 years of age, 2) display no severe mental health problems or drug dependency and infants who were not reliant on medical care at the time of the study.

Apparatus and Materials

Infant Directed Speech. A 15-minute caregiver-infant play interaction was video- and audio-recorded to measure IDS. The play interaction was recorded using four video cameras (Sony HDR CX240 handy-cam) mounted on tripods that focussed on a large, soft padded, gym-style play mat. A Sennheiser ew112G3 wireless clip-on microphone was attached to the caregivers for the audio recording. Maternal utterances were identified by vocalisations from the mother separated by a breath or more than 300 milliseconds of non-speech (Kitamura & Burnham, 2003). The maternal utterances were then classified using a script in Praat 5.3.51 (Boersma & Weenink, 2019) written for the purposes of this study. The script allowed trained researchers to classify the pitch contours into one of 8 pitch shapes, rising, bell-shaped, sinusoidal, u-shaped, slowly-falling, rapidly-rising/falling, flat, and complex, adapted from the procedure used by Gratier and Devouche (2011). Five separate coders were used across the entire data set, each receiving the same script and training. Utterances or contours were excluded when containing whispered speech, interruptions by non-speech sounds (e.g., laughing), infant sounds, and background noises (e.g., sounds from toys), as these either do not contain pitch or do not contain human vocalisations. Singing was also excluded as these sounds involve pre-determined pitch. The frequency of each contour used by caregivers within the play interaction, after exclusions, were recorded and used within the analysis. Overall pitch minimum, maximum, median, range, and interquartile range across the interaction for each caregiver was also calculated.

Bayley Scales of Infant and Toddler Development - Third Edition. The Bayley Scales of Infant and Toddler Development - Third Edition (Bayley-III; Bayley, 2006) was used to assess infant development. The Bayley-III screener is an adaptive version of the full Bayley-III which was used to measure development at six months, whereas the full Bayley-III was used at 12 months. Development is measured through a range of subtests testing the infant's abilities across three scales: cognitive, language, and motor. The language scale provides a measure of two constructs, receptive and expressive language, while the motor scale encompasses both fine and gross motor skills. Higher scores on each scale indicated more development within that area. Data collected from the screener and full Bayley-III were all analysed as potential covariates. Reliability coefficients for each scale ranged from .83 to .89. Subtests within each scale ranged from .78 to .92. Test-retest reliability was shown to range between .77 to .85 for the scales, and .77 to .86 for the subtests (Bayley, 2006).

Questionnaires

Sociodemographic Questionnaire. Sociodemographic information about maternal age, country of birth, education, occupation, medical history and infant gender, age was collected.

Infant/Toddler Sensory Profile. The Infant/Toddler Sensory Profile (ISP/TSP; Dunn, 2002) is a caregiver questionnaire consisting of 48-items that assess sensory processing abilities for children between 0-36 months. The frequency of the child's behaviour is rated on a 5-point Likert scale with answers ranging from 1 (almost always) to 5 (almost never). Scores are grouped into four sensory quadrants (seeking, avoiding, sensitivity, and registration) based on Dunn's model. Higher scores on each quadrant represent, more sensory seeking behaviours, more sensory avoiding behaviours, a lower threshold of sensory input required before a response, and a higher threshold of sensory input required before giving a response, respectively. Scores more than one standard deviation from the norm data mean are categorised as “less and more than others” depending on the direction. Scores more than two standard deviations from the norm data mean are categorised as “much less and more than others”. The ISP/TSP has been shown to have good reliability scores ranging between 0.69-0.85 for the various quadrants (Dunn, 2002).

Revised Infant Temperament Questionnaire and Toddler Temperament Scales. The Revised Infant Temperament Questionnaire (RITQ; Carey & McDevitt, 1978) and Toddler Temperament Scales (TTS; Fullard, McDevitt, & Carey, 1984) are parent-reported measures looking at the temperament of infants and toddlers. Temperament itself is a measure of differences in behaviour with a biological origin and is believed to be a good indicator of behavioural problems and language acquisition long term (Chong, Chittleborough, Gregory, Lynch, & Smithers, 2015). The RITQ and TTS specifically focus on the child's temperament in eight different domains outlined in research by Thomas, Chess, and Birch (1968): rhythmicity, adaptability, approach to novelty, intensity of emotion, quality of mood, sensory threshold, distractibility, and persistence. Caregivers rate their child's temperament for each domain on a 6-point Likert scale with answers ranging from 1 (almost never) to 6 (almost always). Higher scores for each domain represent a more challenging temperament. Infant/toddler temperament was measured at the six- and 12- month time points and analysed as potential covariates. The RITQ has been shown to have a test-retest reliability coefficient of .86 and an internal consistency of .83 (Carey & McDevitt, 1978). The TTS has also shown to have good psychometric properties with internal consistency scores ranging from .47 to .80 (McDevitt, & Carey, 1996).

Social-Emotional Adaptive Behaviour Questionnaire. The Social-Emotional Adaptive Behaviour Questionnaire (SEABQ; Bayley, 2006) is part of the overall Bayley-III and is a caregiver-reported questionnaire measuring the development of social-emotional functioning and adaptive behaviour in infants. Caregivers rate their infant's behaviours on a 5 point Likert scale ranging from 0 (not able to tell if the infant is presenting the behaviour) to 5 (the infant displays the behaviour regularly). The SEABQ provides one social/emotional composite and a general adaptive composite (GAC) which is comprised of constructs: conceptual (self-direction skills), social (social interaction skills), and practical (personal care skills). Higher overall scores represent more developed functioning. The SEABQ was administered at both the six and 12 month time points with results included in analysis as potential covariates. Strong reliability coefficients have been found for the SEABQ with items ranging between .83 and .94 (Bayley, 2006).

Edinburgh Postnatal Depression Scale. The Edinburgh Postnatal Depression Scale (EPDS; Cox, Holden, & Sagovsky, 1987) is a 10 item self-report questionnaire used to screen for postpartum depression. Higher scores on the EPDS indicate increased risk of postnatal depression symptoms with scores of 10 or above indicating elevated risk. As maternal depression has been linked with poorer quality interactions with their infants (Murray, Fiori-Cowley, Hooper, & Cooper, 1996), the EPDS was used to screen adult participants for postnatal depression at both six and 12 months with data being analysed as a potential covariate. The internal reliability of the EPDS has been shown to be .84 (Hartley, et al., 2014).

Parent Stress Index. The Parenting Stress Index - Short Form (PSI-SF; Abidin, 2012) is a 36 item self-report questionnaire assessing parental stress with higher scores representing more stress. Parental stress has been shown to relate with more developmental problems for infants (Neece, Green, & Baker, 2012), and as such was measured at both the six and 12 month time periods and included in analysis as a potential covariate. The internal consistency of the scale has been shown to have a Cronbach's α ranging from .88 to .95 with a test re-test coefficient of .84 (Abidin, 2012).

Procedure

Caregivers and their infants attended HMRI when the infants were six- and 12-months of age for data collection. Caregivers were given a packet of questionnaires either at this appointment or via post two weeks prior. Developmental testing was conducted during these sessions by a trained researcher before caregiver-infant dyads completed the videoed and audio recorded IDS interaction task. This interaction took place in a private room with only the mother and infant present. Caregivers were asked to play with their infants normally "as if they were in their homes". Halfway through the interaction the researcher briefly entered the room and left age appropriate toys (i.e., plastic keys and a musical phone at six months, a plane, tractor and mobile phone at 12 months) with the caregiver and infant for them to use, if desired, while completing the interaction. Some interactions were cut short due to infant fussiness however these were removed from the analysis. Following this interaction all participants were debriefed and reimbursed with a $20 Coles gift card.

Results

Demographic data of the participants within the study were first identified followed screening tests for normality. Correlation analysis between IDS contours were then conducted to see if those with similar functions as outlined in the literature could be collapsed into single variables. Descriptive statistics for IDS and sensory processing variables were then analysed to provide an overview for the current population as well as checking for differences between six- and 12-month interactions. Bayesian correlations were then conducted to see if any evidence of relationships between IDS and sensory processing could be found. Similar correlations were also conducted for IDS variables with measures of infant development, temperament, and social emotional and adaptive functioning, as well as caregiver stress and depression, for inclusion as covariates. Finally Bayesian regression analyses were conducted to determine if any evidence of a predictive relationship between IDS and sensory processing could be found. Cross-sectional regressions at both six- and 12-months were used to inform hypotheses 1 and 2, while longitudinal analyses between sensory processing at six months and IDS at 12 months addressed hypotheses 3 and 4. Both research questions were exploring all links between IDS and sensory processing and, as such, were answered by both cross-sectional and longitudinal analyses.

The age of the mothers at the birth of their babies ranged between 22 and 44 years old with a mean age of 31.88 (SD = 4.18). The average birth weight of the infants ranged between 1,100g and 4,690g with a mean weight of 3,158g (SD = 836.44). When screening for postnatal depression, 8 out of 30 caregivers scored above the “at risk” cut-off at the 6-month time period. This proportion decreased at 12 months with only 2 out of 10 scoring above the cut-ff, however the total responses for this questionnaire had reduced. See Table 3 for a summary of caregiver and infant demographics.

(Place Table 3 here)

Statistical analysis was conducted in JASP, version 10.2 (JASP Team, 2020). See Table 4 for written descriptors of Bayes Factors used when reporting analyses which are based on the scale provided by Jeffreys (1998).

(Place Table 4 here)

The Shapiro-Wilk test of normality was used for continuous variables (see Tables 5 & 6). The majority of the pitch contour and pitch variables at both six and 12 months were found to violate the assumption of normality, while none of the Sensory Profile scores at either time period were normally distributed (p<.05). The data was transformed using logarithmic methods in an attempt to produce normality, however no changes were found. As a result, non-parametric alternatives were used for the analysis such as Kendall's tau-b in place of Pearson's rho.

Maternal IDS Pitch Contours

Correlations were conducted between pitch contours as some share similar functions (e.g., bell-shaped, u-shaped, sinusoidal) to see whether any could be combined (Table 7. The strength of most relationships ranged between .2 - .5 and did not provide strong enough links resulting in contours being kept separate for further analysis.

(Place Table 7 here)

The medians, ranges, and interquartile ranges for the maternal IDS ratios as well as the Bayes Factors for the *t*-test comparisons can be found in Table 8. Of the 149 total participants, 62 caregiver-infant dyads completed the 15-minute interaction at the 6-month time period. The median number of utterances that the caregivers spoke at this time was 282.44. The caregiver who spoke the most recorded 488 utterances with the caregiver who spoke the least recording only 21. Sinusoidal contours, which were normally distributed, were the most commonly used (*M* = 152.3, *SD* =54.28). No complex contours were found at the six months interactions. Of the contours that were recorded, flat and rapidly-falling were used the least frequently with medians of 1.5 and 1 respectively.

One-hundred and seven caregiver-infant dyads completed the interaction at the 12-month time period. A Bayesian Paired Sample *t*-test found strong evidence for a difference in the number of utterances between the six- and 12-month time points (BF = 10.05). The median number of utterances at 12 months was 347 meaning caregivers, generally, spoke more during this interaction. The caregiver with the most utterances spoke 543 times while the caregiver with the least only spoke 160 times. Sinusoidal contours were again the most commonly used with a median score of 77. Rapidly-rising contours were the least used at 12 months with a median recording of only 1 utterance. *T*-test comparisons found strong evidence for an increase in bell-shaped and u-shaped contours at the 12-month interaction as well as extreme evidence for a decrease in sinusoidal contours. Anecdotal evidence was found for an increase in rising and rapidly-falling contours. All other contours were found to be consistent across the two time points with no evidence for a difference being found.

(Place Table 8 here)

(Place Figure 1 here)

(Place Figure 2 here)

A series of Bayesian Paired Sample *t*-tests were used to compare the overall pitch properties of the cohort between the two infant-caregiver interactions (see Table 9). No evidence was found for a difference between minimum pitch scores, across the time points, however extreme evidence was found for differences in median pitch (BF = 172.8), maximum pitch (BF > 1000), and pitch range (BF > 1000) indicating that caregivers of older infants consistently used higher frequencies and more diverse pitch in their play interactions.

(Place Table 9 here)

Infant/Toddler Sensory Profile scores

The medians, range, and interquartile ranges for the Infant and Toddler Sensory Profile scores can be found in Table 10. Data from 71 caregiver-infant dyads were recorded at 6 months and 94 at 12 months. Due to the different age versions of the profile, direct comparisons, by way of *t*-tests, were not appropriate.

(Place Table 10 here)

Correlations Between Sensory Quadrants and IDS

Correlations were conducted between the ISP and TSP quadrant scores and each of the IDS contour proportions and pitch properties to see if any relationships could be found. Two sets of cross-sectional analyses were conducted using the six- and 12-month interactions. Longitudinal correlations were also conducted looking at six-month ISP data as a predictor of 12-month IDS outcomes.

Six Month Cross-Sectional Correlations

In relation to the first hypothesis, no evidence was found for a relationship between the registration quadrant and any IDS variables. When looking at the second hypothesis however, moderate evidence was found for a positive relationship between bell contours and sensitivity quadrant scores (Kendall's = .249, BF = 3.73) suggesting mothers of infants who are able to detect stimuli easier used more bell-shaped contours aimed at maintaining attention.

Analysis of the research question found moderate evidence for a positive relationship between rapidly-rising contours were found with the seeking (Kendall's = .243, BF - 3.2) and avoiding (Kendall's = .267, BF = 5.75) quadrants. These results suggest that mothers had a higher usage of maternal rapidly-rising contours, used for increasing arousal or prohibiting behaviours, when they had infants who were more likely to seek more sensory input or to more frequently avoid it. No other significant correlations were identified.

12 Month Cross-Sectional Correlations

Correlations between TSP and IDS variables at 12 months found no evidence for a relationship between the registration quadrant and any contours with an attention function. Strong evidence for a negative relationship between the total number of utterances by caregivers during the interaction and infants scores on the registration quadrant as found however (Kendall's = -.227, BF = 20.96). This suggests that infants who were less responsive to sensory stimulation had caregivers who spoke more during the interaction. No evidence of any relationships between sensitivity quadrant scores and IDS variables were found in the analysis.

Moderate evidence for a negative relationship between total maternal utterances and the avoiding quadrant (Kendall's = -.185, BF = 3.79) was found. These findings suggest infants who were less avoidant of sensory input had caregivers who spoke more often during the interaction. No other significant correlations were identified.

Longitudinal Correlations

Longitudinal correlations were also conducted between six month ISP scores and 12 month IDS variables. Strong evidence was found for a negative relationship between sinusoidal contours and the registration quadrant (Kendall's = -.332, BF = 12.2). This suggests that caregivers of infants who were less responsive to sensory stimuli used less sinusoidal contours aimed at maintaining attention.

Similarly, moderate evidence was found for a negative relationship between sinusoidal contours and the sensitivity quadrant (Kendall's = -.274, BF = 3.33). This suggests that caregivers of infants who are more responsive to sensory stimuli also used less sinusoidal contours aimed at maintaining attention. These findings indicate that any deviations in sensory sensitivity thresholds in earlier infancy from the majority of infants related with a reduction in sinusoidal contours from their caregivers six months later.

No evidence was found for any relationships between the seeking quadrant and IDS variables however numerous relationships were found for the avoiding quadrant. Moderate evidence was found for a positive relationship between the avoiding quadrant at six months and rising contours (Kendall's = .296, BF = 5.34), maximum pitch (Kendall's = .307, BF = 6.77), and pitch range (Kendall's = .27, BF = 3.13) all at 12 months. This indicates that caregivers of infants who were more avoidant of sensory stimulation in earlier infancy used more rising contours aimed at attaining attention, as well as both higher total and more variable pitch frequencies when interacting with their children at 12 months. Strong evidence for a positive relationship was also found between slow-falling contours and the avoiding quadrant (Kendall's = .339, BF = 14.49) suggesting that caregivers used more speech aimed at soothing their infants who demonstrated an earlier tendency to avoid sensory stimulation.

There was also strong evidence for a negative relationship between sinusoidal contours and the avoiding quadrant, similarly to the registration and sensitivity quadrants (Kendall's = -.377, BF = 39.61). These findings suggest that caregivers of sensory avoiding infants early made less use of attention maintaining speech at 12 months.

Screening for Covariates

Further correlation analyses were conducted with the IDS outcome variables that showed evidence for a relationship with ISP/TSP variables with other variables to explore if any effects remained and to identify the strongest models. Screening analysis included demographic variables, Carey Infant/Toddler variables (infant temperament), Bayley Screener and Full Bayley Scores (infant developmental level [cognition, receptive and expressive language, fine and gross motor skills]), as well as both six- and 12-month scores for the SEABQ (infant social-emotional development and adaptive functioning), PSI (maternal stress), and EPD (maternal depression). Only covariates that showed evidence of being related to each ISP/TSP outcome variables, respectively, were included in the multiple regression analyses below. A summary of related covariates can be found in Tables 11, 12, 13, 14, & 15.

(Place Table 11 here)

(Place Table 12 here)

(Place Table 13 here)

(Place Table 14 here)

(Place Table 15 here)

Multiple Regression Analysis

A series of Bayesian linear regressions were conducted to further analyse the predictive properties of correlated sensory processing variables and covariates with IDS outcomes. All variables with evidence of correlation were added at the same time with JASP highlighting the model with the most evidence in favour of predicting the outcome variable.

Six Month Cross-Sectional Regressions

The first regression was run using bell contours as the outcome variable and sensitivity quadrant scores, adaptive functioning scores, and maternal depression total scores as predictor variables. While ambiguous evidence was found for all the models that included sensory processing variables, moderate evidence was found for the model of infant adaptive functioning and maternal depression scores as being predictive of bell contours (BF = 5.12, r^2 = .427). Maternal depression (BFinclusion = 5.46, β =1.38) were shown to have stronger evidence as a predictor than infant adaptive behaviour (BFinclusion = 4.5, β = 1.23). This suggested that caregivers of infants with higher levels of overall adaptive functioning who also had mothers with a higher prevalence of maternal depression more frequently used attention maintaining speech.

A second regression was run to explore the predictive qualities of avoiding and seeking quadrant scores on rapidly-rising contours as an outcome variable with ambiguous evidence being found for the inclusion of both variables. No other models had evidence as being predictive of IDS.

12 Month Cross-Sectional Regressions

Regression analysis of the total number of utterances spoken by caregivers during the 12-month interaction with registration and avoiding quadrants, maternal depression, social emotional composite, and receptive language as predictive variables found ambiguous evidence for the predictive qualities of all variables. This indicated that, while they may all be related, none were influencing the amount of speech of caregivers when interacting with their infants.

Likewise, regression analysis for minimum pitch frequency spoken by caregivers, with the distractibility (temperament) scores, also showed ambiguous evidence indicating lower pitch frequency in caregiver speech to their infants was not able to be predicted by the infants' temperament despite evidence for the two being related. No other models had evidence as being predictive of IDS.

Longitudinal Regressions

A series of regressions were conducted analysing the predictive nature of sensory processing quadrants at six months on the pitch contour and frequency properties of caregivers IDS during the 12 month play interactions.

The first regression looked at predictors of sinusoidal contours and included the avoiding, sensitivity, and registration quadrants, and the temperament domains of intensity (temperament) scores at six months and adaptability (temperament) scores at 12 months as predictor variables. Moderate evidence was found for the model of registration quadrant scores at six months and intensity scores also at six months (BF = 4.19, r^2 .448). More evidence was found for intensity scores (BFinclusion = 3, β = -.89) as a predictor of sinusoidal contours compared to registration scores (BFinclusion = 1.53, β = -.22). This means that caregivers of infants with more intense emotional responses who also were less responsive to sensory stimulation in earlier infancy used more speech aimed at maintaining the infant's attention at 12 months.

Another regression was conducted looking at rising contours and included the avoiding quadrant, intensity (temperament), and fine motor scores at six months and the temperament variables of adaptability and mood as well as expressive language scores at 12 months as predictor variables. The best model was shown to only include intensity (temperament) scores at six months with the regression finding moderate evidence for this predictive relationship (BF = 9.74, r^2 = .368). This suggests that of the included variables only the energy levels of the infant's emotional responses were related to rising contours that typically are used to attain the attention of the child.

A regression was also conducted looking at slow-falling contours with predictor variables of the avoiding quadrant, intensity (temperament), and fine motor scores at six months and activity and adaptability (temperament), and expressive language at 12 months. Moderate evidence was shown for the model of intensity scores at six months, activity scores at 12 months, and adaptability scores at 12 months (BF = 5.03, r^2 = .586). Six-month intensity scores had the most evidence as a predictor of slow-falling contours (BFinclusion = 3.34, β = 1.05) followed by 12-month adaptability scores (BFinclusion = 1.96, β = .87) and 12-month activity scores (BFinclusion = 1.18, $\beta = -.62$) respectively. This is indicative that caregivers used more speech aimed at soothing their children when the infants demonstrated more: intense emotional reactions in earlier infancy; emotional response challenges during motor activities; and difficulties with behavioural flexibility when faced with changing situations at 12 months.

Regression analysis looking at maximum pitch frequency at 12 months with the avoiding quadrant at six months found moderate evidence for the predictive qualities (BF = 4.11, $r^2 = .163$). This suggested that infants more likely to avoid sensory stimulation in early infancy had caregivers with higher maximum pitch frequencies used during interactions at 12 months.

A regression was also run looking at the range of pitch frequency at 12 months with only the avoiding quadrant scores at six months being included as this was the only variable to have evidence for a correlational relationship in prior analysis. Moderate evidence was found for the predictive nature of this quadrant (BF = 3.65, $r^2 = .157$). This indicated that infants more likely to avoid sensory stimulation in early infancy had caregivers who used a higher variation in pitch during interactions at 12 months. No other models had evidence as being predictive of IDS.

Discussion

The current study explored whether caregiver's IDS differed as a function of infants' sensory processing, specifically their thresholds and seeking/avoidance patterns. In order to explore this, caregiver-infant dyads completed a 15-minute play interaction when the infant was both six and 12 months of age and during these naturalistic interactions their IDS was recorded for later analysis.

With regards to the pattern of sensory profiles, the current sample were predominantly dominated by participants with sensory processing patterns in the typical range, however 22.30% and 21.30% of participants were also represented in the "more than others" range of infants for seeking and sensitivity patterns respectively. Normative data typically places only 13.59% of infants within this range demonstrating the current sample had a higher proportion. These findings suggest that approximately one in five infant participants had a tendency to seek out sensory stimulation more than the average infant of the same age. Similarly, approximately, one in five infant participants were also found to require lower overall levels of sensory stimulation before it would be processed, compared to the average infant.

Within the current study data there was a large amount of variability on how much caregivers spoke to their infants during the interactions. Caregivers spoke more to their children at 12 months of age, with the pitch being generally higher and more variable. More bell- and u-shaped contours were used at 12 months, however less sinusoidal contours were used, with all of these serving the purpose of maintaining attention. It is possible that the use of sinusoidal contours were replaced with the other attention maintaining contours at the later time point resulting in a minimal change in function of speech.

Overall most of the hypotheses were not supported by the results of this study. While a large number of relationships were found between IDS and sensory processing behaviours, these were mostly weak in strength and were not shown to be predictive in nature. Cross-sectional analysis of both sensory threshold variables, registration and sensitivity, found no evidence in support of the predictions on the first two hypotheses. While sensory thresholds did not predict IDS variables, the adaptive functioning of infants paired with rates of maternal depression was able to predict attention maintaining bell contours. Longitudinal analysis however was able to find evidence for infants who require higher levels of sensory stimulation before it is processed at six months being predictive of the amount of attention maintaining speech, through the use of sinusoidal contours, by caregivers during the 12 month interaction. These findings were in the opposite direction of what was predicted in hypothesis 3 however with caregivers using less sinusoidal speech when their infants required more sensory input. Analysis also suggested that difficulties with temperament, specifically higher levels of emotional responses, was the main contributing factor above sensory registration. A possible explanation for these findings is that caregivers may be less able to gain their infants' attention in the first place due to higher sensory threshold requirements meaning they have less opportunities to try and maintain attention as they do not have it in the first place. It is also possible that caregivers may be conditioned by challenging and intense emotional responses by their infants resulting in apprehension at maintaining their attention and prolonging the interaction.

Most of the findings of this study related to the research question exploring different sensation seeking and avoiding behaviours. While no evidence was found for sensation seeking as a predictor of IDS, infants who try to avoid sensory stimulation were shown to have some predictive capabilities. This had been largely unstudied to this point in time and as such no predictions were made. All of the findings were longitudinal in nature however with no evidence being found in the cross-sectional analyses. Infants with higher avoiding tendencies at six months were shown to have caregivers who used more attention gaining speech through the use of rising contours at 12 months, however this was better explained by difficult temperament, specifically a more intense emotional response to situations. In contrast however, infant avoiding behaviours was shown to predict longitudinal use of higher maximum pitch frequency and overall pitch range. It is logical to suggest that these pitch qualities would also serve to try and obtain the infants' attention. Stimulation avoidance and difficult temperament may present in similar ways however and further research is needed to explore how they may interact to predict caregiver interaction behaviours. Finally early avoiding behaviours were also found to relate to later caregiver use of soothing contours, but this was better explained by difficult temperament intensity at six months and cross-sectional temperament difficulty with motor functioning and behavioural flexibility. It would appear logical that infants who present with more temperamental difficulties may seem to be distressed more often with caregivers using soothing speech contours in response to try and calm their infants down. Infants who avoid stimulation may also appear distressed as the avoidance may be due to fear, pain, or irritation, again resulting in a conditioning of soothing verbal interactions from their caregivers.

The overall findings did suggest that infant sensory processing and caregiver speech may be related, however more evidence was shown for infant temperament being the most influential factor for accounting for differences in IDS. These results were similar to those found by Woolard (2020) where links were shown between temperament activity levels and the use of slow-falling contours, and links between temperamental intensity and sinusoidal contours. Additional links between temperament and IDS were found in Woolard's study that were not replicated here, which may have been due to the differing age ranges as this study investigated 12 month old infants only. Future research is needed to further explore the relationship between temperament and IDS directly as they appear to be linked. Temperament is a more broad measure in which sensory processing is one component. Dunn (2001) argued that the mechanisms of sensory processing underpin what makes up temperament as it drives the capacity to process and respond to stimuli. Johnson et al. (2014) expands the idea of temperament beyond sensory processing to include the key components of effortful control, i.e., attention, and the role of emotional sensitivity. The high prevalence of correlational relationships within this study may be explained by the fact that sensory processing is one component of temperament. The lack of predictive evidence suggests that it may in fact be other elements of temperament that are responsible for the caregiver IDS adaptions.

. This study also found that the influence on caregiver speech was, for the most part, stronger longitudinally. This suggests a lag effect in that caregivers take time to notice patterns of behaviour in their infants before adjusting their own interactions. Providing parents with information on temperament and sensory processing behaviours in infants early on with education on the various ways in which they can respond to engage and sooth their infants could be beneficial in promoting more positive and stimulating early interactions.

Despite strengths in allowing for both cross-sectional and longitudinal analysis, there were several limitations in this study. Coding was completed by five different individuals with no cross-checking to ensure high inter-rater reliability. Future studies should incorporate a review of each coders assessments to ensure similar judgements were being made. Only 24 of all possible participant dyads completed the interaction at both time points, limiting overall numbers in the analysis and making direct comparisons of infants at the two time points more difficult. The play interaction was also in a clinical setting and was a new environment for infants and caregivers which may have also impacted on their behaviours and responses. The population was ethnically homogenous limiting the external validity of the findings. These limitations could be addressed in future research where caregiver-infants may be measured over multiple occasions and in a more familiar setting, such as the home environment. Finally, only the caregivers' behaviour was actually measured in the interactions as well. Future studies could look at IDS responses to infants' behaviour in real time with a view to determine patterns of sensitivity and receptiveness from the caregivers themselves.

Conclusion

Infant sensory processing abilities influence the way in which they are able to interpret and interact with information in their environment. These early life interactions are important for a number of positive developmental trajectories. Caregivers are the primary source of social interaction with infants, with these interactions being bi-directional in nature. IDS serves as an important tool for caregivers when interacting with infants as it allows for the regulation of attention and emotions without the need for developed language skills. This study was able to find evidence for small relationships between infant sensory processing behaviours and caregiver speech however difficulties in temperament for the infant was shown to be much more predictive and should be focused on in research in future.

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Tables

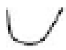
Table 1

Summary of Dunn's Patterns of Sensory Processing

	High Threshold	**Low Threshold**
Sensation Avoiding	Low Registration	Sensation Avoidance
	e.g., uninterested in surrounding and not responding to voices or sounds	*e.g., uncooperative, use of rules and ritualised behaviours*
Sensation Seeking	Sensation Seeking	Sensory Sensitivity
	e.g., excitable, always moving, make repeated sounds and noises	*e.g., easily distracted, hyperactive, irritable*

Table 2

Types and Function of Pitch Contours Commonly Seen in IDS

Pitch contour	Visual representation	Description of pitch contour	Function of pitch contour during IDS
Rising		Increase in slope	Attain attention of the infant
Bell-Shaped		Increase followed by a decrease	Maintain attention of the infant
Sinusoidal		Slope has two changes in direction (rise-fall-rise, fall-rise-fall)	Maintain attention of the infant
U-shaped		Decrease followed by increase	Maintain attention of the infant
Flat		No or slight change in horizontal slope	No function has been investigated in IDS
Rapid fall		Slope decreases at steep decline	Rapidly increase arousal of the infant or prohibit behaviour
Rapid rise		Slope increase at a steep incline	Rapidly increase arousal of the infant or prohibit behaviour
Slowly-falling		Slope decreases at gradual decline	Decrease arousal in the infant and soothing
Complex		More than two changes in direction of slope	No function has been investigated in IDS

Note. Table adapted from Woolard (2019).

Table 3

Mother and Infant Demographics

Maternal Demographics	**(*n* = 149)** **n (%)**	
Country of Birth		
Australia	120 (80.5%)	
New Zealand	1 (.76%)	
South Africa	1 (.76%)	
Fiji	1 (.76%)	
Malaysia	1 (.76%)	
Germany	1 (.76%)	
England	1 (.76%)	
USA	1 (.76%)	
Estonia	1 (.76%)	
Maternal Occupation**		
Maternity Leave	51 (34.2%)	
Full Time	9 (6%)	
Part Time	26 (17.4%)	
Student	4 (2.7%)	
Stay at Home Parent	30 (20.1%)	
Casual	11 (7.4%)	
Maternal Education		
High School	11 (7.4%)	
Certificate	17 (11.4%)	
Diploma	1 (0.7%)	
Advanced Diploma	44 (29.5%)	
Bachelor's Degree	10 (6.7%)	
Master's Degree	2 (1.3%)	
Doctoral Degree		
Household Income		
$0-18,200	8 (5.4%)	
$18,201-$37,000	7 (4.7%)	
$37,001-$80,000	26 (17.4%)	
$80,001-$180,000	71 (47.7%)	
$180,001 and over	16 (10.7%)	
Current Relationship		
with Biological Father	104 (69.8%)	
Yes	14 (9.4%)	
No		
Infant Demographics	**(*n* = 149)** **n (%)**	
Infant Gender		
Male	70 (47%)	
Female	67 (45%)	
Premature		
Yes	35 (23.5%)	
No	79 (53%)	
	Mean (SD)	**Minimum**	**Maximum**
Birthweight (grams)	3157.55 (836.45)	1100	4690

Note. Values do not sum to the total, and percentages do not add to 100% due to missing values. Therefore, the *n* is reported for each category.

***This item was not mutually exclusive with participants being able to answer as many as applicable*

Table 4

Written Descriptors for Bayes Factors

Bayes Factor	Verbal Descriptor of Evidence in Favour of the Alternative Hypothesis
3-9	Moderate
10-99	Strong
100+	Extreme

Table 5

Normality Tests for IDS Contour Ratios

Maternal IDS	6 Months		12 Months	
	W-statistic	*p*-value	W-statistic	*p*-value
Rising Contours	.93	.002	.94	<.001
Bell-shaped Contours	.93	.001	.97	.03
Sinusoidal Contours	.99	.75	.93	<.001
U-shape Contours	.87	<.001	.95	<.001
Rapidly-Rising Contours	.86	<.001	.74	<.001
Rapidly-Falling Contours	.72	<.001	.87	<.001
Flat Contours	.77	<.001	.85	<.001
Slowly-falling Contours	.93	.001	.95	.001
Complex Contours	N/A	N/A	.73	<.001
Pitch Minimum	.92	.001	.90	<.001
Pitch Median	.95	.016	.99	.31
Pitch Maximum	.53	<.001	.91	<.001
Pitch Range	.55	<.001	.92	<.001

Table 6

Normality Tests for Toddler Sensory Profile Quadrants

Toddler Sensory Profile	6 Months		12 Months	
	W-statistic	*p*-value	W-statistic	*p*-value
Total Score	.76	<.001	.92	<.001
Seeking/Seeker	.80	<.001	.95	.002
Avoiding/Avoider	.91	<.001	.93	<.001
Sensitivity/Sensor	.90	<.001	.95	.001
Registration/Bystander	.89	<.001	.95	.001

Table 7

Correlation Matrix for Maternal Pitch Contour Ratios

Variable	Bell-Shaped	Sinusoidal	U-Shape	Rapidly-Rising	Rapidly-Falling	Flat	Slowly-Falling	Complex
6 Months								
Rising	.405*** BF >1000	-.02 BF = .17	.276** BF = 31.17	.146 BF = .71	.16 BF = .95	.102 BF = .33	.306*** BF = 104.36	N/A
Bell-Shaped		.122 BF = .45	.268** BF = 23	.303** BF = 92.05	.159 BF = .92	.258** BF = 15.92	.273** BF = 27.47	N/A
Sinusoidal			.14 BF = .62	.124 BF = .47	.181 BF = 1.56	.177 BF = 1.41	.062 BF = .21	N/A
U-Shape				.215* BF = 3.94	.339*** BF = 456.3	.037 BF = .18	.162 BF = .99	N/A
Rapidly-Rising					.231* BF = 6.4	.023 BF = .166	.062 BF = .21	N/A
Rapidly-Falling						-.023 BF = .17	.154 BF = .83	N/A
Flat							.208* BF = 3.22	N/A
Slowly-Falling								N/A
12 Months								
Rising	.523*** BF >1000	-.165 BF = 2.96	.309*** BF >1000	.289*** BF >1000	.336*** BF >1000	.349*** BF >1000	.431*** BF >1000	.086 BF = .29
Bell-Shaped		-.016 BF = .13	.303***	.366*** BF >1000	.392*** BF >1000	.429***	.404***	.109 BF = .5

			BF >1000			BF >1000	BF >1000	
Sinusoidal			-.066 BF = .21	.091 BF = .33	-.231** BF = 58.84	-.182* BF = 5.72	-.262*** BF = 337.98	-.095 BF = .36
U-Shape				.379*** BF >1000	.28*** BF >1000	.176* BF = 4.51	.225** BF = 43.64	-.04 BF = .15
Rapidly-Rising					.322*** BF >1000	.197** BF = 10.88	.138 BF = 1.14	-.04 BF = .15
Rapidly-Falling						.34*** BF >1000	.416*** BF >1000	-.034 BF = .144
Flat							.446*** BF >1000	-.033 BF = .14
Slowly-Falling								.15 BF = 1.67

Note. *BF > 3, **BF > 10, ***BF > 100, Kendall's correlations were calculated for all contours.

Table 8

Comparison of Central Tendency for IDS Pitch Contours

Maternal IDS	6 Months			12 Months			T-Test Comparison
	Median	Range	IQR	Median	Range	IQR	Bayes Factor
Total Utterances	282.44	467	95.75	347	383	102	10.05**
Rising Contours	6	21	7.25	13	51	15	2.76
Bell-shaped Contours	12	43	10	29	81	28	39.84**
Sinusoidal Contours	152.3*	255	66.5	77	204	50	158.73***
U-shape Contours	4	20	6	12	45	10	29.17**
Rapidly-Rising Contours	2	8	2.25	1	16	3	.23
Rapidly-Falling Contours	1	10	2	3	15	5	2.63
Flat Contours	1.5	11	2	3	19	4	.6
Slowly-Falling Contours	5	17	6	8	27	9	.66
Complex Contours	N/A	N/A	N/A	4	64	10	N/A

*Note: IQR = Interquartile Range, *Mean reported due to normal distribution*
***BF > 3, ***BF > 100*

Table 9

Descriptive Table of IDS Pitch Properties

Maternal IDS	6 Months			12 Months			T-Test Comparison
	Median	Range	IQR	Median	Range	IQR	Bayes Factor
Minimum Pitch	89.43	34.14	4.42	90.12	79.37	5.23	.22
Median Pitch	266.79	124.1	28.16	279.11	120.73	37.93	172.8***
Maximum Pitch	529.5	322.74	2.46	658.97	394.13	103.97	> 1000***
Pitch Range	440.08	318.24	11.44	569.13	391.53	107.52	> 1000***

*Note: IQR = Interquartile Range, *** BF > 100*

Table 10

Comparison of Central Tendency for Infant and Toddler Sensory Profile Quadrants

Infant/Toddler Sensory Profile	6 Months			12 Months		
	Median	Range	IQR	Median	Range	*IQR*
Seeking Quadrant	23	15	14	30.5	13	5.25
Avoiding Quadrant	5	12	7	15	24	5.25
Sensitivity Quadrant	9	20	13	23	33	7
Registration Quadrant	6	12	7	16	29	6

Note: IQR = Interquartile Range,

Table 11

Covariates for Six Month Bell Contours

Variable	6m SEABQ GAC	EPD Total
Bell	.263* BF = 3.53	.324* BF = 3

Note. *BF > 3, **BF > 10, ***BF > 100, Kendall's correlations were calculated for all contours.

Table 12

Covariates for 12 Month Total Utterances

Variable	12m SEABQ Sensory Processing	12m SEABQ 12m Social Emotional Composite	12m Bayley Receptive Language	12m EPD Total Score
Total Utterances	.225* BF = 3.1	.254* BF = 6.81	.223** BF = 27.02	-.552* BF = 3.44

Note. *BF > 3, **BF > 10, ***BF > 100, Kendall's correlations were calculated for all contours.

Table 13

Covariates for 12 Month Rising Contours

Variable	Premature	6m Carey Intensity	6m Bayley Screener Fine Motor Skills	12m Carey Adaptability	12m Carey Mood	12m Bayley Expressive Language
Rising	-.262*** BF = 256.83	.492*** BF >1000	-.294** BF = 20.43	.249** BF = 33.78	.197* BF = 5.2	-.195 BF = 7.84

Note. *BF > 3, **BF > 10, ***BF > 100, Kendall's correlations were calculated for all contours.

Table 14

Covariates for 12 Month Sinusoidal Contours

Variable	6m Carey Intensity	12m Carey Adaptability
Sinusoidal	-.253* BF = 3.59	-.22** BF = 10.2

Note. *BF > 3, **BF > 10, ***BF > 100, Kendall's correlations were calculated for all contours.

Table 15

Covariates for 12 Month Slow-Falling Contours

Variable	6m Carey Intensity	6m Bayley Screener Fine Motor Skills	12m Carey Activity	12m Carey Adaptability	12m Bayley Expressive Language
Slowfall	.299** BF = 11.56	-.315** BF = 40.74	-.294*** BF = 399.78	.225** BF = 12.44	-.193* BF = 7.18

Note. *BF > 3, **BF > 10, ***BF > 100, Kendall's correlations were calculated for all contours.

Figures

Figure 1

Six Month Average Number of Contour Utterances

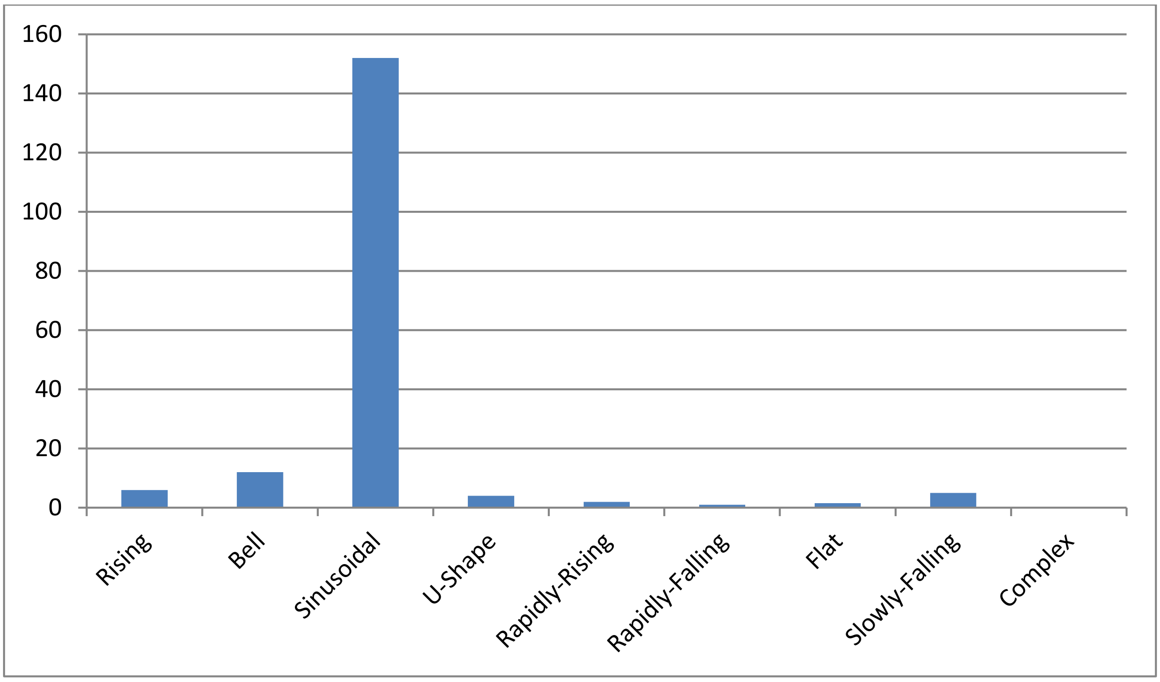
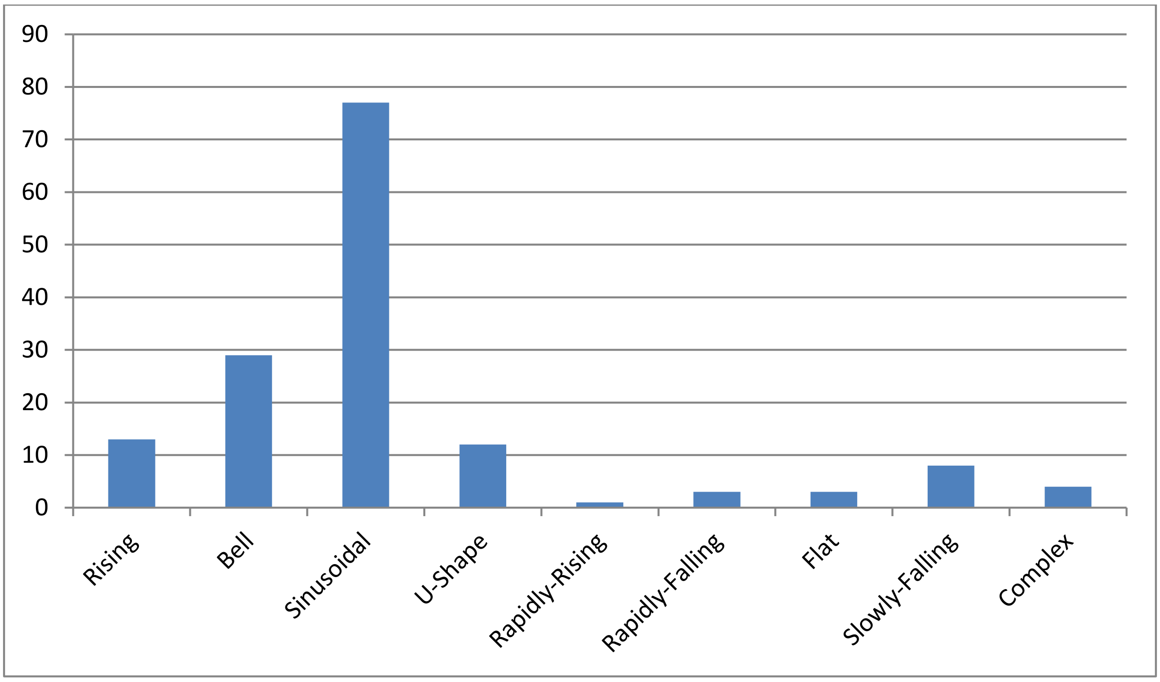


Figure 2

12 Month Average Number of Contour Utterances



Appendix A - Journal Submission Guidelines

Journal of Autism and Developmental Disorders

Submission guidelines

Instructions for Authors

Editorial procedure

Double-Blind Peer Review

MANUSCRIPT FORMAT

All JADD manuscripts should be submitted to Editorial Manager in 12-point Times New Roman with standard 1-inch borders around the margins.

APA Style

Text must be double-spaced; APA Publication Manual standards must be followed.

As of January 20, 2011, the Journal has moved to a double-blind review process. Therefore, when submitting a new manuscript, DO NOT include any of your personal information (e.g., name, affiliation) anywhere within the manuscript. When you are ready to submit a manuscript to JADD, please be sure to upload these 3 separate files to the Editorial Manager site to ensure timely processing and review of your paper:

- A title page with the running head, manuscript title, and complete author information. Followed by (page break) the Abstract page with keywords and the corresponding author e-mail information.
- The blinded manuscript containing no author information (no name, no affiliation, and so forth).
- The Author Note

Types of papers

Articles, Commentaries Brief Reports, Letters to the Editor

- The preferred article length is 20-23 double-spaced manuscript pages long (not including title page, abstract, tables, figures, addendums, etc.) Manuscripts of 40 double-spaced pages (references, tables and figures counted as pages) have been published. The reviewers or the editor for your review will advise you if a longer submission must be shortened.

Review your manuscript for these elements

1. Order of manuscript pages

Title Page with all Author Contact Information & Abstract with keywords and the corresponding author e-mail information.

Blinded Manuscript without contact information and blinded Abstract, and References

Appendix

Figure Caption Sheet

Figures

Tables

Author Note

Manuscript Submission

Manuscript Submission

Submission of a manuscript implies: that the work described has not been published before; that it is not under consideration for publication anywhere else; that its publication has been approved by all co-authors, if any, as well as by the responsible authorities – tacitly or explicitly – at the institute where the work has been carried out. The publisher will not be held legally responsible should there be any claims for compensation.

Permissions

Authors wishing to include figures, tables, or text passages that have already been published elsewhere are required to obtain permission from the copyright owner(s) for both the print and online format and to include evidence that such permission has been granted when submitting their papers. Any material received without such evidence will be assumed to originate from the authors.

Online Submission

Please follow the hyperlink “Submit online” on the right and upload all of your manuscript files following the instructions given on the screen.

Please ensure you provide all relevant editable source files. Failing to submit these source files might cause unnecessary delays in the review and production process.

Title page

The title page should include:

- The name(s) of the author(s)
- A concise and informative title
- The affiliation(s) and address(es) of the author(s)
- The e-mail address, telephone and fax numbers of the corresponding author

Abstract

Please provide an abstract of 120 words or less. The abstract should not contain any undefined abbreviations or unspecified references.

Keywords

Please provide 4 to 6 keywords which can be used for indexing purposes.

Text

Text Formatting

Manuscripts should be submitted in Word.

- Use a normal, plain font (e.g., 10-point Times Roman) for text.
- Use italics for emphasis.
- Use the automatic page numbering function to number the pages.
- Do not use field functions.
- Use tab stops or other commands for indents, not the space bar.
- Use the table function, not spreadsheets, to make tables.
- Use the equation editor or MathType for equations.
- Save your file in docx format (Word 2007 or higher) or doc format (older Word versions).

Headings

Please use no more than three levels of displayed headings.

Abbreviations

Abbreviations should be defined at first mention and used consistently thereafter.

Footnotes

Footnotes can be used to give additional information, which may include the citation of a reference included in the reference list. They should not consist solely of a reference citation, and they should never include the bibliographic details of a reference. They should also not contain any figures or tables.

Footnotes to the text are numbered consecutively; those to tables should be indicated by superscript lower-case letters (or asterisks for significance values and other statistical data). Footnotes to the title or the authors of the article are not given reference symbols.

Always use footnotes instead of endnotes.

Acknowledgments

Acknowledgments of people, grants, funds, etc. should be placed in a separate section on the title page. The names of funding organizations should be written in full.

Body

- The body of the manuscript should begin on a separate page. The manuscript page header (if used) and page number should appear in the upper right corner. Type the title of the paper centered at the top of the page, add a hard return, and then begin the text using the format noted above. The body should contain:
- Introduction (The introduction has no label.)
- Methods (Center the heading. Use un-centered subheadings such as: Participants, Materials, Procedure.)
- Results (Center the heading.)
- Discussion (Center the heading.)

Headings

Please use no more than three levels of displayed headings.

Level 1: Centered

Level 2: Centered Italicized

Level 3: Flush left, Italicized

Footnotes

Center the label “Footnotes” at the top of a separate page. Footnotes can be used to give additional information, which may include the citation of a reference included in the reference list. They should not consist solely of a reference citation, and they should never include the bibliographic details of a reference. They should also not contain any figures or tables.

Footnotes to the text are numbered consecutively; those to tables should be indicated by superscript lower-case letters (or asterisks for significance values and other statistical data). Footnotes to the title or the authors of the article are not given reference symbols.

Always use footnotes instead of endnotes. Type all content footnotes and copyright permission footnotes together, double-spaced, and numbered consecutively in the order they appear in the article. Indent the first line of each footnote 5-7 spaces. The number of the footnote should correspond to the number in the text. Superscript arabic numerals are used to indicate the text material being footnoted.

Author Note

The first paragraph contains a separate phrase for each author's name and the affiliations of the authors at the time of the study (include region and country).

The second paragraph identifies any changes in the author affiliation subsequent to the time of the study and includes region and country (wording: "authors name is now at affiliation".)

The third paragraph is Acknowledgments. It identifies grants or other financial support and the source, if appropriate. It is also the place to acknowledge colleagues who assisted in the study and to mention any special circumstances such as the presentation of a version of the paper at a meeting, or its preparation from a doctoral dissertation, or the fact that it is based on an earlier study.

The fourth paragraph states, "Correspondence concerning this article should be addressed to…" and includes the full address, telephone number and email address of the corresponding author.

Terminology

- Please always use internationally accepted signs and symbols for units (SI units).

Scientific style

- Generic names of drugs and pesticides are preferred; if trade names are used, the generic name should be given at first mention.
- Please use the standard mathematical notation for formulae, symbols etc.:Italic for single letters that denote mathematical constants, variables, and unknown quantities Roman/upright for numerals, operators, and punctuation, and commonly defined functions or abbreviations, e.g., cos, det, e or exp, lim, log, max, min, sin, tan, d (for derivative) Bold for vectors, tensors, and matrices.

References

Citation

Cite references in the text by name and year in parentheses. Some examples:

- Negotiation research spans many disciplines (Thompson 1990).
- This result was later contradicted by Becker and Seligman (1996).
- This effect has been widely studied (Abbott 1991; Barakat et al. 1995; Kelso and Smith 1998; Medvec et al. 1999).

Ideally, the names of six authors should be given before et al. (assuming there are six or more), but names will not be deleted if more than six have been provided.

Reference list

The list of references should only include works that are cited in the text and that have been published or accepted for publication. Personal communications and unpublished works should only be mentioned in the text. Do not use footnotes or endnotes as a substitute for a reference list.

Reference list entries should be alphabetized by the last names of the first author of each work.

Journal names and book titles should be *italicized*.

- Journal article Harris, M., Karper, E., Stacks, G., Hoffman, D., DeNiro, R., Cruz, P., et al. (2001). Writing labs and the Hollywood connection. *Journal of Film Writing*, 44(3), 213–245.
- Article by DOI Slifka, M. K., & Whitton, J. L. (2000) Clinical implications of dysregulated cytokine production. *Journal of Molecular Medicine*, https://doi.org/10.1007/s001090000086
- Book Calfee, R. C., & Valencia, R. R. (1991). *APA guide to preparing manuscripts for journal publication*. Washington, DC: American Psychological Association.
- Book chapter O'Neil, J. M., & Egan, J. (1992). Men's and women's gender role journeys: Metaphor for healing, transition, and transformation. In B. R. Wainrib (Ed.), *Gender issues across the life cycle* (pp. 107–123). New York: Springer.
- Online document Abou-Allaban, Y., Dell, M. L., Greenberg, W., Lomax, J., Peteet, J., Torres, M., & Cowell, V. (2006). Religious/spiritual commitments and psychiatric practice. Resource document. American Psychiatric Association. http://www.psych.org/edu/other_res/lib_archives/archives/200604.pdf. Accessed 25 June 2007.

For authors using EndNote, Springer provides an output style that supports the formatting of in-text citations and reference list.

Tables

- All tables are to be numbered using Arabic numerals.
- Tables should always be cited in text in consecutive numerical order.
- For each table, please supply a table caption (title) explaining the components of the table.
- Identify any previously published material by giving the original source in the form of a reference at the end of the table caption.
- Footnotes to tables should be indicated by superscript lower-case letters (or asterisks for significance values and other statistical data) and included beneath the table body.

Each table should be inserted on a separate page at the back of the manuscript in the order noted above. A call-out for the correct placement of each table should be included in brackets within the text immediately after the phrase in which it is first mentioned. Copyright permission footnotes for tables are typed as a table note.

Figure caption sheet

The figure caption sheet contains a list of only the captions for all figures used. Center the label "Figure Captions" in uppercase and lowercase letters at the top of the page. Begin each caption entry flush left, and type the word "Figure", followed by the appropriate number and a period, all in italics. In the text of the caption (not italicized), capitalize only the first word and any proper nouns. If the caption is more than one line, double-space between the lines, and type the second and subsequent lines flush left. Table notes: Copyright permission footnotes for figures are typed as part of the figure caption.

- Each figure should appear on a separate page. The page where the figure is found should have the figure number and the word "top"[ie, Figure 1 top] typed above the figure. Figures or illustrations (photographs, drawings, diagrams, and charts) are to be numbered in one consecutive series of arabic numerals. Figures may be embedded in the text of a Word or Wordperfect document. Electronic artwork submitted on disk may be in the TIFF, EPS or Powerpoint format (best is 1200 dpi for line and 300 dpi for half-tones and gray-scale art). Color art should be in the CYMK color space. Assistance will be provided by the system administrator if you do not have electronic files for figures; originals of artwork may be sent to the system administrator to be uploaded. *** After first mention in the body of the manuscript, a call-out for the correct placement of each figure should be included in brackets on a separate line within the text.

Disclosures and declarations

All authors are requested to include information regarding sources of funding, financial or non-financial interests, study-specific approval by the appropriate ethics committee for research involving humans and/or animals, informed consent if the research involved human participants, and a statement on welfare of animals if the research involved animals (as appropriate).

The decision whether such information should be included is not only dependent on the scope of the journal, but also the scope of the article. Work submitted for publication may have implications for public health or general welfare and in those cases it is the responsibility of all authors to include the appropriate disclosures and declarations.

Ethics approval

When reporting a study that involved human participants, their data or biological material, authors should include a statement that confirms that the study was approved (or granted exemption) by the appropriate institutional and/or national research ethics committee (including the name of the ethics committee) and certify that the study was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. If doubt exists whether the research was conducted in accordance with the 1964 Helsinki Declaration or comparable standards, the authors must explain the reasons for their approach, and demonstrate that an independent ethics committee or institutional review board explicitly approved the doubtful aspects of the study. If a study was granted exemption from requiring ethics approval, this should also be detailed in the manuscript (including the reasons for the exemption).

Appendix B - Ethics Approval

HUMAN RESEARCH ETHICS COMMITTEE
Notification of Expedited Approval

To Chief Investigator or Project Supervisor: **Doctor Linda Campbell**
Cc Co-investigators / Research Students: **Ms Claire Frazer**
Ms Sarah Morris
Miss Olivia Whalen
Ms Belinda Allen
Miss Alix Woolard
Miss Carly Mallise
Ms Madeline Cordingley
Professor Frini Karayanidis
Associate Professor Alison Lane
Ms Tegan Morgan
Miss Helena Predojevic
Ms Hana Prevodnik
Ms Stephanie Kumar
Mr Jordan Tait
Doctor Titia Benders
Miss Sophia Georgas
Mrs Tanya Crawford
Ms Sze Wing Wong
Miss Hiu Chung Esther Chan
Miss Madison Turner-Presker
Ms Tanayah Tooze
Re Protocol: **Baby Minds: A Study of Infant Development and Parental Well-Being**
Date: **21-Aug-2018**

Reference No: **H-2016-0425**

Thank you for your **Variation** submission to the Human Research Ethics Committee (HREC) seeking approval in relation to a variation to the above protocol. Variation to add Claire Frazer to the research team. Your submission was considered under **Expedited** review by the Ethics Administrator. I am pleased to advise that the decision on your submission is **Approved** effective **21-Aug-2018**. The full Committee will be asked to ratify this decision at its next scheduled meeting. A formal *Certificate of Approval* will be available upon request.

Associate Professor Helen Warren-Forward
Chair, Human Research Ethics Committee
For communications and enquiries:
Human Research Ethics Administration
Research & Innovation Services
Research Integrity Unit
The University of Newcastle
Callaghan NSW 2308
T +61 2 492 17894
Human-Ethics@newcastle.edu.au
RIMS website - https://RIMS.newcastle.edu.au/login.asp

Linked University of Newcastle administered funding:

Funding body	Funding project title	First named investigator	Grant Ref
Association for Psychological Science/Research Grants(**)	Many Babies - Pilot International Collaboration	Campbell, Linda	G1700652

HUMAN RESEARCH ETHICS COMMITTEE
Notification of Expedited Approval

To Chief Investigator or Project Supervisor: **Doctor Linda Campbell**
Cc Co-investigators / Research Students: **Doctor Emma Axelsson**
Mr James Meredith
Mr Ghadeer Ali
Ms Elise Tobin
Ms Sarah Morris
Miss Olivia Whalen
Ms Belinda Allen
Miss Alix Woolard
Miss Carly Mallise
Professor Frini Karayanidis
Associate Professor Alison Lane
Ms Tegan Morgan
Ms Hana Prevodnik
Mr Jordan Tait
Doctor Titia Benders
Mrs Tanya Crawford
Ms Sze Wing Wong
Miss Hiu Chung Esther Chan
Miss Zoe Crittenden
Mr Joshua Mattiske
Mrs Bianca Cranswick
Mr Isaac Goodchild
Miss Megan Son Hing

Re Protocol: **Baby Minds: A Study of Infant Development and Parental Well-Being**

Date: **24-Jun-2019**

Reference No: **H-2016-0425**

Thank you for your **Response to Deferred** submission to the Human Research Ethics Committee (HREC) seeking approval in relation to a variation to the above protocol.

Variation to:
1. Research Personnel.
a. Addition of: Emma Axelsson; Joshua Mattiske; Bianca Cranswick; Isaac Goodchild; and Megan Son Hing.
b. Removal of: Madeline Cordingley; Claire Frazer; Sophia Georgas; Stephanie Kumar; Hana Prevodnik; Tanayah Tooze; and Maddison Turner Presker.

2. Add the following questionnaires to the study;
• Brief Infant Sleep Questionnaire
• 12-Month Infant Questionnaire for the Breathing for Life Trial
• History of ADHD questionnaire

3. Offer participants (mothers and fathers) the option to complete questionnaires online instead of using paper versions. All questionnaires will be made available either using the publishers online platforms or using the web platform Qualtrics. Research data will be stored securely by the researchers using a password protected electronic storage system provided by the University. In order to ensure that we can link the participant data, a personalised link will be provided to each parent.

4. Participants who have already participated in the BabyMinds study will be sent an email (if an email was provided) or post, to inform them of the additional questionnaires. A researcher will contact them via the phone to inform them about the measures alternatively the parents can click on an online link to access participant information and if they agree, they can complete the questionnaires that will be hosted on Qualtrics immediately. The mothers and fathers and fathers will only be asked to complete those questionnaires not previously completed. When parents click on the link they will be provided with some brief information about the questionnaires, and will provide implied consent by clicking on a button named “Yes, I would like to complete the additional questionnaires now/later”. They can also choose not to complete the questionnaires.

5. For new participants in the study, they will be provided with a link to the online questionnaires when enrolling in the study. The full existing participant information sheet will be made available to them electronically and they will similarly be asked to complete the implied consent. A full written consent will be collected, after full information about the study were provided, as per the original approval when they attend the first research assessment.

- Information Statement for Parents/Guardians (v10, dated 07/06/2019)
- Online Questionnaire Participant Information (v2, dated 07/06/2019)
- BLT Infant Questionnaire (submitted 08/05/2019)
- The Brief Infant Sleep Questionnaire (submitted 08/05/2019)
- Wender Utah Rating Scale for ADHD (submitted 08/05/2019)

Your submission was considered under **Expedited** review by the Ethics Administrator. We are pleased to advise that the decision on your submission is **Approved** effective **24-Jun-2019**. The full Committee will be asked to ratify this decision at its next scheduled meeting. A formal *Certificate of Approval* will be available upon request.

Human Research Ethics Committee
For communications and enquiries:
Human Research Ethics Administration
Research & Innovation Services
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T +61 2 492 17894
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RIMS website - https://RIMS.newcastle.edu.au/login.asp

Linked University of Newcastle administered funding:

Funding body	Funding project title	First named investigator	Grant Ref
Association for Psychological Science/Research Grants(**)	Many Babies - Pilot International Collaboration	Campbell, Linda	G1700652