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Three physiological responses in fathers and non-fathers' to vocalizations of typically developing infants and infants with Autism Spectrum Disorder

Gianluca Esposito^{1,2}, Stefano Valenzi³, Tanvir Islam^{3,4}, and Marc H. Bornstein⁵

¹Affiliative Behavior and Physiology Lab, Department of Psychology and Cognitive Sciences, University of Trento, Rovereto (TN), Italy

²Early Cognition Laboratory, Division of Psychology, Nanyang Technological University, Singapore

³RIKEN Brain Science Institute, Laboratory for Advanced Brain Signal Processing, Saitama, Japan

⁴RIKEN Brain Science Institute, Laboratory for Developmental Gene Regulation, Saitama, Japan

⁵Eunice Kennedy Shriver National Institute of Child Health and Human Development, Bethesda, MD, USA

Abstract

Children with ASD, even before receiving a formal diagnosis, express atypical patterns of distress vocalizations (namely, episodes of crying). Their cries have higher fundamental frequencies, shorter inter-bout pauses, and fewer utterances. Cries of children with ASD are also perceived differently from other cries, and these perceptual differences may alter parent-infant interaction. This study assessed multiple physiological responses in fathers and non-fathers to atypical distress vocalizations (cries of children with ASD), acoustically matched typical distress vocalizations (cries of typically developing children), and positive vocalizations (laughter of typically developing children). The experimental procedures were designed to measure how components of the autonomic nervous system respond to typical and atypical infant vocalizations. Three convergent methodologies (Galvanic Skin Response – GSR; cardiac dynamics via Inter-Beat Interval – IBI; right hand temperature change – RHTC) were performed on two groups with contrasting caregiving experience: fathers of typically developing children ($n=10$) and non-fathers ($n=10$). Inferential statistical analysis compared the two groups (fathers, non-fathers) and three stimulus types (ASD cry, typical cry, laughter) for the three measures (GSR, IBI, RHTC). Both fathers and non-fathers showed greater negative responses (increased GSR) to ASD cries compared to typical cries and laughter. Fathers showed higher IBI and greater temperature increases (RHTC) than non-fathers while listening to typical and atypical cries. Fathers and non-fathers showed more emotional arousal mediated by sympathetic activation while listening to cries

Send Correspondence to: gianluca.esposito@unitn.it.

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of children with ASD. Fathers were calmer and acted more promptly than non-fathers while listening to typical cries, perhaps because the fathers had more experience in caring for crying infants. These findings point to similarities and differences in fathers' and non-fathers' physiological responsiveness to cries of children with ASD and might guide specific intervention programs for parents of children at risk of ASD.

Keywords

ASD cry; Atypical cry; Communication; atypical development

1. Introduction

Caregiver behavioral responses ideally satisfy infant needs and ensure good future relationships (Bornstein, 2015). Deviations in infants' communicative signals and/or misunderstanding their messages can compromise infant care, parental effectiveness, and the budding parent-infant relationship (Adachi et al., 1985; LaGasse et al., 2005), as seems sometimes the case in parent-infant interaction in early autism (Esposito & Venuti, 2008). Results from different research groups (Bieberich & Morgan, 1998; Esposito & Venuti, 2009, 2010; Esposito et al., 2011, 2012, 2013; Oller et al., 2010; Sheinkopf et al., 2000, 2012) have shown that children with Autism Spectrum Disorder (ASD), even before they receive a diagnosis, express atypical patterns of cry (higher fundamental frequency, shorter inter-bout pauses, fewer utterances) in response to social (Esposito et al., 2014b) and non-social stressors (Sheinkopf et al., 2012). A number of studies of women (mothers and non-mothers) have also revealed how episodes of crying in children with ASD are perceived as unexpected (Esposito and Venuti, 2008) and more 'negative' than those of typically developing children (Venuti et al., 2012). However, the literature on how men (fathers and non-fathers) react to children's typical and atypical cries is still scant. In the present study, we begin to fill that gap by exploring how fathers and non-fathers respond to a highly salient form of infant communication: crying.

Economic and social changes have greatly modified contemporary paternal involvement in child caring, and fathers are as important as mothers in children's development (Parke, 2002). Some contemporary observers have noted fathers' increasing involvement with their children (Gray & Anderson, 2010; Pleck, 2012). Following this social trend, the psychological literature has investigated paternal involvement in caregiving by assessing behavioral, hormonal, and central nervous system responses to stimuli produced by infants. This literature suggests that experiences acquired in 'being a father' engender different reactions to child cries in comparison to non-fathers (Seifritz et al., 2003; Storey et al., 2000). Although paternal involvement in childcare is important in challenging situations, as in tending children with ASD (Ozturk et al., 2014), there is still limited research on the topic. Recent evidence has pointed to similarities and differences in parenting between mothers and fathers of children with ASD and relations among parental stress, mental health, and parenting attitudes (Ozturk et al., 2014). These results in turn point to the importance of developing specific intervention programs where fathers might play a specific therapeutic role.

1.1 Crying in typical and atypical development

Infant crying is a highly organized but complex communication that prompts parent-infant interaction. Crying in infancy appears to motivate caregiver proximity, instigate social interactions, and express needs (Wood & Gustafson, 2001), and these vital functions are evident in typical and atypical development alike. When the system functions optimally, parents seem to know what their crying baby needs even before they check diapers or feeding schedules. One clue that parents use in determining the wants and needs of their baby can be found in the acoustic components of infant distress vocalization. At least three different clusters of crying have been identified based on the acoustic properties of cries, and all are widely observed in infants: the anger cry (loud and prolonged vocalization), the hunger and basic cry (rhythmic and repetitive vocalization), and the pain cry (sudden onset, initially long, and extended breath holding) (Wolff, 1969). These three patterns of crying are present in typically developing children in different cultures (Barr et al., 1991) and likely arise in response to aversive internal or external stimulation. They are produced by coordination among several brain regions, including the brainstem, midbrain, and limbic system (LaGasse et al., 2005; Lester & LaGasse, 2008). The lower brain stem controls the muscles of the larynx (Lester & Boukydis, 1990). The limbic system and the hypothalamus participate in crying initiation, the midbrain in the configuration of crying patterns (midbrain), and the reticular activating system in the motor coordination of respiration, larynx, and articulation (Zeskind & Lester, 2001).

Cries of children with ASD are perceived differently from cries of typically developing (TD) children, and this different perception may alter basic parent-infant interaction. Esposito et al. (2012, 2013) found that the cries of children with ASD are judged to be more distressing than the cries of TD children by adults even from diverse cultural groups (Asian and European). A concordant pattern of results, where ASD cries were processed as more 'negative' than cries of TD children, was found in an fMRI study in adults with and without caregiving experience. Venuti et al. (2012) reported that the cries of infants with ASD, compared to those of TD infants, elicited increased activity in brain regions (left inferior frontal gyrus/anterior insula) associated with the emotional processing of aversive and arousing stimuli, suggesting that ASD cries may be perceived as even more aversive and/or arousing than TD cries. Finally, Esposito and Venuti (2009) found that maternal reactions to the crying of 1-year-olds later diagnosed with autism were qualitatively different (fewer touch and/or rocking and more verbal production) from responses to cries of matched TD control children.

1.1 Current Study

Most of the literature in this field has focused on behavioral responses to crying in women. Here, we explored physiological (rather than behavioral) responses in men to normal distress vocalizations (TD crying) and atypical distress vocalizations (crying of ASD children) matched with positive vocalizations (laughter). The autonomic nervous system (ANS) functions largely below the level of consciousness; it is divided into a parasympathetic nervous system (PSNS; a quick response mobilizing system) and a sympathetic nervous system (SNS; a more slowly activated system). Our experimental procedures were designed to measure how different components of the ANS respond to typical and atypical infant

distress vocalizations. Specifically, we employed three methodologies that measure different components of the ANS. (i) Perception assessed by measuring the Galvanic Skin Response (GSR; skin conductance increases with sweating that is regulated by the SNS which is aroused by negative stimuli). (ii) Physiological assessments of calm versus stress assessed by monitoring heart dynamics measured by cardiac Inter-Beat Interval (IBI; temporal distance in msec between two consecutive beats of the heart; increases of IBI are associated with a calming, and decreases are associated with stress, mediated by both the SNS and PSNS). (iii) Promptness to action assessed by measuring increases in the temperature of the right hand (increases in skin temperature of the right hand are associated with arousal and activation mediated by the SNS; Rimm-Kaufman & Kagan, 1996). These physiological assessments were performed on two groups of men with contrasting caregiving experience (fathers of typically developing children and non-fathers) with the aim of testing the following hypotheses:

- i. GSR: we expected that both fathers and non-fathers would show greater negative responses, measured as increased GSR, to atypical cries because ASD cries have specific characteristics (143 higher fundamental frequency, shorter interbout pauses, fewer utterances, and perception as unexpected) that render them unexpected and negative.
- ii. IBI: we expected that fathers will be calmer than non-fathers while listening to cries (fathers will have higher IBI, a measure of a calming response) because fathers have more experience in caring for crying infants. Following Seifritz and colleagues (2003), non-fathers may be more attracted than fathers to positive vocalizations; thus, we expected non-fathers to show higher IBI than fathers.
- iii. RHTC: In terms of arousal and activation, we expected that fathers would be more activated or prompted to act (showing greater increases of the temperature of the right hand) than non-fathers while hearing cries. In terms of activations we did not expect differences between fathers and non-fathers to non-distress infant vocalizations.

2. Method

2.1 Participants

A total of 22 adult males recruited from a database of people who had previously given consent to be enrolled in psychological human studies in the urban area of Wako-Shi, Saitama (Japan) participated. Exclusion criteria were neurological or psychiatric disorders, including substance abuse/dependence and psychotropic medication. In research involving autonomic measures, care is taken to control participants' use of prescription medications/illicit drugs and alcohol consumption. Participants were not drinkers nor had they consumed alcohol or taken medication in the 24 hours preceding the study. All participants signed informed consents and no incentives were given to the participants. All participants' education levels were matched across father and non-father groups. Participants were all highly educated (all had at least a University degree) and their socioeconomic status, measured with the Four-Factor Index of Social Status (Hollingshead, 1975) did not differ for the two groups (medium-high level). Of the 22 participants recruited, data were analyzed for

20; this number enabled us to detect large effects (effect size $>.8$) employing *t*-test family statistics on independent groups with a *p*-value set at 0.05. One participant (a non-father) was excluded from the sample because he was being treated for a psychiatric condition, and data from another participant (a father) were excluded because of technical problems during the experiment. Fathers of TD children under 3 years of age ($n = 10$), mean age of 33 years ($SD = 3.2$) did not statistically differ from non-fathers ($n = 10$), mean age of 32 ($SD = 4.5$), $t(19) = .95$, *ns*. Finally, for the father group, the amount of time spent with their children was assessed. All the fathers were living with their spouse and children 7 days/week and spent the majority of their free time with their children. All fathers declared that they were involved daily in some caregiving activities (i.e., milk bottle preparation, changing diapers, and bedtime routines).

2.2. Stimuli

Target stimuli were distress vocalizations (infant cries). Typically developing infants' cries [Typ-C] were compared with two other infant vocalizations: atypically developing infants' cries (cries of children with ASD [ASD-C]) as well as positive vocalizations (infant laughter [L]). Infant vocalizations were extracted from home videos (details for the specific groups are provided below). A research assistant, who was unaware of the purposes of the study and blind to children's typical versus atypical group membership, reviewed video records of the children for appropriate stimuli. An exclusion criterion was that the audio recording of infant vocalization contained background noise that would interfere with acoustic analysis (e.g., adult talk, sounds from toys, or other environmental noise). To optimize and equate for sound quality and volume, and ensure that the stimuli were representative of the typical range of infant vocalizations, the first 5 sec of infant vocalizations were used as experimental stimuli. A total of 8 stimuli per class were selected (Typ-C, ASD-C, and L).

Typical cry stimuli [Typ-C]—Infant distress vocalizations (cries) were extracted from home videos of unedited cry bouts of 10 TD (5 girls/5 boys) firstborn 13-month-olds. TD children were part of a longitudinal research project and did not present any cognitive concerns as confirmed by their Wechsler Preschool and Primary Scale of Intelligence-II (WPPSI-II; the reliability coefficients for the WPPSI-II U.S. composite scales range from .89 to .95; Wechsler, 1989) scores at age 4 years.

Atypical crying stimuli [ASD-C]—Infant distress vocalizations (cries) were extracted from home videos of unedited cry bouts of 10 ASD (5 girls/5 boys) firstborn 13-month-olds later diagnosed with Autism Spectrum Disorder. The home videos belonged to a database collected during a longitudinal study of early markers of autism. Children with ASD received a clinical diagnosis between 36 and 40 months of age (1) from a child psychiatrist according to DSM-IV-TR criteria (APA, 2004), and (2) they met the Clinical diagnosis of ASD for the DSM-5 (APA 2013), confirmed by (2a) the Autism Diagnostic Interview-Revised (ADI-R; a semi-structured, investigator-based interview for caregivers of individuals who may be ASD; ADI-R psychometric characteristics were excellent: both specificity and sensitivity are higher than 90%; Lord, Rutter, & Couteur, 1994) and (2b) the Autism Diagnostic Observation Schedule-Generics (ADOS-G; a semi-structured assessment of social interaction, communication, play, and imaginative use of materials for individuals

who may have ASD; ADOS specificity = 97% and sensitivity = 96.7%; Lord et al., 2000). To eliminate cases of secondary autism, children with ASD were free from other medical conditions (e.g., seizures, Fragile X syndrome) and had no visual or hearing impairments. Their cognitive level was evaluated as average at the age of 4 years using the Griffiths Mental Development Scales (reliability of the administration is 90%; Griffiths, 1996; Hanson, 1982; Luiz, Barnard, Knoesen, & Kotras, 2004).

Acoustic details of crying stimuli—To be sure that Typ-C and ASD-C stimuli were acoustically different and representative of the typical range of cry sounds for TD and ASD groups, respectively, cry sounds were digitized and analyzed using Praat acoustic analysis software (Boersma & Weenink, 2005). Episodes of crying of the two types differed in the duration of pauses (a silence longer than 250 ms within the episode of crying) in sec (TD: $M = 1.25$, $SD = 0.29$ and ASD: $M = 0.62$, $SD = 0.91$), $F(1,19) = 2.59$, $p < .05$), and in the number of utterances (expressed vocalization of distress between two pauses; TD: $M = 3.15$, $SD = 1.33$ and AD: $M = 2.06$, $SD = 1.91$), $F(1,19) = 3.88$, $p < .05$, within episodes of crying. Next, long-term average spectrum (LTAS) was employed to provide spectral information for each cry episode. LTAS is helpful in discriminating cry characteristics of different categories of children (Lin & Green, 2007). For all cries, the First Spectral Peak (FSP) of the LTAS was obtained. FSP is the frequency value (in Hz) of the first amplitude peak across the LTAS. It is an estimate of the average f_0 of an episode of crying (Lin & Green, 2007). FSPs (in Hz) of cries were lower for TD children ($M = 469.89$, $SD = 29.97$) than for ASD children ($M = 519.67$, $SD = 27.21$), $F(1,19) = 3.35$, $p < .05$. These results are consistent with previous findings that have indicated that cries of children with autism usually have different waveform modulations in terms of shorter pauses, fewer utterances, and higher fundamental frequency and are perceived as more unexpected (Esposito & Venuti, 2010; Esposito et al., 2011, 2012, 2013, 2014b).

Laughter stimuli—Infant positive vocalizations (laughter) were extracted from home videos of unedited laughter bouts of the same infants used for extracting the Typ-C stimuli. The duration of pauses (a silence longer than 250 ms within the episode of laughter) in sec was $M = 1.38$ ($SD = 0.50$), and the number of utterances (expressed positive vocalization between two pauses) was $M = 3.63$, $SD = 0.91$. FSPs (in Hz) of laughter were $M = 371.51$, $SD = 18.07$. These results accord with previous research (Scheiner et al., 2002).

2.3. Stimulus presentation and response measurements

After stimulus preparation, 24 audio files were presented randomly to participants (recorded at 44,100 Hz with a stereo resolution of 32 bit) interspaced with 10 sec of silence, using a personal computer in a sound shielded room. Every stimulus was presented twice. Participants were asked to listen to the stimuli while focusing on a “+” sign on a light-green neutral background, shown on a large LCD display (101 cm) placed at 100 cm from the participants.

To monitor ANS responses during the task different measures were collected with a Biosemi Active 2-system with electrodes: (i) Galvanic Skin Response (GSR) measured by the impedance of the skin and placed on the right hand; (ii) Inter-Beat Interval (IBI) was

extracted from a plethysmograph sensor from ADI instruments (MLT1020) that uses an infrared photoelectric sensor to detect changes in tissue blood volume and placed on the right hand; and (iii) Peripheral temperature was measured with a sensor from HP-Company (Agilent 21078A) and placed on the right hand. We connected the PC's audio card line output to the Biosemi amplifier, and the audio track was used as temporal marker. All signals were sampled at 2048 Hz.

2.4. Preliminary analyses and analytic plan

Prior to data analysis, correlations among the three measures were assessed. Because they are associated with different characteristics and modulated by different components of the ANS (SNS and PSNS), the three measures were not correlated (r range = $-.12$ to $+.15$). Then, univariate and multivariate distributions of dependent variable scores were examined for normality, homogeneity of variance, outliers, and influential cases (Fox, 1997). IBI scores were normally distributed; GSR and temperature scores were not and were treated as non-continuous variables in the subsequent analyses. The distance of each case to the centroid was evaluated to screen for multidimensional outliers (Fox, 1997). To compare fathers' versus non-fathers' physiological responses to the different acoustic stimuli for the IBI scores (continuous variable) an RM-ANOVA (repeated measures = Typical Cry, ASD Cry, and Laughter) was used. For the non-continuous variables (GSR and temperature changes), configural frequency analyses used Lehmacher's test ($z'L$) with Küchenhoff's continuity correction (von Eye, 2002).

3. Results

(i) Galvanic Skin Response

Participants with GSR increases were not equally distributed across the three stimuli, $\chi^2(11) = 28.01, p < .05$. Figure 1 shows that both fathers and non-fathers were significantly more likely to show GSR increases while listening to ASD cries ($z'L = 1.75, p < .05$).

(ii) Inter-Beat Interval (IBI)

The RM-ANOVA showed a significant interaction, $F(1,734) = 24.42, p < .05, \eta_p^2 = .07$, but no main effects for stimuli or parental status. Figure 2 shows that fathers had higher IBI than non-fathers to both the typical cries (Typ-C: M difference (Fathers – Non-Fathers) = 5.42, SE = .01, $p < .05, \eta_p^2 = .06$) and ASD cries (ASD-C: M difference (Fathers – Non-Fathers) = 11.45, SE = .009, $p < .01, \eta_p^2 = .08$).

(iii) Right Hand Temperature Change

Participants with peripheral temperature increases were not equally distributed across the three stimuli, $\chi^2(11) = 31.73, p < .01$. Figure 3 shows that more fathers had a right hand temperature increase than non-fathers for both for typical cries ($z'L = 1.81, p < .05$) and ASD cries ($z'L = 1.96, p < .05$).

4. Discussion

The parenting literature has emphasized how differential patterns of child behavior in early infancy may influence caregiver behavior. Most of this literature focuses on behavioral responses to stimuli produced by infants (vocalizations, faces, etc.) primarily in women (often mothers). However, considering contemporary increases in fathers' involvement in child caring (Bornstein, 2015; Gray & Anderson, 2010; Ozturk et al., 2014; Parke, 2002; Pleck, 2012), in this study we explored responses in males to such stimuli. Specifically, we assessed multiple physiological responses in fathers and non-fathers to typical infant distress vocalizations and atypical distress vocalizations matched with positive vocalizations. In summary, measuring different components of the autonomic nervous system, we found some different responses to these stimuli are activated in fathers and non-fathers and that specific activations are prompted by the developmental typicality of the stimuli. Both fathers and non-fathers showed enhanced negative responsiveness (increased Galvanic Skin Response) to crying of children with ASD. This result is consistent with previous studies of women (that revealed negative patterns of behavioral responses to crying of children with ASD; Esposito & Venuti, 2008; Venuti et al., 2012; Esposito et al., 2015b). It seems that ASD cries are regularly processed as more negative. This result is likely driven by specific characteristics of ASD cries (higher fundamental frequency, shorter inter-bout pauses, fewer utterances, and perception as unexpected). This finding is informative from a parental care perspective. It is possible that biases in evaluating levels of distress expressed in cries of children with special needs undermine the adequacy of caregiver responses. Overestimating the level of distress expressed in an episode of crying may jeopardize caregiver responsiveness, whereas "successful recognition and evaluation of children's vocalizations can be critical for bonding mechanisms and for offspring well-being and survival" (Seifritz et al., 2003, p. 1367). Additional studies might yield greater understanding of mechanisms underlying early social parent-infant interaction and may guideline expert support for caregivers and practitioners interacting with children with ASD.

We also found that fathers were generally calmer (lower IBI) than non-fathers while listening to infant cries, perhaps because fathers have more exposure to or experience in caring for crying infants. The fact that fathers were less excited while listening to crying is not an indication that they were less aroused. Differences in peripheral temperature, specifically increased temperature of the right hand, were evident when fathers listened to crying. Although the mechanism behind the emotional regulation of temperature via the sympathetic nervous system is still not clear, a number of studies (see for example: Esposito et al., 2014a, 2015a) have pointed out how changes in temperature may be used to measure arousal and activation, and increases in skin temperature of the right hand are normally associated with arousal and activation mediated by the SNS (Rimm-Kaufman & Kagan, 1996). Thus, it may be that fathers act more promptly while listening to a crying baby. This result may also be interpreted as related to infant exposure. In other words, fathers having more experience in caring for crying infants may develop specific neural mechanisms that facilitate their reactions to infant distress.

4.1 Limitation and Future Studies

Some limitations of this experiment point to future directions of study. First, we only analyzed small samples ($N=20$), and only fathers of typically developing children participated. Larger samples and parents of children with ASD may be informative because parents of children with ASD may be more used to cries of children with ASD and not consider them as distressing as do parents of typically developing children. Our results also underscore the desirability of future research on brain responses of adults to infant crying. Future studies might employ electrophysiological techniques (Maupin et al., 2015) to identify brain neural networks that render the perception of atypical cries as more distressed. We also suggested that it will repay to implement “hyperscanning” sessions (parallel recording of multiple participants) to investigate the responses of multiple caregivers (e.g. mothers and fathers) who are simultaneously exposed to typical and atypical cries.

5. Conclusions

In accord with behavioral studies that have been conducted principally in women, fathers and non-fathers show more emotional arousal mediated by sympathetic activation (increased GSR) while listening to cries of children with ASD. It seems that ASD cries are processed as more negative. This result is likely engendered by specific characteristics of ASD cries. Fathers were less excited (lower IBI) than non-fathers while listening to cries, perhaps because fathers have more exposure to or experience in caring for crying infants. Fathers were also more prompted to act (increase of the RHTC) than non-fathers while listening to cries. However, no differences emerged between fathers and non-fathers in these reactions to infant non-distress vocalizations.

These findings highlight similarities and differences in fathers’ and non-fathers’ physiological responsiveness to cries of children with ASD and might guide intervention programs for parents of children at risk of ASD. Specifically, as the current study highlights for male participants and previous studies have shown for female participants (Esposito & Venuti, 2008; Venuti et al., 2012), the acoustic qualities of a cry of a child with ASD may elicit more negative reactions and more distress. Because of this distress, there is increased risk that caregivers may give inadequate feedback to the child in order to reduce the cause of a specific crying episode. An intervention program for parents at risk of ASD might train them to attend to atypical crying episodes so parents can correctly interpret the distress signals of their child even though their child’s cries are atypical. An excellent example of this process of accommodation, where parents better understand a signal after training, is provided in Cri-du-Chat syndrome. The Cri-du-Chat syndrome (also called deletion 5p syndrome) is a rare genetic disorder resulting from a missing portion of chromosome 5. The peculiarity of this syndrome (from which it gets its name) is the characteristic cry sound, like a meowing kitten and is characterized by cries of very high pitch and short duration. Although the meaning of an episode of Cri-du-Chat is difficult to impossible to understand at first, parents of children with this disorder can, after adequate training, come to understand their child’s needs and wants.

In conclusion, we believe that the current study highlights how fathers differ from non-fathers in responding to some key infantile communicative cues. Our results raise further

questions of how fathers may differently respond from mothers and how these differences may inform clinical settings as well as typical development.

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References

- Adachi T, Murai N, Okada H, Nihei Y. Maternal perception of infant cries. *Japanese Journal of Educational Psychology*. 1985; 33:146–151.
- Barr RG, Konner M, Bakeman R, Adamson L. Crying in Kung San infants: A test of cultural specificity hypothesis. *Developmental Medicine and Child Neurology*. 1991; 33:601–610. [PubMed: 1879624]
- Bieberich A, Morgan SB. Brief report: Affective expression in children with autism or Down's syndrome. *Journal of Autism and Developmental Disorders*. 1998; 28:333–338. [PubMed: 9711490]
- Boersma, P.; Weenink, D. Praat: Doing phonetics by computer (Version 5.0.06) PC Software. 2005. Available from <http://www.praat.org>
- Bornstein, MH. Children's parents. In: Bornstein, MH.; Leventhal, T., editors. *Ecological settings and processes in developmental systems*. Volume 4 of the *Handbook of child psychology and developmental science*. 7e. Hoboken, NJ: Wiley; 2015. p. 55-132. Editor-in-chief: R. M. Lerner
- Esposito G, Nakazawa J, Ogawa S, Stival R, Kawashima A, Putnick DL, Bornstein MH. Baby, You Light-up My Face: Culture-General Physiological Responses to Infants and Culture-Specific Cognitive Judgements of Adults. *PloS ONE*. 2014a; 9(10):e106705.
- Esposito G, Nakazawa J, Ogawa S, Stival R, Putnick DL, Bornstein MH. Using Infrared Thermography to Assess Emotional Responses to Infants. *Early Child Development and Care*. 2015a; 185(3):438–447.
- Esposito G, Nakazawa J, Venuti P, Bornstein MH. Perceptions of distress in young children with autism compared to typically developing children: A cultural comparison between Japan and Italy. *Research in Developmental Disabilities*. 2012; 33:1059–1067. [PubMed: 22502830]
- Esposito G, Nakazawa J, Venuti P, Bornstein MH. Componential deconstruction of infant distress vocalizations via tree-based models: A study of cry in autism spectrum disorder and typical development. *Research in Developmental Disabilities*. 2013; 34:2717–2724. [PubMed: 23774058]
- Esposito G, Nakazawa J, Venuti P, Bornstein MH. Judgment of Infant Cry: The Roles of Acoustic Characteristics and SocioDemographic Characteristics. *Japanese Psychological Research*. 2015b; 57(2)
- Esposito G, Rostagno M del C, Venuti P, Haltigan JD, Messinger DM. Atypical expression of distress during the separation phase of the Strange Situation in infant siblings at high risk for ASD. *Journal of Autism and Developmental Disorders*. 2014b; 44(4):975–980. [PubMed: 24026913]
- Esposito G, Venuti P. How is crying perceived in children with Autistic Spectrum Disorder? *Research in Autism Spectrum Disorders*. 2008; 2:371–384.
- Esposito G, Venuti P. Comparative analysis of crying in children with autism, developmental delays, and typical development. *Focus Autism and Other Developmental Disabilities*. 2009; 24:240–247.
- Esposito G, Venuti P. Developmental changes in the fundamental frequency (f0) of infants' cries: A study of children with Autism Spectrum Disorder. *Early Child Development and Care*. 2010; 180(8):1093–1102.
- Esposito G, Venuti P, Bornstein MH. Assessment of distress in young children: A comparison of autistic disorder, developmental delay, and typical development. *Research in Autism Spectrum Disorders*. 2011; 5:1510–1516. [PubMed: 21647245]

- Fox, J. Applied regression analysis, linear models and related methods. SAGE; Thousand Oaks, CA: 1997.
- Gray, PB.; Anderson, KG. Fatherhood: Evolution and human paternal behavior. Cambridge, MA: Harvard University Press; 2010.
- Griffiths, R. The Griffiths Mental Development Scales 1996 revision. UK: Henley: Association for Research in Infant and Child Development, Test Agency; 1996.
- Hanson R. Item reliability for the Griffiths scales of mental development? Child Care Health Development. 1982; 8(3):151–161.
- Hollingshead, AA. Four-factor index of social status Unpublished manuscript. New Haven, CT: Yale University; 1975.
- LaGasse LL, Neal AR, Lester BM. Assessment of infant cry: Acoustic cry analysis and parental perception. Mental Retardation and Developmental Disabilities. 2005; 11:83–93.
- Lester, BM.; Boukydis, CF. No language but a cry. In: Papousek, H.; Jurgens, J.; Papousek, M., editors. Nonverbal vocal communication: Comparative and developmental approaches. New York: Cambridge University Press; 1990. p. 41-69.
- Lester, BM.; La Gasse, LL. Crying. In: Haith, MM.; Benson, JB., editors. Encyclopedia of infant and early childhood development. San Diego: Academic Press; 2008. p. 332-343.
- Lin H, Green J. Effects of posture on newborn crying. Infancy. 2007; 11:175–189.
- Lord C, Risi S, Lambrecht L, Cook EH, Leventhal BL, DiLavore PC, et al. The Autism Diagnostic Observation Schedule — Generic: A standard measure of social and communication deficits associated with the spectrum of autism. Journal of Autism and Developmental Disorders. 2000; 30:205–223. [PubMed: 11055457]
- Lord C, Rutter M, Le Couteur A. Autism Diagnostic Interview-Revised: a revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. Journal of Autism and Developmental Disorders. 1994; 24:659–685. [PubMed: 7814313]
- Luiz, DM.; Barnard, A.; Knoesen, N.; Kotras, N. The Griffiths Mental Development Scales Extended Revised (GSMD-ER) – technical manual. United Kingdom, Amersham: ARICD; 2004.
- Maupin AN, Hayes NJ, Mayes LC, Rutherford HJV. The Application of Electroencephalography to Investigate the Neural Bases of Parenting: A Review. Parenting: Science and Practice. 2015; 15:1–15.
- Oller DK, Niyogi P, Gray S, Richards JA, Gilkerson J, Xu D, et al. Automated vocal analysis of naturalistic recordings from children with autism, language delay, and typical development. Proceedings of the National Academy of Sciences. 2010; 107(30):13354–13359.
- Ozturk Y, Riccadonna S, Venuti P. Parenting dimensions in mothers and fathers of children with Autism Spectrum Disorders. Research in Autism Spectrum Disorders. 2014; 8(10):1295–1306.
- Parke RD. Fathers and families. Handbook of Parenting. 2002; 3:27–73.
- Pleck JH. Integrating father involvement in parenting research. Parenting: Science and Practice. 2012; 12(2–3):243–253.
- Rimm-Kaufman SE, Kagan J. The psychological significance of changes in skin temperature. Motivation and Emotion. 1996; 20(1):63–78.
- Scheiner E, Hammerschmidt K, Jürgens U, Zwirner P. Acoustic analyses of developmental changes and emotional expression in the preverbal vocalizations of infants. Journal of Voice. 2002; 16(4): 509–529. [PubMed: 12512639]
- Seifritz E, Esposito F, Neuhoff JG, Luthi A, Mustovic H, Dammann G, et al. Differential sex-independent amygdala response to infant crying and laughing in parents versus nonparents. Biological Psychiatry. 2003; 12:1367–1375. [PubMed: 14675800]
- Sheinkopf SJ, Iverson JM, Rinaldi ML, Lester BM. Atypical cry acoustics in 6-month-old infants at risk for autism spectrum disorder. Autism Research. 2012; 5(5):331–339. [PubMed: 22890558]
- Sheinkopf SJ, Mundy P, Oller DK, Steffens M. Vocal atypicalities of preverbal autistic children. Journal of Autism and Developmental Disorders. 2000; 30:345–354. [PubMed: 11039860]
- Storey AE, Walsh CJ, Quinton RL, Wynne-Edwards KE. Hormonal correlates of paternal responsiveness in new and expectant fathers. Evolution and Human Behavior. 2000; 21:79–95. [PubMed: 10785345]

- Venuti P, Caria A, Esposito G, de Pisapia N, Bornstein MH, de Falco S. Differential brain responses to cries of infants with autistic disorder and typical development: An fMRI Study. *Research in Developmental Disabilities*. 2012; 33(6):2255–2264. [PubMed: 22835685]
- von Eye, A. *Configural frequency analysis: methods, models, and applications*. Mahwah, NJ: Erlbaum; 2002.
- Wechsler, D. *Wechsler Preschool and Primary Scale of Intelligence-Revised (WPPSI-R)*. San Antonio, TX: Psychological Corp; 1989.
- Wolff, P. The natural history of crying and other vocalizations in early infancy. In: Foss, B., editor. *Determinants of infant behaviour*. Vol. 4. London: Mathuen; 1969.
- Wood RM, Gustafson GE. Infant crying and adults anticipated caregiving responses: Acoustic and contextual features. *Child Development*. 2001; 72:1287–1300. [PubMed: 11699671]
- Zeskind, PS.; Lester, BM. Analysis of infant crying. In: Singer, LT.; Zeskind, PS., editors. *Biobehavioral assessment of the infant*. New York: Guilford Publications Inc; 2001. p. 149-166.

Highlights

- Some children with ASD express atypical patterns of crying.
- Cries of children with ASD are perceived differently from other cries, and these perceptual differences may alter parent-infant interaction.
- Both fathers and non-fathers show greater negative responses (increased GSR) to ASD cries compared to typical cries and laughter.
- Fathers and non-fathers show more emotional arousal mediated by sympathetic activation while listening to cries of children with ASD.
- Fathers are calmer and act more promptly than non-fathers while listening to typical cries.

Figure 1.

Percentage of participants who showed GSR increases while listening to three classes of stimuli (Typically developing infants' Cries [TYP-C]; cries of children with ASD [ASD-C]; and positive vocalizations (infant laughter [L]). Fathers and non-fathers were significantly more likely to show GSR increases while listening to ASD cries (Lehmacher's test $z'L = 1.75$, $p < .05$). * $p < .05$.

Figure 2.

Mean levels of Inter-Beat Interval (IBI) while listening to the three classes of stimuli (Typically developing infants' Cries [TYP-C]; cries of children with ASD [ASD-C]; and positive vocalizations (infant laughter [L])). Fathers had higher IBI than non-fathers to both typical cries ($p < .05$) and ASD cries ($p < .01$). * $p < .05$. ** $p < .01$.

Figure 3.

Percentage of participants who showed peripheral temperature increases (measured on the right hand) while listening to the three classes of stimuli (Typically developing infants' Cries [TYP-C]; cries of children with ASD [ASD-C]; and positive vocalizations (infant laughter [L])). More fathers had right hand temperature increases than non-fathers for typical cries ($z'L = 1.81, p < .05$) and ASD cries ($z'L = 1.96, p < .05$). * $p < .05$.