Universidade do Minho
Escola de Psicologia

Vera Lúcia Esteves Mateus

Joint attention abilities in infancy: The impact of prematurity, quality of caregiving behaviors and infant physiological regulation

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Vera Lúcia Esteves Mateus
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Joint attention abilities in infancy: The impact of prematurity, quality of caregiving behaviors and infant physiological regulation

Tese de Doutoramento em Psicologia Básica

Trabalho efetuado sob a orientação da
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e da
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janeiro de 2018

STATEMENT OF INTEGRITY

I hereby declare having conducted my thesis with integrity. I confirm that I have not used plagiarism or any form of falsification of results in the process of the thesis elaboration.

I further declare that I have fully acknowledged the Code of Ethical Conduct of the University of Minho.

University of Minho, 23/01/2018

Full name: Vera Lúcia Esteves Mateus

Signature: Vera [signature]

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Joint attention abilities in infancy: The impact of prematurity, quality of caregiving behaviors and infant physiological regulation

Abstract

Emerging in the last quarter of first year of life, joint attention represents a qualitative shift in infants' understanding of the social world. By coordinating their visual attention with another person regarding an external object, infants begin to acknowledge that others may have an intentional and attentional agenda different from their own, and whose focus of interest may be followed or directed. The capacity for sharing attention seems to reflect the interplay between infant's individual characteristics and environment factors. Thus, the present doctoral dissertation aims to explore the contribution of three variables – prematurity, quality of maternal behaviors, and infant physiological regulation – in explaining inter-individual differences in joint attention. The first study, a meta-analysis, investigates the effect of prematurity on several behavioral dimensions of joint attention – initiating joint attention, responding to joint attention, and episodes of joint attention. The second paper analyzes whether infant birth status (late preterm vs. full term) and the quality of two maternal behaviors – maintaining infant's focus of attention and appropriate mind-related comments – predict joint attention abilities at 12 months. In addition, we also examine the potential moderating effect of maternal interactive style on the impact of prematurity on infants' responding to joint attention. The last study explores the longitudinal link between one-month-old infant's vagal regulation (Respiratory Sinus Arrhythmia, RSA), at rest and in response to auditory stimulation, and later joint attention behaviors. The results of meta-analysis suggest that distinct dimensions of joint attention, namely responding to joint attention and episodes of joint attention, may be particularly vulnerable to varying degrees of prematurity. In this line, study 2 showed that late preterm birth predicted significantly lower levels of responding to (but not initiating) joint attention. On the other hand, none of the maternal interactive behaviors independently predicted or moderated the effects of prematurity on joint attention abilities. Finally, in paper 3, infant's lower RSA baseline and RSA augmentation from baseline to auditory stimuli was associated with more instances of joint attention, especially responding to bids for joint attention, suggesting that distinct profiles of physiological regulation may facilitate social engagement. Overall, findings showed that responding to joint attention was affected by prematurity and infant physiological functioning, perhaps, through the impact they might have on infants' attentional capabilities (engaging, disengaging, and shifting of attention). Initiating joint attention is likely to be influenced by affective and motivational factors, that should be addressed in future studies. On the other hand, we suggested

that maternal interactive behaviors did not contribute to joint attention behaviors, possibly due to a decreasing of influence as infants become more capable of intentional communication and joint attention acts become more frequent in their behavioral repertoires. Future research should examine the interplay between individual brain and behavior and environmental factors in order to contribute for a more complete and comprehensive understanding of infants' joint attention abilities.

Competências de atenção partilhada na infância: Impacto da prematuridade, qualidade dos cuidados e regulação fisiológica do bebé

Resumo

Com início no último trimestre do primeiro ano de vida, a atenção partilhada representa uma mudança qualitativa na compreensão do bebé acerca do mundo social. Ao coordenar a sua atenção visual face a um objeto externo com outra pessoa, o bebé começa a reconhecer que os outros podem ter intenções e um foco atencional diferentes dos seus, e que esse foco de interesse pode ser seguido ou direcionado. A capacidade de partilhar atenção parece reflectir a interação entre caraterísticas individuais do bebé e fatores ambientais. Assim, a presente dissertação de doutoramento pretende explorar a contribuição de três variáveis – prematuridade, qualidade dos comportamentos maternos e regulação fisiológica do bebé – para as diferenças individuais na atenção partilhada. O primeiro estudo, uma meta-análise, investiga o efeito da prematuridade em várias dimensões comportamentais de atenção partilhada – iniciação de atenção partilhada, resposta a sugestões de atenção partilhada e episódios de atenção partilhada. O segundo estudo analisa se o estatuto do bebé ao nascimento (prematuro tardio vs. termo) e a qualidade de duas dimensões do comportamento materno – manter o foco atencional do bebé e comentários mentais apropriados – predizem os comportamentos de atenção partilhada aos 12 meses de idade. Adicionalmente, também examinamos o potencial efeito moderador do estilo interativo materno no impacto da prematuridade na resposta a atenção partilhada dos bebés. O último estudo explora a relação longitudinal entre a regulação vagal (Arritmia Sinusal Respiratória – ASR) do bebé a 1 mês de idade, em descanso e em resposta a estimulação auditiva, e os comportamentos de atenção partilhada avaliados mais tarde. Os resultados da meta-análise sugerem que dimensões específicas de atenção partilhada, nomeadamente resposta a atenção partilhada e episódios de atenção partilhada, podem ser particularmente vulneráveis a diferentes graus de prematuridade. Neste sentido, o estudo 2 demonstrou que ser prematuro tardio revelou ser um preditor significativo de níveis inferiores de resposta a (mas não iniciação de) atenção partilhada. Por outro lado, nenhum dos comportamentos interativos maternos foi preditor ou moderou o efeito da prematuridade na atenção partilhada. Por fim, no estudo 3, menor ASR basal e aumento de ASR face a estimulação auditiva estavam associados a melhores competências de atenção partilhada, especialmente de resposta a sugestões de atenção partilhada, sugerindo que diferentes perfis de regulação fisiológica podem facilitar o envolvimento social. De uma forma geral, os resultados mostraram que a resposta a atenção partilhada foi afetada pela prematuridade e funcionamento

fisiológico do bebé, talvez através do impacto que podem ter nas capacidades atencionais dos bebés (envolver, desviar e alternar entre focos de atenção). A iniciação de atenção partilhada será provavelmente influenciada por fatores afetivos e motivacionais, os quais devem ser abordados em estudos futuros. Por outro lado, sugerimos que os comportamentos interativos maternos não contribuíram para os comportamentos de atenção partilhada, possivelmente, devido a uma diminuição da sua influência à medida que os bebés se tornam mais competentes na comunicação intencional e os atos de atenção partilhada se tornam mais frequentes nos seus repertórios comportamentais. Investigações futuras deverão examinar a interação entre desenvolvimento cerebral e comportamento do indivíduo e fatores ambientais, com vista a contribuir para uma compreensão mais completa e abrangente das competências de atenção partilhada.

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ABBREVIATION LIST

ASD – Autism Spectrum Disorder

BSI – Brief Symptom Inventory

ECG – Electrocardiogram

ESCS – Early Social Communication Scales

GA – Gestational age

GDQ – Global Developmental Quotient

GMDS – Griffiths Mental Development Scales

GSI – General Severity Index

IBI – Inter-Beat Interval

IJA – Initiating joint attention

JAE – Joint attention episodes

MPM – Multiple Process Model

NICU – Neonatal Intensive Care Unit

PRISMA – Preferred Reporting Items for Systematic Reviews and Meta-Analyses

PSDI – Positive Symptom Distress Index

PST – Positive Symptom Total

RJA – Responding to joint attention

RSA – Respiratory Sinus Arrhythmia

SCM – Social Cognitive Model

UCM – Universal Cognitive Model

USA – United States of America

CHAPTER 1

GENERAL INTRODUCTION

Joint attention as an early milestone of social cognition during infancy.

One of the defining characteristics of human nature is the ability to engage in reciprocal interactions with others from birth, for example, by attending to human faces and stimuli with face-like configuration (e.g., Farroni et al., 2005; Johnson, Dziurawiec, Ellis, & Morton, 1991; Mondloch et al., 1999; Valenza, Simion, Cassia, & Umiltà, 1996). These early social interactions are believed to provide opportunities for infants to gradually acknowledge themselves as similar to other persons, but separate and distinct entities (Tomasello, 1995). In humans, this understanding of the self and others as intentional agents undergoes an important revolution by the end of first year of life with the emergence of joint attention (Carpenter, Nagell, & Tomasello, 1998; Tomasello, 1995). Considered the initial "*meeting of minds*" (Bruner, 1995, p. 6), joint attention refers to the infant's ability to share attention with another person towards an object of common interest (e.g., a toy) (Bakeman & Adamson, 1984; Mundy, Seibert, & Hogan, 1984; Tomasello, 1995; Tomasello & Todd, 1983). Indeed, infants' engagement in joint attentional states with others seems to reflect their increasing understanding that people may have their own intentional and attentional agenda, which will influence their behavior, and whose focus of interest may be followed or directed (Carpenter et al., 1998; Tomasello, 1995). Emerging at around 9 months of age (Bakeman & Adamson, 1984; Carpenter et al., 1998), it is during the second year of life that infants become more competent in coordinating their visual attention (Carpenter et al., 1998; Mundy et al., 2007).

Over time, the empirical study of joint attention has covered distinct behavioral dimensions of this phenomenon, either focusing on infants' specific behaviors or dyad's capacity for joint engagement. In this regard, joint attention was investigated in terms of coordinated joint engagement states, with a certain duration of time, which required infant's gaze alternation between the object and the social partner during the episode (e.g., Bakeman & Adamson, 1984; Tomasello & Todd, 1983). Simultaneously, another line of research, anchored in the development of the Early Social Communication Scales (ESCS; Mundy et al., 2003; Seibert, Hogan, & Mundy, 1982), assessed infants responding to joint attention (RJA) and initiating joint attention (IJA). More specifically, RJA reflects the infant's ability of following an adult's direction of gaze and pointing gestures, whereas IJA refers to the frequency of infants' spontaneous initiatives (e.g., eye contact, showing and pointing gestures) to engage the adult in shared attention (Mundy et al., 2003; Mundy et al., 1984). Subsequently, Carpenter and colleagues (1998) defined three categories of behaviors to study joint attention: sharing attention, following attention, and directing attention. The former corresponds to relatively extended periods of time during which infant and adult share attention towards a common object. In turn, following attention occurs when infants orient their own attention in the direction of the adult's visual gaze or pointing gestures, whereas directing attention refers to infants' spontaneous communicative behaviors (e.g., pointing or showing gestures) directed to others in order to capture their attention. Common to all three categories is the *sine qua non* condition of infant's alternation of gaze between the object and the social partners' face during such occasions. Briefly, joint attention is studied in terms of the frequency or duration of dyads' (infant and social partner) joint engagement, infants' responding to and initiating joint attention behaviors.

Regarding measurement issues, two paradigms of observational assessment of joint attention are often used in the literature: infant-tester paradigms (e.g., ESCS; Mundy et al., 2003; Seibert et al., 1982) and infant-mother interactions (e.g., Bakeman & Adamson, 1984; Gaffan, Martins, Healy, & Murray, 2010; Osório, Martins, Meins, Martins, & Soares, 2011; Tomasello & Todd, 1983), each potentially uncovering distinct aspects on the phenomenon. On the one hand, a structured procedure with trained testers will more likely reduce the influence of the social partner, providing a clearer picture of infants' inter-individual differences in initiating and responding to joint attention. On the other hand, it can be argued that infant's optimal capacity for sharing attention, as well as dyadic measures of joint attention (e.g., duration and frequency of shared attention episodes), might be better captured by infant-mother interactions, often in a context of free toy-play. However, as joint attention is assessed at the dyadic level, it becomes difficult to discern the relative contributions of the infant and the social partner to joint attention (Mundy & Sigman, 2006).

Infants' individual differences in joint attention behaviors have been related to subsequent adaptive communicative and social functioning. In this regard, it has been demonstrated that joint attentional routines seem to scaffold infants' language development to the extent they facilitate the association between a new word and the object labeled by the adult (e.g., Baldwin, 1995; Colonnesi, Stams, Koster, & Noom, 2010; Morales et al., 2000; Mundy & Gomes, 1998), especially when the social partner follows the infant's focus of interest (Dunham, Dunham, & Curwin, 1993; Tomasello & Farrar, 1986). In addition, joint attention in infancy also contributes to later social competence insofar that it reflects important processes, such as self- and other-monitoring (Mundy & Jarrold, 2010), positive emotionality (Kasari, Sigman, Mundy, & Yirmiya, 1990; Mundy, Kasari, & Sigman, 1992), attentional and behavioral regulation (Mundy & Jarrold, 2010; Mundy & Sigman, 2006), and social approach tendencies (Mundy, 1995), which are core features in the development of adaptive social functioning (Eisenberg et al., 1995; 1997; Masten & Coatsworth, 1998). Thus, higher frequency of joint attention instances have been associated with better social-behavioral outcomes, namely less disruption and externalizing problems and more positive and prosocial behaviors (e.g., Sheinkopf, Mundy, Claussen, & Willoughby, 2004; Vaughan van Hecke et al., 2007). Finally, previous studies suggest that infants' joint attention abilities constitute an earlier precursor of more advanced understanding of others minds, or later Theory of Mind (Charman et al., 2000; Nelson, Adamson, & Bakeman, 2008; Sodian & Kristen-Antonow, 2015). In this sense, joint attentional engagement provides major opportunities for the infant to start experiencing perspective taking, processing and comparing information from different viewpoints, and, in turn, making inferences about others' attentional focus, intentions and actions (Mundy, 2017; Tomasello, 1995), setting the foundation for infant's later understanding of more complex states of mind. Altogether, empirical evidence points to joint attention as a relevant socio-cognitive milestone to be investigated, not only due to its influence on the normative trajectory of related developmental outcomes (e.g., language, Theory of Mind), but also because of its potential for detecting early social-communicative impairments in atypically developing populations, such as children with Autism Spectrum Disorder (ASD) or developmental delay, and at-risk groups, such as preterm infants.

Models of joint attention development.

Over time, three major theoretical accounts have been developed about the nature of joint attention, which, although postulating different assumptions, complement each other.

A first attempt to explain the development of this important socio-cognitive milestone was the Universal Cognitive Model (UCM; Seibert et al., 1982), which hypothesizes joint attention as a result of successive levels of increased cognitive complexity that allow the infant to understand and adapt to the social and physical world. Furthermore, the model assumes continuity between preverbal communicative acts (i.e., joint attention) and posterior linguistic communication. Thus, according to this model, different behavioral dimensions of joint attention will be intercorrelated, as they primarily reflect common cognitive processes (Seibert et al., 1982). In this line, early joint attention was observed to be associated with general measures of cognitive performance at later ages (Smith & Ulvund, 2003; Ulvund & Smith, 1996).

On the other hand, the Social Cognitive Model (SCM; Tomasello, 1995; Tomasello, Carpenter, Call, Behne, & Moll, 2005), a variant of the previous model, argues that joint attention and theory of mind should be considered in a continuum of children's increasing comprehension of other persons.

According to this view, a significant qualitative shift in infants' knowledge about the others' and their own actions can be observed from 9 to 12 months of age (Brooks & Meltzoff, 2005; Tomasello, 1995; Tomasello et al., 2005). By this time, infants begin to acknowledge others as intentional agents, who may have intentions and an attentional agenda different from their own, in turn allowing them to follow or direct their partner's attention. This shared intentionality would simultaneously involve motivational and cognitive factors that promote social engagement (Tomasello, 1995; Tomasello et al., 2005). In this line, joint attention abilities would make unique contributions to infants' subsequent development (e.g., language acquisition) over and above their current cognitive developmental level (Mundy et al., 2007). Additionally, different behavioral manifestations of joint attention should rely on the same basic assumption – comprehension of the others as having intentions of their own – and, therefore, are expected to be correlated and reflect similar socio-cognitive processes (Tomasello, 1995).

In contrast, the Multiple Process Model (MPM; Mundy, Card, & Fox, 2000) offers an alternative perspective on the development of joint attention. Thus, different dimensions of joint attention would recruit distinct areas of the brain (e.g., Mundy et al., 2000) and attention-regulation systems (Posner & Petersen, 1990), reflecting motivational and executive processes involved in attentional and behavioral regulation, information processing, self- and other-monitoring (Mundy & Newell, 2007; Mundy & Sigman, 2006). Consequently, infants' attention sharing behaviors would express common, but also unique contributions of specific mental processes (Mundy et al., 2007). A growing body of empirical evidence provides support to this hypothesis. Thus, infants' initiatives to share attention (IJA) tend to be unrelated to responding to joint attention (RJA) (e.g., Claussen, Mundy, Mallik, & Willoughby, 2002; De Schuymer, De Groote, Beyers, Striano, & Roeyers, 2011; Mundy et al., 2007; Sheinkopf et al., 2004; Vaughan van Hecke et al., 2007; Vaughan et al., 2003), but also seem to display specific age-related changes through infancy (Mundy et al., 2007). In addition, different dimensions of joint attention seem to present specific patterns of association with infant's subsequent socio-cognitive development. For example, IJA and RJA make significant and unique contributions to common but also distinct aspects of social competence (e.g., Sheinkopf et al., 2004; Vaughan van Hecke et al., 2007) and linguistic capacity (e.g., De Schuymer et al., 2011; Mundy & Gomes, 1998; Vaughan van Hecke et al., 2007). This theoretical account also challenges the Social Cognitive Model's assumption that any instance of joint attention prior to the age of 9-months would be purely conditioned response or a random coincidence (Tomasello, 1995). In this regard, it has been shown that infants may evidence gaze following as early as six-months, which was associated with later expressive and receptive language ability assessed during the second year of life (Morales, Mundy, & Rojas, 1998) and at 30 months of age (Morales et al., 2000). This early ability to follow gaze may be explained by the important role played by the posterior attention system, which becomes completely functional in the first six months after birth (Rothbart, Posner, & Rosicky, 1994; Weijer-Bergsma, Wijnroks, & Jongmans, 2008), in the regulation of infants' ability to orient their attention toward salient and biologically meaningful stimuli in the environment (Mundy & Jarrold, 2010; Mundy & Newell, 2007).

An ecological framework for understanding joint attention abilities.

The socio-cognitive development in the first two years of life seems to simultaneously reflect maturational changes related to age (e.g., motor coordination, acuity of perception, attentional preferences) as well as the influence of early social experiences. In that sense, a fruitful theoretical framework for the study of joint attention is that of Bronfenbrenner's (1979) bioecological model of development. The author conceptualizes human development as a result of the interaction between distinct intertwined contexts of environmental influence, in which the individual is embedded, and that directly and indirectly shape their developmental path throughout the life span. Therefore, a broadened perspective to understand human development should take into consideration the influence of immediate (e.g., family) but also more remote (e.g., culture) settings. Thus, the developing infant, carrying his/her own individual characteristics, will evolve by progressively accommodating to stability and change occurring in the surrounding contexts over time, as a function of the bidirectional interactions between the individual and the environment (Bronfenbrenner, 1979; 1994). During infancy, environmental effects operate primarily through the familial context (microsystem), mostly taking place in the form of parent-infant relationships, which require the need of including both individual characteristics and parental influences in the study of infant's joint attention development in the first two years of life. Indeed, despite their own internal motivations and interests, infants are very sensitive to variations on the social stimulation from the adult (Trevarthen & Aitken, 2001). More specifically, social experiences in which the adult responds contingently and reciprocates the infant's behavior are particularly effective in facilitating several aspects of infant development, namely joint attentional engagement (Dunham & Dunham, 1995). Thus, on the present project, we focused our attention on the effects of two contexts on infants' joint attention: infant's own individual characteristics and quality of the caregiving conditions.

Infant individual characteristics. Previous investigations have focused on infant's specific characteristics that may promote their social engagement with others and attention-sharing behaviors, such as gestational age (e.g., De Schuymer et al., 2011; Olafsen et al., 2006), autonomic functioning (Heilman, Bal, Bazhenova, & Porges, 2007), or early attention orienting and dyadic social engagement (Salley et al., 2016). Two aforementioned variables – gestational age and autonomic functioning – deserve our consideration due to their relevance to the development of positive social functioning, and of joint attention in particular.

In 2010, preterm birth (before 37 completed weeks of gestation) accounted for approximately 15 million infants born worldwide and rising, being a major cause of neonatal death and having long lasting effects on the physical and psychological development of the surviving preterm infants (Blencowe et al., 2013; March of Dimes, PMNCH, Save the Children, & WHO, 2012). In addition to the potential health complications associated with prematurity (e.g., visual and hearing impairments, respiratory diseases) (Behrman & Butler, 2007; March of Dimes et al., 2012), preterm infants are also at heightened risk for exhibiting emotional and behavioral problems (Bhutta, Cleves, Casey, Cradock, & Anand, 2002; Clark, Woodward, Horwood, & Moor, 2008; de Jong, Verhoeven, & van Baar, 2012; Jones, Champion, & Woodward, 2013; Potijk, Winter, Bos, Kerstjens, & Reijneveld, 2016), compromised cognitive ability (Barre, Morgan, Doyle, & Anderson, 2011; Bhutta et al., 2002; de Jong et al., 2012; Landry, Denson, & Swank, 1997; Sansavini et al., 2010; Wolke et al., 2015), and poorer social skills (Braarud et al., 2013; De Groote, Roeyers, & Warreyn, 2006; Jones et al., 2013; Landry et al., 1997; Wong, Huertas-Ceballos, Cowan, & Modi, 2014). Nevertheless, preterm infants are not a homogeneous group and the magnitude of the sequelae depends largely on the degree of prematurity and neonatal complications, with lower gestational age and more neonatal medical morbidities related to increased likelihood of adverse outcomes (Blencowe et al., 2013; McCormick, Litt, Smith, & Zupancic, 2011). About 84% of preterm births occur between 32 and < 37 weeks of gestation, therefore, corresponding to moderate (32 – < 34 weeks) and late (34 – < 37 weeks) preterm infants (March of Dimes et al., 2012). However, the deleterious effect of late prematurity on subsequent infant development may well be underestimated. Thus, in recent years, more attention has been devoted to the developmental outcomes of late preterm infants. Findings suggest that this particular group is more likely to present poorer cognitive performance (e.g., Baron et al., 2014; Shah, Kaciroti, Richards, Oh, & Lumeng, 2016; Talge et al., 2010) and social-emotional problems (e.g., Stene-Larsen, Lang, Landolt, Latal, & Vollrath, 2016; Talge et al., 2010), when compared to their full term counterparts.

In the scientific and empirical field of joint attention, studies also report impairments in premature (vs. full-term) infants (e.g., Garner, Landry, & Richardson, 1991; Olafsen et al., 2006), particularly those with low birth weight (< 1600g) and concomitant neonatal complications (Garner et al., 1991). Yet, joint attention has been unevenly investigated across groups of premature infants (extremely preterm, very preterm, moderate preterm, and late preterm), prioritizing those infants at lower gestational ages. Thus, further investigation is needed in order to systematically examine the effect of the most common type of preterm birth – late prematurity – across different behavioral dimensions of joint attention.

Another line of research has focused on the contribution of infants' own autonomic functioning to their social engagement with others. Indeed, infants' regulation of their physiological and behavioral states is a fundamental condition for the child to become involved and explorative in the surrounding social environment, which can be achieved through an adequate functioning of the vagal brake (Porges, Doussard-Roosevelt, Portales, & Greenspan, 1996; Porges & Furman, 2011). By modulating the control exerted by the vagus nerve on the heart, this important neurophysiological mechanism allows the individual to restore calmness and rapidly adopt engagement/disengagement behaviors with other persons or objects in order to deal with environmental demands (Porges, 2001, 2007). An effective vagal regulation will promote positive social-oriented behaviors (e.g., positive facial expressions, increased eye contact, head orientation toward stimuli) (Porges, 2007), which are pivotal in the establishment of joint attentional states. Previous studies observed that infants who better regulated their vagal tone presented more optimal social functioning, to the extent that they were more socially engaged and responsive to the interaction with others (e.g., Stifler & Corey, 2001; Van Hecke et al. 2009) and showed less behavioral problems (e.g., Calkins & Keane, 2004; Van Hecke et al. 2009).

However, the relationship between infant vagal regulation and joint attention has been less explored. To the best of our knowledge, only two studies examined this issue in typically developing children (Heilman et al., 2007) and children with ASD (Patriquin, Scarpa, Friedman, & Porges, 2013), both concluding that better vagal regulation was associated with more frequent joint attention behaviors (e.g., eye contact). Nevertheless, because the previous works assessed preschool and school-aged children in cross-sectional designs, we wonder whether this relation would hold even when joint attention abilities are still emerging. Therefore, how early on in development does infant physiological vagal regulation predict subsequent joint attention behaviors? We posit that the longitudinal link between these two variables – vagal regulation and joint attention – should first be clarified in typically developing infants, so that one might, then, investigate the implications for the development of joint attention in populations at risk of less mature autonomic functioning, like preterm infants (e.g., Feldman, 2006; Feldman & Eidelman, 2007; Richards, 1994; Shinya, Kawai, Niwa, & Myowa-Yamakoshi, 2016).

Quality of caregiving environment. Family is the most proximal and influential context of infants' development after birth and throughout the first years of life. In this sense, an adaptive and successful developmental trajectory is constructed within the dynamic interplay between the infant's individual characteristics and the quality of the caregiving environment (Sameroff, 2004).

In the family setting, the mother's role on infant development has been widely studied. Therefore, high quality mother-infant interactions characterized, for example, by higher levels of sensitivity and responsiveness to the infant's signals, positive affect, maintaining of infant's focus of interest, and verbal stimulation, have been associated with infants' more optimal outcomes in the cognitive-linguistic (e.g., Hirsh-Pasek & Burchinal, 2006; Landry, Smith, Swank, & Miller-Loncar, 2000; Page, Wilhelm, Gamble, & Card, 2010; Tamis-LeMonda, Shannon, Cabrera, & Lamb, 2004), and social domains (e.g., Landry, Smith, Miller-Loncar, & Swank, 1998; Landry et al., 2000; Page et al., 2010; Steelman, Assel, Swank, Smith, & Landry, 2002). Furthermore, such maternal tendencies have also been widely associated with secure attachment (e.g., Bigelow et al., 2010; Braungart-Rieker, Garwood, Powers, & Wang, 2001; De Wolff & van IJzendoorn, 1997; McElwain & Booth-LaForce, 2006), and better physiological regulation from the infant (e.g., Calkins, Graziano, Berdan, Keane, & Degnan, 2008; Perry et al., 2013). Similarly, the beneficial effects of optimal caregiving environments have also been corroborated in studies with biologically immature (i.e., premature) infants, in which the quality of parent-infant relationships assumes a crucial role in infants' adaptive developmental trajectories. Accumulated evidence suggests that parenting behaviors that are highly sensitive to the infant's interests and focus of attention and less restrictive of children's behavior facilitate premature infants' later cognitive (e.g., Landry, Smith, Miller-Loncar, & Swank, 1997; Shah, Robbins, Coelho, & Poehlmann, 2013), and social development (e.g., Gueron-Sela, Atzaba-Poria, Meiri, & Marks, 2015; Landry et al., 1997; 1998), with particularly significant gains for high-risk preterm infants (e.g., low birth weight, medical complications).

In the particular case of joint attention, early social interactions provide valuable opportunities for the infant to experience different points of view and process information as a receiver and a sender of the signal/communication (Mundy, 2017) with the quality of the experiential input being determinant on how much the infant learns from the sharing experience. With this regard, previous studies have highlighted the role played by several maternal interactive behaviors, such as sensitivity, cooperation with infant's current activities, scaffolding, following the infants' attentional focus, and consideration for infants' inner states, in facilitating infants' engagement in triadic interactions (Fadda & Lucarelli, 2017; Gaffan et al., 2010; Hobson, Patrick, Crandell, Pérez, & Lee, 2004; Legerstee, Markova, & Fisher, 2007; Mendive, Bornstein, & Sebastián, 2013; Olafsen et al., 2006; Roberts et al., 2013; Vaughan et al., 2003). However, how impactful are maternal behaviors on infants' joint attention development? In what instances may positive mother-infant interactions be enough to obviate the infant's biological immaturity (i.e., prematurity), which places them at risk for difficulties in several domains, namely social development? These questions remain to be answered.

Aims of the present work.

Based on the important role infants' gestational age and autonomic functioning as well as parenting behaviors may have on the development of joint attention abilities, and given the existing caveats in the literature, this doctoral dissertation aimed to extend the literature by analyzing the contribution of these three variables in explaining inter-individual differences in joint attention. Three central research questions guided our work:

1. *What is the state-of-the-art of studies investigating joint attention skills in premature infants? Does preterm birth systematically affect different behavioral dimensions of joint attention, regardless of infant's degree of prematurity?*
2. *What is the effect of late prematurity and maternal interactive style on joint attention abilities at 12 months? Does the maternal interactive style moderate the adverse effects of prematurity on joint attention?*
3. *Does the infant's early vagal regulation influence their later joint attention abilities?*

Thus, this dissertation is composed of three papers.

Paper 1 was titled ***Effects of prematurity on infants' joint attention abilities: A meta-analytic study*** (cf. Chapter 2) and, to our knowledge, is the first meta-analysis conducted on studies investigating joint attention behaviors in premature infants. This paper combined and compared different studies in order to answer two specific research questions:

a) Do premature infants systematically differ from their full-term counterparts in several dimensions of joint attention, namely initiating joint attention, responding to joint attention, and joint attention episodes?
b) Does the effect of prematurity on joint attention depend on preterm infants' gestational age?

Paper 2 was titled ***Joint attention abilities at 12 months: Effects of late prematurity and maternal interactive style*** (cf. Chapter 3). This work was part of a larger longitudinal investigation assessing late preterm infants' development at several time points during infancy, at 6, 10, 12, and 15 months of chronological age. In addition, a sample of full term infants was also recruited and assessed at 10, 12, and 15 months of age. Paper 2 focused on the 12-month assessment and included those infants with complete data on joint attention and mother-infant interaction measures.

For this empirical study, our goals were threefold. Firstly, we intended to fill a gap in the literature by examining whether late preterm infants (born between 34 – < 37 weeks of gestation) would be impaired in their joint attention abilities, as demonstrated by previous studies with more severe prematurity. Secondly, we explored the contribution of two specific dimensions of maternal interactive behavior to infants' joint attention. Lastly, we aimed to investigate whether the quality of maternal behaviors would attenuate the negative effect of preterm birth on joint attention abilities. Thus, we could simultaneously assess joint attention skills in an understudied group of premature infants – late prematurity –, which accounts for the greater percentage of preterm birth, and uncover the extent of the positive impact of maternal interactive behaviors on infants' capacity for joint engagement. The specific research questions addressed in paper 2 were:

a) Does infant birth status – preterm vs. full term – predict joint attention behaviors at 12-months chronological age, in a sample of late preterm and full term infants?
b) Does the quality of specific maternal interactive styles – maintaining infant's focus of attention and appropriate mind-related comments – predict joint attention abilities?
c) Does the quality of the maternal interactive styles moderate the effect of birth status on concurrent responding to joint attention?

Two methodological features of this study are noteworthy. First, the standard practice of correcting age for prematurity (Wilson & Cradock, 2004), although compensating for the maturational disadvantage of preterm infants, may, at the same time, mask the real impact of the quality of mother-infant interaction. Thus, given that the sample was composed by late preterm and full terms infants, and by assessing all infants according to their chronological age, we assured that the time of interaction with their mothers would, approximately, be the same, and that, in turn, would enable us to disentangle the effects of the quality of maternal interactive behaviors from the maturational ones. In addition, the option for an infant-tester paradigm allowed for the measurement of infants' capacity for sharing attention independently of the influences of the social partner, and the analysis of the unique contributions of maternal interactive behaviors in explaining infant's inter-individual differences in joint engagement.

Paper 3 was titled ***Contributions of infant vagal regulation at one month to subsequent joint attention abilities*** (cf. Chapter 4). We investigated whether infants' vagal regulation, an indicator of individual physiological functioning, would be linked to joint attention abilities in interaction with the mother at 12 months. This study was part of an ongoing investigation conducted with healthy full term infants and constitutes an innovative approach on the study of joint attention skills. In this case, the assessment of typically developing infants would elucidate us on the contribution of autonomic functioning to joint attention development when undisturbed by biological immaturity. The following research questions guided our work:

a) Does infants' vagal response patterns at rest, assessed at one-month of age, contribute to their subsequent joint attention behaviors?
b) Does infants' vagal regulation to auditory stimuli, at one-month of age, relate to their subsequent joint attention behaviors?

In our view, this set of papers would provide valuable evidence and would help to uncover the effects of prematurity, quality of maternal behaviors, and infant physiological regulation on joint attention abilities, thus contributing for a more ecological perspective on the study of this important developmental milestone.

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CHAPTER 2

Effects of prematurity on infants' joint attention abilities: A meta-analytic study

Effects of prematurity on infants' joint attention abilities: A meta-analytic study[1]

Abstract

Several studies found preterm infants to be impaired in their ability to coordinate attention with a social partner regarding an object. The present meta-analysis aimed at investigating whether premature infants differ systematically from full-term infants in several dimensions of joint attention – Initiating Joint Attention, Responding to Joint Attention, and Joint Attention Episodes – and explore whether such differences are dependent on gestational age. Several bibliographic databases and repositories of dissertations and theses were searched from January 1970 to June 2016. Empirical studies were eligible if an observational measure was used to assess joint attention abilities from 9- to 24-months- corrected age and a full-term comparison group was included. The random-effects model revealed that, overall, the preterm group did not differ significantly from the full-term group across all joint attention dimensions. However, high heterogeneity was identified across studies. A differential effect emerged for responding and joint attention episodes when degree of prematurity was taken into account, indicating more impairments in specific preterm groups. Results suggest that distinct dimensions of joint attention may be differently influenced by prematurity. The role that environmental factors may play in the development of this important ability is discussed.

*Keywords***:** preterm infant; responding to joint attention; initiating joint attention; episode of joint attention; meta-analysis

[1] Submitted to *Social Development*

Introduction

Every year, one in 10 babies are born worldwide before completing 37 weeks of gestation, varying in gestational age and neonatal complications (March of Dimes, PMNCH, Save the Children, & WHO, 2012), rendering the group of preterm infants a very heterogeneous one. Still, the detrimental effects of prematurity on infant's subsequent development is well-established in the literature, being associated with higher risk of behavioral problems (de Jong, Verhoeven, & van Baar, 2012), poorer cognitive functioning (de Jong et al., 2012; McGowan, Alderdice, Holmes, & Johnston, 2011; Wolke et al., 2015), and decreased social abilities (Braarud et al., 2013; Crnic, Ragozin, Greenberg, Robinson, & Basham, 1983; Jones, Champion, & Woodward, 2013; Treyvaud et al., 2012; Wong, Huertas-Ceballos, Cowan, & Modi, 2014).

One important social-cognitive milestone believed to be impaired in premature infants is joint attention - defined as the ability to coordinate attention with a social partner regarding an external event or object (e.g., a toy) (Bakeman & Adamson, 1984). Emerging at around 9 months of age, this ability becomes increasingly frequent in infants' behavioral repertoires during the second year of life (Bakeman & Adamson, 1984; Carpenter, Nagell, & Tomasello, 1998), and has been linked to subsequent language acquisition (Colonnesi, Stams, Koster, & Noom, 2010; Morales et al., 2000; Mundy & Gomes, 1998; Tomasello & Farrar, 1986) and social competence (Sheinkopf, Mundy, Claussen, & Willoughby, 2004; Vaughan van Hecke et al., 2007).

Two types of joint attention behaviors are often assessed: a) initiating joint attention – which regards the infants' spontaneous attempts to direct the adult's attention (e.g., showing and pointing gestures); and b) responding to joint attention – infants' response to adult bids for joint attention (e.g., following eye gaze or pointing gestures) (e.g., Mundy et al., 2007; Osório, Martins, Meins, Martins, & Soares, 2011). On the other hand, some authors investigate joint engagement in terms of episodes of shared attentional focus regardless of whom initiated it, requiring the infant to alternate their gaze between the adult and the object at some point during the episode (e.g., Bakeman & Adamson, 1984; Gaffan, Martins, Healy, & Murray, 2010).

The literature investigating joint attention abilities in preterm infants presents mixed results. Whereas some studies point to significantly lower levels of joint attention in preterm compared to full-term infants (e.g., Kmita, Kiepura, & Majos, 2014; Olafsen et al., 2006; Sansavini et al., 2015; Garner, Landry, & Richardson, 1991), others reported no differences between the two groups (e.g., De Schuymer, De Groote, Beyers, Striano, & Roeyers, 2011; Suttora & Salerni, 2012), or the pattern of results varied across different measures of joint attention (e.g., Rowell, 2014; Sperotto, 2015;

Steelman, Assel, Swank, Smith, & Landry, 2002). Despite general agreement on the deleterious effects of prematurity on social development, the case for a specific effect on infant joint attention remains unclear. Degree of prematurity, age of testing, assessment paradigm, and even type of joint attention behaviors assessed, varied greatly across studies. The present meta-analytic study aims to combine and compare different studies in order to investigate whether premature infants systematically differ from their full-term counterparts in joint attention abilities. Empirical evidence suggests that different joint attention dimensions may reflect common, but also unique aspects of the social experience, probably involving distinct patterns of brain activation and expressing specific mental processes (Mundy et al., 2007; Mundy, Card, & Fox, 2000). Thus, effect sizes were computed and analyzed separately for each joint attention dimension: Responding to Joint Attention bids (RJA), Initiating Joint Attention (IJA), and Joint Attention Episodes (JAE). Additionally, given the heterogeneity within the group of premature infants, we explored whether the results would vary according to the mean gestational age of the preterm infants in each study – extremely preterm (<28 weeks), very preterm (28 - <32 weeks), moderate preterm (32 - <34 weeks), and late preterm (34 - <37 weeks) (March of Dimes et al., 2012).

Method

The present meta-analysis followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Moher, Liberati, Tetzlaff, Altman, & The PRISMA Group, 2009).

Search strategy

The literature search was conducted in several bibliographic databases (Academic Search Complete, Medline, PsycARTICLES, PsycINFO, Pubmed, Scielo, SCOPUS, and Web of Science) and repositories of dissertations (Networked Digital Library of Theses and Dissertations, Open Access Theses and Dissertations, OpenAIRE, ProQuest, and RCCAP), using the following keywords related to joint attention – "joint attention", "shared attention", "coordinat* attention", "joint engagement", "triadic interaction", "nonverbal communication", "gaze following", "social skills", "soci* communication skills", and "soci* cognitive skills" – combined with terms related to prematurity – (preterm OR premat*). All the terms were used in English and searches were carried out in July 2016.

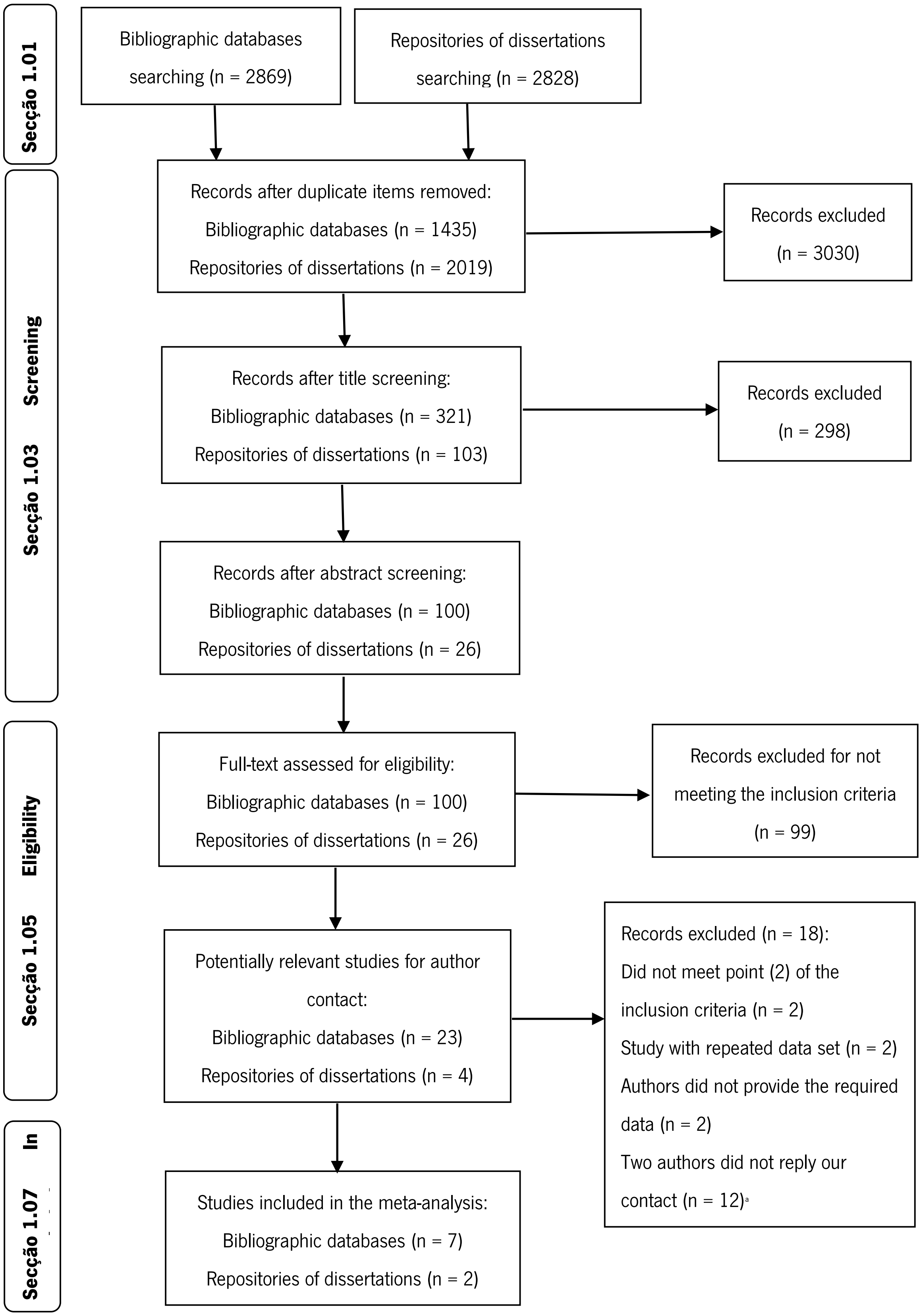

Figure 1A. *Meta-analysis search flowchart*

[a]One of the authors accounted for 11 records, possibly representing two to three independent data sets.

As shown in Figure 1A, search strategy included several sequential steps until the final sample of studies was reached. An initial list of 5697 records resulted from the search performed in the electronic databases (n = 2869) and repositories of dissertations and theses (n = 2828). Subsequently, 2243 items were removed due to duplication in the different databases. After screening the remaining 3454 on basis of title and abstract, 126 full-text (100 in bibliographic databases and 26 in repositories) were retained to determine whether the inclusion criteria were met. Twenty-seven (23 in bibliographic databases and 4 in repositories) were identified as potentially relevant. If needed, their authors were contacted for further clarification and/or additional information. Eighteen records were excluded for several reasons, namely not meeting the inclusion criteria after author's clarification (n = 2), repeated data set (n = 2), insufficient information provided by the authors and in the full-text document (n = 2), and no reply to our contact (n = 12) (one of the authors accounted for 11 records, possibly corresponding to two to three independent data sets). Thus, a final set of nine independent studies, seven from bibliographic databases and two unpublished dissertations, were obtained and are described in Table 1A.

Study selection

In order to be included in the meta-analysis, studies should meet the following criteria: (1) empirical study published between January 1970 and June 2016; (2) joint attention defined as the infant being actively involved with and coordinating his or her attention to both social partner and object of interest, by looking back and forth between the adult's face and the object (Bakeman & Adamson, 1984); (3) joint attention abilities assessed through observational measures, using a tester-infant or caregiver-infant paradigm, and coded in terms of frequency of joint attention behaviors or duration/ frequency of joint attention episodes; (4) birth before 37 weeks of gestation; (5) joint attention assessed between 9 and 24 months of age corrected for prematurity; (6) inclusion of a full-term comparison group.

Studies were excluded if (1) infants had received a diagnosis of developmental problems (e.g., cerebral palsy); (2) they reported intervention programs without preterm control group or pretest measure of joint attention; and (3) rating scales were used to assess joint attention abilities.

Coding procedure

All the included studies were coded for (a) study descriptors (e.g., authors, year of publication, title), (b) sample characteristics (e.g., sample size, gestational age, age of assessment of joint attention abilities), and (c) methodology (e.g., design, paradigm and task used to assess joint attention, types of joint attention behaviors that were measured) (cf. Table 1A).

Data Analyses

Authors provided raw data on joint attention variables (means, SDs and sample size) and the analyses were performed using the Comprehensive Meta-Analysis version 2 software (Borenstein, Hedges, Higgins, & Rothstein, 2005). A combined mean effect size was computed separately for Initiating Joint Attention (IJA), Responding to Joint Attention bids (RJA), and Joint Attention Episodes (JAE), the latter being considered whenever the authors did not code who the initiator of the episode was (the adult or the infant) or did not specify whether the dimension assessed was a response or an initiation of joint attention.

The random-effects model was used to generate each study's and the combined effect sizes (Hedges' g). By assuming that the effect sizes may vary across studies as a result of different methodologies and population variability, the random-effects model incorporates both the within- and between-study variance. Additionally, the computation of a weighted mean, by assigning a weight to each study through the inverse-variance method, allows for a more precise estimate of the overall mean effect size (Borenstein, Hedges, Higgins, & Rothstein, 2009; Card, 2012).

Heterogeneity among the effect sizes was assessed through the Q tests and I^2 index. While the former examines whether the set of effect sizes in the meta-analysis are heterogeneous, the latter reflects the amount of variation across studies that is due to true heterogeneity (Borenstein et al., 2009). Finally, and even though unpublished studies were included in this meta-analysis, two analyses were used to deal with the publication bias: (i) the Rosenthal's (1979) fail-safe number, which calculates how many studies with an effect size of zero would be required so that the overall mean effect size would become non-significant; and (ii) the Egger and colleagues' (1997) regression test, which measures the funnel plot asymmetry.

Table 1A. *Studies Included in the Meta-Analysis*

Study	Country	N	Mean gestational age (weeks)	Mean Age at testing (months)[d]	Procedure of assessment	Joint Attention variable
Borsato, 2010[a]	Brazil	17 PT 21 FT	PT: 32.37 FT: 38.70	PT: 13 FT: 14.08	ESCS	IJA, RJA
De Schuymer, De Groote, Beyers, Striano, & Roeyers, 2011	Belgium	25 PT 30 FT	PT: 29.44 FT: 40.09	PT: 9.02 / 14.34[e] FT: 9.12 / 14.03	Modified still face procedure / ESCS[e]	JAE, IJA, RJA
Fasolo, D'Odorico, Constantini, & Cassibba, 2010	Italy	18 PT 18 FT	PT: 29.50 FT: 39.40	PT: 14.10 FT:14.11	Toy play with the mother	JAE
Gueron-Sela, Atzaba-Poria, Meiri, & Marks, 2015	Israel	81 PT 62 FT	PT: 32 FT: 39	PT: 11.80 FT: 11.70	ESCS	IJA, RJA
Kmita, Kiepura, & Majos, 2014	Poland	37 PT 22 FT	PT: 29.38 FT: 39.50	PT: 12.76 FT: 12.52	Toy play with the father	JAE
Olafsen, Ronning, Kaaresen, Ulvund, Handegard, & Dahl, 2006	Norway	66 PT 70 FT	PT: 30 FT: 39.30	PT: 12.25 FT: 12.21	ESCS	IJA, RJA
Sansavini, Zavagli, Guarini, Savini, Alessandroni, & Faldella, 2015	Italy	20 PT 20 FT	PT: 25.80 FT: 39.60	PT: 12.20 FT: 12.20	Toy play with the mother	JAE
Sperotto, 2015[a b]	UK	40 PT 65 FT	PT: 34.27 FT: 39.95	PT: 11.96 FT: 13.21	ESCS	IJA, RJA
Suttora & Salerni, 2012[c]	Italy	16 PT 15 FT	PT: 30 FT: n.a.	PT: 12.08 FT: 12.04	Toy play with the mother	JAE

Note: PT = Preterm group; FT = Full-term group; IJA = Initiating Joint Attention; RJA = Responding to Joint Attention; JAE = Joint Attention Episodes; ESCS = Early Social Communication Scales (Mundy et al., 2003). n.a. = information not available. [a]Unpublished dissertation; [b]The 13-months data was used due to close temporal proximity to the mean age of assessment of the remaining studies. [c] The 12-months data was used due to close temporal proximity to the mean age of assessment of the remaining studies. [d]All but two studies (Borsato, 2010 and Sperotto, 2015) adopted corrected age at testing. The authors of the two exceptions provided the needed information upon request. [e]Mean age/ procedure of assessment at 9- and 14-months assessment, respectively.

Results

The present meta-analysis was based on data from 323 full-term infants and 320 preterm infants (Table 1A). The mean gestational age of the premature infants was 30.31 weeks (*SD* = 2.39), whereas the full-term group was born, on average, at 39.44 weeks (*SD* = 0.46) (information available for eight studies). The mean age of the participants at the assessment was between 11 and 14 months, age corrected for prematurity (one study reported an additional measure of joint attention at 9 months). For the assessment of joint attention, five studies used an infant-tester paradigm, the Early Social Communication Scales (ESCS; Mundy et al., 2003), while the remaining opted for an infant-caregiver interaction (three with the mother and one with the father).

Fifteen effect sizes could be computed as follows: five effect sizes for IJA, five for RJA, and five for JAE. A positive effect size would favor the preterm group.

Regarding IJA, the combined mean effect was Hedges' $g = 0.001$ (95% CI: - 0.40 to 0.41; $z = 0.005$; $p = .996$), indicating no significant differences between the two groups (Figure 2A). The statistics of the heterogeneity analysis confirmed a high variation in the effect sizes across the studies ($Q = 17.57$; $I^2 = 77.24$; $p = .001$).

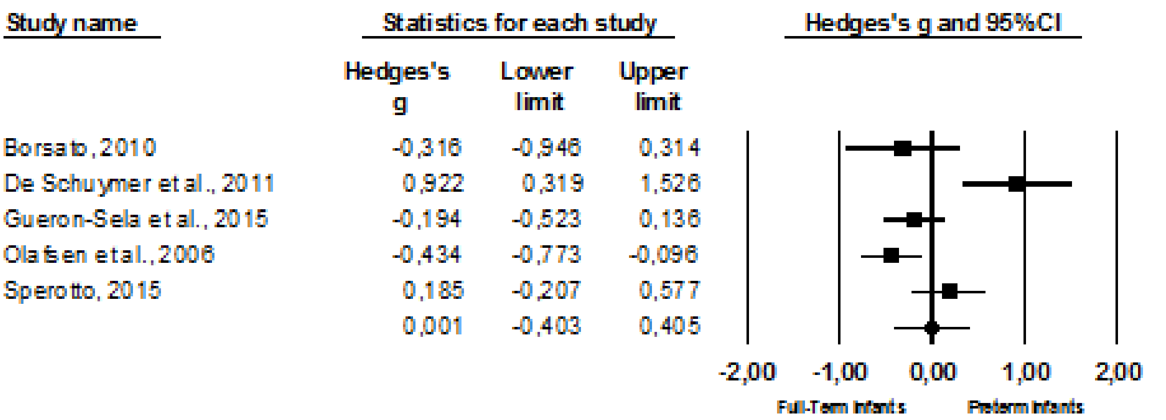

Figure 2A. *Difference between preterm and full-term groups in Initiating Joint Attention (IJA)*

Similarly, the combined mean effect for RJA did not reveal any statistically significant differences between preterm and full-term infants (Hedges' $g = -0.411$; 95% CI: - 0.93 to 0.10; $z = -1.567$; $p = .117$) (Figure 3A). The distribution of the effect sizes was also heterogeneous ($Q = 26.53$; $I^2 = 84.92$; $p < .001$).

Study name	Hedges's g	Lower limit	Upper limit
Borsato, 2010	0,439	-0,195	1,073
De Schuymer et al., 2011	-0,222	-0,818	0,375
Gueron-Sela et al., 2015	-0,120	-0,451	0,210
Olafsen et al., 2006	-0,814	-1,162	-0,465
Sperotto, 2015	-1,208	-1,667	-0,749
	-0,411	-0,926	0,103

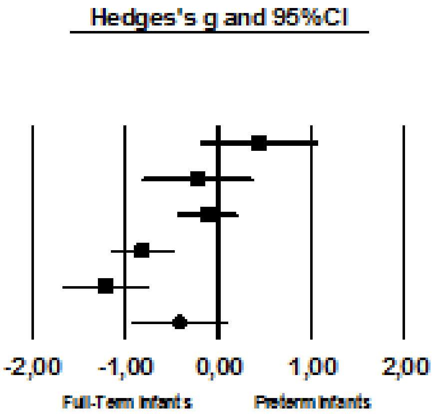

Figure 3A. *Difference between preterm and full-term groups in Responding to Joint Attention (RJA)*

Finally, among the studies used to compute the summary effect size for JAE episodes, one study ((De Schuymer et al., 2011) assessed the duration of the episodes in seconds whereas the remaining measured the frequency of episodes. The analyses were run with and without that study included. As the results did not differ, we opted for reporting the combined mean effect generated from the five studies. Thus, the overall mean effect size was Hedges' g = - 0.343 (95% CI: - 0.77 to 0.09; z = - 1.565; p = .118), indicating no significant differences between preterm and full-term comparison group in this dimension of joint attention (Figure 4A). Again, the heterogeneity test showed significant variation between the effect sizes of the studies (Q = 10.16; I^2 = 60.62; p = .038).

Study name	Hedges's g	Lower limit	Upper limit
De Schuymer et al., 2011	-0,486	-1,017	0,045
Fasolo et al., 2010	-0,075	-0,714	0,564
Kmita et al., 2014	-0,590	-1,122	-0,059
Sansavini et al., 2015	-0,920	-1,561	-0,280
Suttora & Salerni, 2012	0,475	-0,221	1,171
	-0,343	-0,772	0,086

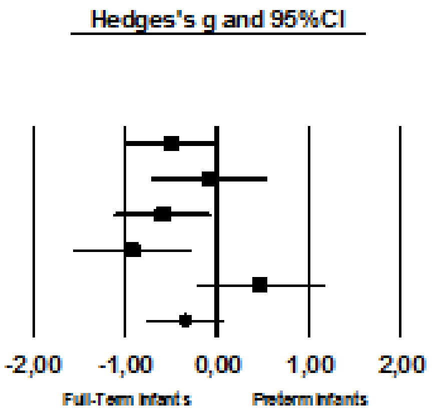

Figure 4A. *Difference between preterm and full-term groups in Joint Attention Episodes (JAE)*

Since the overall mean effect size for the three dimensions of joint attention did not reach statistical significance, the fail-safe number analysis became irrelevant. On the other hand, Egger and colleagues' (1997) regression test suggested no evidence of publication bias for any of the joint attention variables.

Table 2A presents the group analysis when each individual study was assigned to one of four groups – extremely preterm (mean GA < 28 weeks), very preterm (mean GA between 28 - <32 weeks), moderate preterm (mean GA between 32 - <34 weeks) or late preterm infants (mean GA between 34 - <37 weeks) – according to the mean gestational age at birth of their preterm sample. Although with a small sample size of studies allocated to each group according to degree of prematurity, by comparing each group of preterm infants to their full-term peers, we attempted to explore how different degrees of prematurity may affect the expression of the assessed joint attention variables.

Table 2A. *Effect size for joint attention variables according to preterm infants' mean gestational age*

Gestational age	IJA	RJA	JAE
Extremely preterm (< 28 weeks) Sansavini et al., 2015	—	—	- 0.92**
Very preterm (28 - < 32 weeks) [a]De Schuymer et al., 2011; Olafsen et al., 2006 [b]De Schuymer et al., 2011; Fasolo et al., 2010; Kmita et al., 2014; Suttora & Salerni, 2012.	0.22[a]	- 0.57[+ a]	- 0.21[b]
Moderate preterm (32 - < 34 weeks) Borsato, 2010; Gueron-Sela et al., 2015	- 0.22	0.09	—
Late preterm (34 - < 37 weeks) Sperotto, 2015	0.19	- 1.21***	—

[+] $p < .10$; ** $p < .01$; *** $p < .001$.

Note: IJA = Initiating Joint Attention; RJA = Responding to Joint Attention; JAE = Joint Attention Episodes

For IJA, no significant effect sizes were found in all three groups: very preterm (Hedges' g = 0.220; 95% CI: - 1.11 to 1.55; z = 0.325; p = .745), moderate preterm (Hedges' g = - 0.220; 95% CI: - 0.51 to 0.07; z = - 1.476; p = .140), and late preterm infants (Hedges' g = 0.185; 95% CI: - 0.21 to 0.58; z = 0.926; p = .354), when compared to their full-term counterparts.

On the other hand, regarding RJA, and in comparison with the full-term group, very preterm group presented marginally lower levels of responding to adult's bids (Hedges' g = - 0.569; 95% CI: - 1.14 to 0.002; z = - 1.955; p = .051), no difference was obtained for the group of moderate preterm infants (Hedges' g = 0.091; 95% CI: - 0.44 to 0.62; z = 0.337; p = .736), and, finally, the late preterm group also displayed significantly lower levels of response to joint attention bids (Hedges' g = - 1.208; 95% CI: - 1.67 to - 0.75; z = - 5.156; p < .001).

In what concerns JAE episodes, only the extremely preterm group revealed a statistically significant effect (Hedges' g = - 0.920; 95% CI: - 1.56 to - 0.28; z = - 2.819; p = .005) when compared to full-term infants, with no differences found in the case of very preterm infants (Hedges' g = - 0.212; 95% CI: - 0.66 to 0.24; z = - 0.929; p = .353).

Discussion

The present meta-analytic study aimed at investigating whether premature infants differ from their full-term counterparts across different dimensions of joint attention – initiating joint attention, responding to joint attention, and episodes of joint attention. Overall, our results revealed no evidence of significant differences between the two groups of infants when the preterm group was analyzed as a whole. However, and despite the small number of studies included, we sought to identify if any specific trends emerged when the degree of prematurity was considered (following the classification by the March of Dimes et al., 2012). Thus, some tentative conclusions could be drawn, with initiating joint attention behaviors remaining unaffected by prematurity, whereas responding to joint attention was impaired in the very preterm and late preterm groups compared to their full-term counterparts. Similarly, preterm birth had a negative effect on joint attention episodes but only for the extremely preterm group, the most immature group among the preterm population. Despite the sample size of studies used in this analysis, we believe it is worthwhile to present these preliminary findings that may help us to develop explanatory hypotheses about the effects of preterm birth on joint attention skills, which, in turn, may guide future research.

As Tomasello (1995) stated, joint attention does not consist of a simple "*geometric phenomenon concerning two lines of visual orientation*" nor "*simply a psychological phenomenon concerning two foci of visual attention*" (p. 106). Instead, as a social-cognitive milestone, joint attention involves two social partners coordinating their attention to a common object of interest and showing their knowledge of the other's focus of attention by means of gaze alternation between the partner and the object (Bakeman & Adamson, 1984; Tomasello, 1995). This growing understanding of the intentionality of others and their own actions manifests itself in different types of joint attention behaviors – the infant's ability to detect and follow the direction of an adult's attention, also known as responding to joint attention, and the infant's spontaneous initiatives to share social experience by directing their partner's attention, referred to as initiating joint attention (Mundy & Newell, 2007).

Empirical evidence suggests that these different behavioral dimensions of joint attention may recruit distinct areas of the cerebral cortex and reflect specific mental processes (Mundy et al., 2007; Mundy et al., 2000), which may help explain the trend for a non-linear impact of the degree of prematurity across the different joint attention measures analyzed. Thus, we argue that preterm birth, per se, does not necessarily place infants at risk for joint attention impairments, but specific dimensions of joint attention may be particularly vulnerable to varying degrees of prematurity, as found for responding to joint attention bids and episodes of joint attention. Although not directly investigated in the present study, it is possible that some environmental influences – such as the quality of parenting behaviors – may outweigh the impact of birth status or, at least, mitigate the unfavorable impact of prematurity.

Initiating joint attention (IJA) has been associated with greater frontal activity (Caplan et al., 1993; Henderson, Yoder, Yale, & McDuffie, 2002; Mundy et al., 2000), which may reflect the functioning of an anterior attention system network (Posner & Petersen, 1990) involving more volitional, executive, and motivational processes (Mundy & Newell, 2007; Rothbart, Posner, & Rosicky, 1994; Stuss, Shallice, Alexander, & Picton, 1995). Therefore, IJA may be strongly influenced by the quality of the sharing experience, in terms of positive affect (Kasari, Sigman, Mundy, & Yirmiya, 1990; Mundy, Kasari, & Sigman, 1992), the reward value of the social stimuli (Nichols, Fox, & Mundy, 2005), and parenting behaviors (Claussen, Mundy, Mallik, & Willoughby, 2002; Gaffan et al., 2010; Meins et al., 2011; Osório et al., 2011; Siller & Sigman, 2002). Indeed, positive and responsive maternal behaviors have been related to preterm infants' better outcomes in the cognitive and social domains (Landry, Smith, Miller-Loncar, & Swank, 1997; Landry, Smith, & Swank, 2006; Treyvaud et al., 2009). Particularly regarding joint attention, Olafsen and colleagues (2006) investigated whether an early intervention targeting parental sensitivity to the infant's cues and readiness for interaction, as well as appropriate and contingent response to those cues, would enhance infants' later capacity for coordinated attention. The authors observed that premature infants whose parents participated in the intervention displayed more IJA behaviors than premature control infants, whose parents did not participate in the intervention program, exhibiting similar levels to those obtained by their full-term counterparts. In addition, a recent meta-analysis by Bilgin and Wolke (2015) concluded that mothers of preterm infants do not differ significantly from mothers of full-term in their parenting behaviors. The aforementioned evidence, combined with our own results in this study, offer support to our argument that quality of parent-infant daily interactions – but not infants' birth status – provides the foundation for an adaptive development of initiating joint attention abilities in preterm infants.

Contrastingly, responding to joint attention (RJA) has been related to the activation of temporal and parietal brain areas (Itier & Batty, 2009; Mundy et al., 2000), possibly reflecting the influence of the posterior attention network (Posner & Petersen, 1990), which serves the perception of a stimulus, spatial location encoding, orienting of attention to specific locations, disengagement and shifting of attention between stimuli (Mundy & Newell, 2007; Rothbart et al., 1994). Responding to bids for joint attention requires not only that the infant be able to detect the adult's focus of attention in the environment and follow their eyes and head orientation, but also be capable of successive engagement, disengagement and shifts of attention between distinct targets. Premature infants appear to be less efficient in orienting, disengaging and shifting their attention (Weijer-Bergsma, Wijnroks, & Jongmans, 2008). Previous studies found that preterm displayed shorter fixation times on social stimuli (Telford et al., 2016), longer gaze durations, less frequent and slower shift rates between stimuli (Rose, Feldman, & Jankowski, 2001; 2009), when compared to full-term infants, suggesting less mature attention skills. Complementary evidence derives from results of previous studies that highlighted the importance of combined gestures (e.g., looking, pointing, and verbalizing), execution of the gesture, object location, and presence of distractors for successful visual attention following (Deák, Flom, & Pick, 2000; Flom, Deák, Phill, & Pick, 2004). Perhaps, preterm infants need more noticeable and redundant cues in order to detect and follow their partner's focus of attention. Finally, as opposed to IJA, Olafsen and colleagues (2006) did not find an intervention effect on preterm infant's responding to joint attention bids, reinforcing the assumption of distinct sources of influence for these two dimensions of joint attention, and, therefore, a possible differential impact of biological and environmental conditions.

In turn, episodes of joint attention, where both partners are attending to the same focus regardless of who initiated it, are commonly assessed in infant-caregiver interaction paradigms and reflect the contribution of the relational context in which the joint attention episode emerges (Mundy & Sigman, 2006). Due to infant young age, adult behavior may play a crucial role in the maintenance of the joint engagement episode. Several studies emphasized how an adult interactive style characterized by higher levels of sensitivity, following infant's focus of interest, and less intrusive behaviors, promotes infant coordinated attention (Gaffan et al., 2010; Hobson, Patrick, Crandell, Pérez, & Lee, 2004; Legerstee, Markova, & Fisher, 2007; Mendive, Bornstein, & Sebastián, 2013; Raver & Leadbeater, 1995). However, the lower the gestational age, the higher the risk of more severe medical complications and developmental problems (March of Dimes et al., 2012), which may explain the result found for the extremely preterm group. Apart from the poorer interactive behaviors (Crnic et al., 1983; Korja et al., 2008), negative affect and lack of clarity of cues (Eckerman, Hsu, Molitor, Leung, & Goldstein, 1999) that seem to characterize preterm infants in general, extremely preterm infants show greater emotional and behavioral difficulties, compared to their very preterm peers (Clark, Woodward, Horwood, & Moor, 2008; Maclean, Erickson, & Lowe, 2009). Consequently, such regulatory problems may render the extremely premature infants a more challenging social partner among the preterm group.

The results of the present meta-analysis contributed to a more comprehensive view of the joint attention abilities of premature infants – a group at higher risk of developing social-emotional problems – and how preterm birth may impact on the developmental course of such abilities. It may be the case that birth status (premature versus term) matters for specific dimensions of joint attention, but what happens next in the extra-uterine environment and how parents facilitate and promote their infant's engagement in social interaction may help to explain the interindividual differences among the preterm group. Thus, future studies could simultaneously address parental variables, such as sensitivity or attention-directing strategies, so as to test the hypothesis that quality of parent-infant interaction may compensate the negative effect of prematurity in joint attention skills.

Another point that requires further investigation is the development of joint attention in late preterm infants. With one notable exception (Sperotto, 2015), all studies have focused on premature infants with gestational ages lower than 34 weeks. Although near term, late preterm infants are still at risk for subsequent developmental problems (Kugelman & Colin, 2013). Compared to their full-term peers, late preterm infants tend to exhibit worse cognitive performance (Baron, Erickson, Ahronovich, Baker, & Litman, 2011; Talge et al., 2010; Woythaler, McCormick, & Smith, 2011) and increased risk of social-emotional problems (Stene-Larsen, Lang, Landolt, Latal, & Vollrath, 2016; Talge et al., 2010; Voegtline, Stifter, & The Family Life Project Investigators, 2010). Nevertheless, the development of joint attention abilities in late preterm infants remains largely unknown, as well as the potential contribution of joint attention for subsequent social outcomes in this preterm group.

A final suggestion for future research consists of replicating this meta-analysis and including more studies that could better capture the heterogeneity of the preterm population. Unfortunately, several studies could not be included in our meta-analysis due to the aforementioned reasons (possibly representing five to six independent data sets), which we believe would have clarified and strengthened our results that were based on nine independent studies. Particularly, when the analyses were run according to preterm infants' gestational age, three effects size (one for the extremely preterm group and two for the late preterm group) were based on a single data set. Therefore, it is uncertain whether the results found were due to specificities of that preterm sample or, indeed, reflect a true proclivity of that population in joint attention skills.

Concluding, the present meta-analytic study fills a gap in the literature and provides some provisional evidence of the differential effect premature birth may have across different dimensions of joint attention. Simultaneously, our results have important implications for the design of early interventions fostering the development of premature infants and parenting behaviors. The well-established link of joint attention as precursor of subsequent language ability and social competence, combined with an increased risk of socio-emotional problems in premature infants, make this a relevant social-cognitive milestone to be targeted in future intervention programs for premature infants.

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CHAPTER 3

Joint attention abilities at 12 months: Effects of late prematurity and maternal interactive style

Joint attention abilities at 12 months: Effects of late prematurity and maternal interactive style[2]

Abstract

Joint attention is believed to be impaired in premature infants, especially high-risk preterm infants, with low birth weight and/or neonatal complications. Yet, less is known about the development of this important milestone in late preterm infants. This study aimed: a) to investigate whether infant birth status (late preterm vs. full term) and maternal interactive style predict joint attention abilities, and b) to explore whether a possible detrimental effect of late prematurity on joint attention is moderated by the quality of maternal interactive style, previously shown to promote infant's capacity to share visual attention. Participants were 21 late preterm and 24 full term infants, and their mothers, assessed at 12-months chronological age. Mothers' behaviors aimed at maintaining their infants' focus of attention as well as her use of appropriate mind-related comments were assessed in a free toy-play mother-infant interaction. The Early Social Communication Scales (Mundy et al., 2003) were used to measure joint attention abilities in terms of initiating joint attention and responding to joint attention. Results showed that birth status predicted infants' responding to joint attention, with late preterm infants presenting significantly lower levels of correct responses. Maternal behaviors did not directly influence joint attention skills, or moderate the effect of prematurity. In addition, infant sex also predicted responding to joint attention, with girls significantly outperforming boys. Results are discussed in terms of the mental processes involved in different behavioral dimensions of joint attention and how these may (or may not) be affected by preterm birth.

Key words: late prematurity; initiating joint attention; responding to joint attention; maternal interactive style; moderation effect.

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Introduction

The last quarter of the first year of life is characterized by significant changes in infants' understanding of the social world. From dyadic interactions (infant – object or infant – another person), infants are increasingly capable of engaging in triadic interactions (infant – object – another person), in which they begin to perceive themselves and others as intentional agents, who may have an intentional and attentional agenda different from their own and behave accordingly (Carpendale & Lewis, 2004; Tomasello, 1995).

These earlier signs of comprehension of intentionality may be evinced by joint attention, or the infant's ability to coordinate attention with a social partner regarding an external object/event (e.g., a toy) (Bakeman & Adamson, 1984; Tomasello, 1995). Prior to linguistic development, joint attention is mostly based on nonverbal communicative acts and may be manifested in terms of two main types of behaviors: infants' spontaneous initiatives to direct others' attention by means of eye contact, pointing and showing gestures – commonly referred to as Initiating Joint Attention (IJA) – and infants' following of others' gaze or pointing gestures – also known as Responding to Joint Attention (RJA) (Carpenter, Nagell, & Tomasello, 1998; Mundy et al., 2007; Mundy et al., 2003). Thus, infants are aware that they may influence the behavior of others – who might have a different focus of interest – by redirecting their attention, and they are also capable of recognizing the same intention in others' actions. The link between this important socio-cognitive milestone and subsequent developmental outcomes is well-documented in the literature, namely its association with language acquisition (e.g., Colonnesi, Stams, Koster, & Noom, 2010; Mundy & Gomes, 1998; Tomasello & Farrar, 1986), social competence (e.g., Sheinkopf, Mundy, Claussen, & Willoughby, 2004; Vaughan van Hecke et al., 2007), and Theory of Mind (Charman et al., 2000; Nelson, Adamson, & Bakeman, 2008; Sodian & Kristen-Antonow, 2015).

The development of joint attention has been widely studied in typically developing infants (e.g., Gaffan, Martins, Healy, & Murray, 2010; Osório, Martins, Meins, Martins, & Soares, 2011; Vaughan van Hecke et al., 2007) and populations with neurodevelopmental disorders, as the case of Autism Spectrum Disorder (ASD) (e.g., Dawson et al., 2004; Mundy, Sigman, & Kasari, 1990). Concurrently, another line of research has focused on samples with biological risk, namely infants born prematurely (e.g., De Groote, Roeyers, & Warreyn, 2006; Olafsen et al., 2006; Smith & Ulvund, 2003). In this regard, there is evidence that joint attention capacities are compromised in premature infants, compared to their full-term counterparts (e.g., Garner, Landry, & Richardson, 1991; Kmita, Kiepura, & Majos, 2014; Landry, 1995; Olafsen et al., 2006), especially high-risk preterm (e.g., birth weight <

1600g, neonatal complications). Thus, premature low birth weight infants with severe early medical complications have significantly more difficulties in engaging in joint attention throughout infancy (e.g., Garner et al., 1991; Landry, 1995). However, some previous investigations have found no significant differences (De Schuymer, De Groote, Beyers, Striano, & Roeyers, 2011; Suttora & Salerni, 2012), or impairments only in specific joint attention behaviors/dimensions (Borsato, 2010; Rowell, 2014; Sperotto, 2015; Steelman, Assel, Swank, Smith, & Landry, 2002). For example, preterm birth may negatively affect infants' ability to follow the direction of others' gaze or pointing gestures but not their initiating joint attention behaviors (Rowell, 2014; Sperotto, 2015), or the inverse pattern (Borsato, 2010). Additionally, some indicators of joint attention (e.g., eye contact with the social partner) may be compromised in premature infants, whereas other behaviors (e.g., gaze following) show no effect of birth status (Steelman et al., 2002). Taken together, empirical findings are mixed and may suggest a differential impact of preterm birth on distinct behavioral dimensions of joint attention, as well as a possible dependence on characteristics of the preterm infants, such as degree of prematurity, birth weight, and/or concomitant medical complications. A common feature among the studies described was the tendency to focus mainly on more premature infants, such that preterm group mean gestational age across almost all studies was lower than 32 weeks of complete gestation, or, in some cases, to adopt a dual criteria of simultaneous low birth weight (Garner et al., 1991; Olafsen et al., 2006; Rowell, 2014; Steelman et al., 2002).

Indeed, a clear caveat in the existing literature is the lack of studies investigating the development of joint attention in late preterm infants. A notable exception is Sperotto's study (2015) that examined joint attention at 13 and 18 months of chronological age, in premature infants born between 30 and less than 37 weeks of completed gestation, therefore including mostly moderately and late preterm infants. Results showed that preterm infants presented significantly lower levels of responding to joint attention than their full term peers, but similar levels of initiating joint attention behaviors. Although near term, late preterm infants (born between 34 and < 37 weeks) (March of Dimes, PMNCH, Save the Children, & WHO, 2012) are still at risk for sub-optimal outcomes comparatively to their full term counterparts (Kugelman & Colin, 2013), namely in terms of cognitive performance (e.g., Baron, Erickson, Ahronovich, Baker, & Litman, 2011; Woythaler, McCormick, & Smith, 2011), and social-emotional problems (Stene-Larsen, Lang, Landolt, Latal, & Vollrath, 2016; Talge et al., 2010). Therefore, joint attention is a relevant ability to be investigated in late preterm infants, and to explore the variables that may promote its development among this specific group. Furthermore, the fact that late preterm infants come into the world a few weeks earlier than expected entails a series of potential risks, but also the opportunity to benefit sooner from the influence of environmental factors, particularly the caregiving environment.

Mother-infant interactions seem to provide an extremely relevant social context that supports the emergence of infant's capacity to share attention (e.g., Bakeman & Adamson, 1984; Gaffan et al., 2010). In general, empirical evidence suggests that a maternal positive interactive style characterized by higher levels of sensitivity, lower interference with the infant's ongoing activities, appropriate guidance, and following of infant's focus of interest seem to promote better joint attention abilities in infancy (Fadda & Lucarelli, 2017; Gaffan et al., 2010; Hobson, Patrick, Crandell, Pérez, & Lee, 2004; Legerstee, Markova, & Fisher, 2007; Mendive, Bornstein, & Sebastián, 2013; Olafsen et al., 2006; Osório et al., 2011; Vaughan et al., 2003). Indeed, when interacting with their infants, mothers frequently use several verbal and non-verbal strategies (e.g., pointing, toys demonstrations, verbal requests) to facilitate the infant's involvement and sustain their interest and attention in the activities (Rocissano & Yatchmink, 1983). However, in some cases, these maternal behaviors may pose substantial attentional demands that make it difficult for the infant to respond appropriately, especially if preterm (Landry, 1995). In this regard, attempts to maintain the infant's current focus of attention/interest seem to be more effective as they require less attentional effort from the infant, as opposed to a more intrusive interactive style that shifts the infant's attention away from the object he/she is already engaged with to a new focus of interest (Landry, 1995; Landry & Chapieski, 1989; Landry, Chapieski, & Schmidt, 1986). Mothers' attention-directing strategies – particularly those aimed at maintaining the infant's focus of attention – have been related to enhanced infant responsiveness and initiation in social interactions (Landry, Smith, Miller-Loncar, & Swank, 1997, 1998; Landry, Smith, Swank, & Miller-Loncar, 2000). There is even evidence for an important effect in premature infants, as higher levels of maintaining predicted greater increases in social initiating in preterm infants compared to their full term peers (Landry et al., 1997, 1998). Specifically regarding joint attention, Mendive and colleagues (2013) observed, in dyads with a typically developing infant, that episodes of coordinated attention were more likely to be preceded by mothers' strategies that maintained their infant's focus of interest rather than any other attention directing strategy.

While the role of maternal behaviors on infant joint attention has received significant attention from researchers, the contribution of maternal speech remains less explored. One such relevant variable may be mind-mindedness, i.e., the mother's proclivity to not only treat her infant as an individual with a mind, but also to make accurate and appropriate comments on their mental states (e.g., emotions, thoughts, desires) (Meins, Fernyhough, Fradley, & Tuckey, 2001; Meins et al., 2002).

We expect that when mothers perceive their infants as an individual with a mind, who may have intentions and interests of his/her own, they will be more likely to recognize their infants' focus of attention (especially when different from their own) and behave sensitively, thus promoting joint engagement. Whereas maternal mind-mindedness predicts children's understanding of others' minds during preschool years (Adrián, Clemente, & Villanueva, 2007; Meins et al., 2003; Meins et al., 2002; Ruffman, Slade, & Crowe, 2002), evidence of an earlier contribution to joint attention abilities is still scarce and somewhat inconsistent. One study reported no significant associations between mothers' use of mental state talk (e.g., volition, cognition, disposition) and infant's joint attention gestures (e.g., pointing, showing, offering) (Slaughter, Peterson, & Carpenter, 2009). Yet, another investigation found that mothers' references to their infants' internal states (e.g., perceptions, emotions, desires, beliefs) at 6 months significantly predicted gaze following and gaze alternation at 12-months (Roberts et al., 2013). It is noteworthy that these two studies analyzed the effect of maternal mental-state talk, and not specifically mind-mindedness, on joint attention. Mind-mindedness goes beyond the simple use of mind-related speech when interacting with one's child – it regards the mother's ability to appropriately infer her infant's mental states. To our knowledge, no study has investigated the link between maternal mind-mindedness and joint attention in premature infants.

Thus, we hypothesize that high quality of parenting behaviors may possibly compensate for the anticipated negative effect of prematurity and foster a normative development of joint attention skills in late preterm infants. In this regard, two dimensions of maternal interactive style may be particularly relevant to the extent that they reflect the mother's ability to perceive her infant as an individual with an intentional and attentional agenda of his/her own: a) maternal behaviors aimed at maintaining the infant's focus of attention and b) maternal use of appropriate mind-related comments, that is, maternal mind-mindedness.

Therefore, the present study had three main goals. First, we aimed to investigate whether infant birth status predicted joint attention behaviors at 12-months chronological age, in a sample of late preterm and full term infants. In line with the study of Sperotto (2015), our best reference considering the gestational age of preterm infants assessed by the author (> 30 weeks), we hypothesized that late preterm birth would significantly predict lower levels of responding to joint attention, but not of initiating joint attention. Secondly, we intended to explore whether maternal interactive style – maintaining the infant's focus of attention and appropriate mind-related comments – predicted infants' joint attention behaviors. Based on previous findings, we hypothesized that mother's interactive behaviors would predict more instances of responding and initiating joint attention. Finally, and if maternal behaviors were significant predictors, would they moderate the effect of prematurity on infant's concurrent responding to joint attention? We expected that when mothers displayed more attempts to maintain the infant's focus of attention and made more appropriate comments to mental states, prematurity would have no effect on infants' responding to joint attention. Contrastingly, late preterm infants would be more strongly affected by birth status when the quality of maternal interactive style was poorer.

Unlike the common practice of using age corrected for prematurity (Wilson & Cradock, 2004), in the present study age was uncorrected for prematurity in order to guarantee that all infants had approximately the same time of experience/contact with their mothers. Thus, we would be able to tease apart the effects of the quality of caregiving conditions from the effect of individual maturation. Furthermore, joint attention was assessed using an infant-tester paradigm, so we could have a clearer picture of infant's inter-individual differences in joint attention and, simultaneously, isolate the contribution of maternal behaviors (Mundy & Sigman, 2006).

Method

Participants

Participants were late preterm infants (born between $34^{+0/7}$ and $36^{+6/7}$ weeks of gestation) and full term infants (born between $37^{+0/7}$ and $41^{+6/7}$ weeks of gestation), and their mothers, who were participating in a larger longitudinal investigation. Apart from the criteria of gestational age, infants were included if they had no diagnosis of sensorial and/or cognitive impairments, no history of medical complications, and their mothers were 18 years or older.

Regarding the late preterm group, families were recruited in a public hospital in the North of Portugal as part of a larger longitudinal investigation. The present study includes those participants with complete data on joint attention and mother-infant interaction at the 12-months of age assessment. Infants were excluded from the analyses for several reasons: 11 infants missed the 12-months assessment (e.g., mothers were unable to attend to the assessment session within the necessary time-frame due to infant illness or their personal availability); two infants were accompanied to the assessment by another relative than the mother; five infants fell asleep at the beginning of the session and observational tasks could not be administered; and 32 infants did not have available data in one of the behavioral measures (one infant did not complete the mother-infant interaction and 31 infants did not complete the joint attention task, due to tiredness or fussiness). Late preterm infants with complete data at 12-months were indistinguishable to those infants with incomplete data in terms of gestational age, birth weight, sex and age at testing, as well as maternal age and educational level. In addition, six full term infants showed signs of fussiness during the assessment and did not complete the joint attention task at 12-months, so were excluded from the analyses. Again, no differences were found regarding the gestational age, birth weight, infant and mothers' age at testing, when compared to the full term infants included in the current study.

Thus, the final sample of this study comprised 21 late preterm (10 boys, 47.6%) and 24 full term infants (13 boys, 54.2%). Late preterm infants' mean gestation was 247.43 days (SD = 6.05) and birth weight was on average 2308 grams (SD = 286). Their 5-min Apgar scores were ≥ 8 and 13 infants (61.9%) were admitted to the neonatal intensive care unit (NICU) after birth, without major neonatal complications. In turn, the full term infants had a mean gestational age of 274.54 days (SD = 7.07), mean birth weight of 3166 grams (SD = 384), and 5-min Apgar scores ≥ 9. All infants were assessed according to their chronological age, with age uncorrected for prematurity. Mothers were aged 23 to 43 years, presenting a similar mean age on both groups (late preterm group: M = 33.95, SD = 5.59; full term group: M = 33.50, SD = 3.96). Table 1B presents complete information on medical and sociodemographic characteristics of the participants included in this study.

Late preterm infants and their full term counterparts were comparable in terms of sex, birth order, chronological age at testing, and maternal age. However, more full term infants had mothers with higher education qualifications (more than 12 years of formal education) compared to the late preterm infants, $\chi 2$ (1) = 6.28, p = .012. All infants were White and Portuguese was the language spoken at their home.

Table 1B. *Medical and sociodemographic characteristics of late preterm and full term groups*

	Late preterm group (n = 21)			**Full term group (n = 24)**			***p*-value**
	n (%)	Min-Max	*M* (*SD*)	n (%)	Min-Max	*M* (*SD*)	
Medical characteristics							
Gestational age (days)		238 - 256	247.43 (6.05)		265 - 290	274.54 (7.07)	<.001[a]
Birthweight (grams)		1590 - 2700	2308 (286)		2515 - 4055	3166 (384)	<.001[a]
Apgar score 5th min		8 - 10	9.52 (0.60)		9 - 10	9.96 (0.20)	.002[b]
Admitted to NICU	13 (61.9)						
Hospitalization (days)		0 - 31	5.71 (7.62)				
C-section	5 (23.8)			5 (20.8)			.811[c]
Sociodemographic characteristics							
Infant							
Sex (boys)	10 (47.6)			13 (54.2)			.661[c]
First-born	13 (61.9)			18 (75.0)			.344[c]
Age at assessment (months)		11 - 13	12.68 (0.51)		11 - 13	12.72 (0.38)	.674[b]
Mother							
Age		23 - 43	33.95 (5.59)		23 - 42	33.50 (3.96)	.753[a]
Educational level							.012[c]
College degree	9 (42.9)			19 (79.2)			
Basic/High school	12 (57.1)			5 (20.8)			

[a] *t*-test for independent samples; [b] Mann-Whitney Test; [c] Chi-Square Test.

Procedure

The recruitment of late preterm infants and data collection were carried out in a public hospital in the North of Portugal, where they were being followed by a neonatologist. In turn, full term infants were recruited from childcare centers as well as from the researchers' personal networks and their assessments were conducted in facilities of the university involved in the coordination of this study. After the study goals and procedures were explained, mothers signed a written informed consent agreeing to participate and allowing their infants to take part in the study. This research was approved by the Portuguese National Commission for Data Protection, as well as by the ethical boards of the hospital, and of the university involved in the study.

Infants and their mothers were tested individually. Each session took approximately 90 minutes and included the assessment of infants' cognitive development, a mother-infant interaction, and the administration of Early Social Communication Scales (ESCS, Mundy et al., 2003). Mothers also completed a sociodemographic questionnaire and reported on their psychological well-being. The entire procedure was video recorded for subsequent behavioral codification.

Instruments

Sociodemographic questionnaire. Mothers provided information on the infant and their birth history (e.g., sex, Apgar scores, weight, length and head circumference at birth, sibling position), parents (e.g., age, educational level, professional occupation, marital status), and pregnancy (e.g., delivery type, medical surveillance, complications of childbirth).

Maternal psychopathological symptomatology. Mothers completed the Brief Symptom Inventory (BSI; Derogatis, 1993; Portuguese version by Canavarro, 1999) that is a self-report measure of psychological symptoms, which comprises 53 items rated on a 5-point scale of distress, ranging from "0 = not at all" to "4 = extremely". Three global indices of distress can be obtained: the General Severity Index (GSI), the Positive Symptom Distress Index (PSDI), and the Positive Symptom Total (PST). In the present study, the Positive Symptom Distress Index was used as a measure of mothers' psychopathological symptomatology. A PSDI score ≥ 1.7 indicates the presence of emotional problems (Canavarro, 2007).

Infant neonatal risk index. An adjusted neonatal risk composite (by Poehlmann et al., 2010) was created using the mean of standardized scores of infant's gestational age in days (reversed), birth weight (reversed), Apgar score 5^{th} min (reversed), and number of days of hospitalization in the Neonatal Intensive Care Unit (NICU), such that a higher score would reflect a greater neonatal risk. This variable was computed for all infants, regardless of their birth status.

Infant mental development. The Griffiths Mental Development Scales (0-2 years) (GMDS; Griffiths, 1984) were used to assess the infant current level of mental development in five separate scales: Locomotor, Personal-Social, Hearing and Language, Eye and Hand-Coordination, and Performance. The sub-quotients for each scale and a global developmental quotient (GDQ), with a mean of 100 and a standard deviation of 15, were calculated according to all infants' chronological age, including for late preterm infants.

Infant joint attention behaviors. Infants' nonverbal communication skills were assessed using the Early Social Communication Scales (ESCS; Mundy et al., 2003), a structured observation procedure that measures the development of early socio-communicative behaviors in children between 8 and 30 months of age. The administration required approximately 20 minutes, during which the infant was seated on mother's lap at a table facing the tester. The infant was presented with several wind-up mechanical and hand-operated toys, a book, as well as opportunities to interact with the tester using several other objects (a hat, a comb, and glasses) or during a turn-taking (with a ball and a car) and a tickle game. Additionally, four colorful posters were placed on the wall, located to each side (Left and Right) and behind (Left-Behind and Right-Behind) the infant, that were used by the tester to direct infant's attention. Throughout the assessment, the infant was also asked to return the toys to the tester. The variety of toys and objects used in the ESCS were designed to elicit infants' spontaneous initiatives to interact with the tester as well as to respond to the tester's communicative bids, which were subsequently classified into one of three mutually exclusive categories of social-communication behaviors: Joint Attention Behaviors, Behavioral Requests, and Social Interaction Behaviors (Mundy et al., 2007; Mundy et al., 2003).

For the purpose of the present study, only joint attention behaviors will be targeted, upon the occurrence of two types of behaviors by the infant: Responding to Joint Attention and Initiating Joint Attention. Thus, Initiating Joint Attention (IJA) refers to the frequency with which the infant spontaneously initiates shared attention with the tester towards the objects/toys presented on the table, by using eye contact, pointing and showing gestures. In turn, Responding to Joint Attention (RJA) evaluates infant's ability in orienting his/her eyes and head in the direction of tester's line of regard and pointing gestures (Mundy, Card, & Fox, 2000; Mundy et al., 2003; Mundy & Gomes, 1998). Two tasks of the ESCS protocol assess infants' responding to proximal targets – in which the tester pointed to pictures in a book placed in front of the infant, and to distal targets – in which the tester pointed to the posters hung on the wall. Thus, a composite measure of RJA was generated by averaging the score of responding to proximal and distal targets, expressed in terms of the percentage of correct answers regarding the total number of trials. Two blind observers coded a random sample of 20% of the ESCS protocols. Inter-rater reliability revealed to be adequate across both measures of joint attention (IJA: mean k = .78; RJA: mean k = .92).

Maternal behaviors. Mothers were asked to play freely with their baby for 5 minutes, as they would do at home, using a set of toys provided by the researcher. Subsequently the videotaped mother-infant interaction was coded for two specific dimensions of maternal interactive style: maintaining of the infant's focus of attention (Landry & Chapieski, 1989; Landry et al., 1986), and appropriate mind-related comments (Meins et al., 2001).

Maintaining infant's focus of attention. Maternal verbal (verbal requests to act on the toy [e.g., "Throw me the ball"]) and non-verbal behaviors to direct the infant's attention (e.g., pointing, showing, and offering gestures) were coded regarding the infant's initial focus of interest or attention. Thus, each maternal attention-directing event received one of three mutually exclusive codings: maintaining, redirecting, and introducing (Landry & Chapieski, 1989; Landry et al., 1986). A maternal behavior was classified as *maintaining* whenever the infants' attention was being directed to the same object or toy they were already looking at and actively engaged with. On the other hand, if the mother directed the infant's attention to another toy different from the one the infant was currently involved with, that maternal behavior was coded as *redirecting*. Finally, when the infant was not involved with or attending to a particular object or toy and the mother directed his/her attention, then, a coding of *introducing* was applied. For the purpose of the present study, in subsequent analyses, only maternal behaviors that were maintaining infant's focus of attention were considered to the extent that this attention-directing style promotes infant's joint engagement. A proportional score was calculated, regarding the total number of maternal attention-directing events. For reliability purposes, 15% of the mother-infant interactions were coded by a second judge, blind to the birth status of the infants, who was previously trained on the coding scheme. Inter-rater reliability for maternal maintaining behaviors of infant's focus of attention was calculated using Gwet's agreement coefficient (Gwet, 2002, 2008) and revealed to be adequate (*Gwet's* AC_1 = .89). The pair of observers who coded the mother's attention-directing behaviors was different from the observers responsible for coding of maternal appropriate mind-related comments of infant joint attention behaviors described above.

Appropriate mind-related comments. Mother-infant interactions were transcribed verbatim and coded for mother's use of mind-related terms (Meins et al., 2001), such as *desires and preferences* (e.g., "Do you want to play with the car?"), *cognitions* (e.g., "Do you know what we can do with this [a bell]?"), *emotions* (e.g., "Don't get mad!"), and *talking on the infant's behalf* (utterances that are meant to be said/thought by the infant). Subsequently, each mind-related comment was classified in terms of its appropriateness (appropriate vs. non-attuned) to the infant's internal state. Thus, a mind-related comment would be considered as appropriate whenever a) the coder agreed with the mother's reading of her infant's current internal state (e.g., "*Do you want the ball?"* [while the infant is trying to reach the ball]); b) the comment linked the infant's current activity with similar events in the past or future (e.g., "*You like this one because it is similar to the one you have at home"*); or c) the comment clarified how to proceed after a pause in the interaction (e.g., "*Do you want to play with the bell?"* [if the infant was not focused on any particular object/activity, gazing around for several seconds]) (Meins & Fernyhough, 2015; Meins et al., 2001). In order to control for maternal verbosity, the variable appropriate mind-related comments was used as a proportional score regarding the total number of words used by the mother during the interaction. For reliability purposes, a randomly selected sample of 20% of the mother-infant interactions were coded by a second blind judge, previously trained on the coding scheme. Inter-rater reliability revealed to be adequate (k = .72).

Analysis plan

The assumption of normality of distribution was tested for all continuous control variables, maternal behaviors, and infants' joint attention behaviors, which informed us of the suitable statistical tests to be used.

The analytical strategy is organized in two phases. First, correlation analyses will be conducted in order to identify potential confound variables among characteristics of the sample and explore the associations between joint attention behaviors and our target variables – birth status and mothers' interactive style. Subsequently, and depending on the previous results, multiple regression analyses will be run with joint attention behaviors (IJA and RJA) as dependent variables. A hierarchical regression model will be adopted, introducing in Step 1 all additional control variables that are marginally or significantly correlated to joint attention behaviors, whereas birth status and/or maternal behaviors will be added at Step 2. Finally, and only in the prediction model for responding to joint attention, a third step will include the interaction terms (moderation effect) as the product of birth status and each maternal behavior (Hayes, 2013). R^2 change across steps will be analyzed, as well as the *p*-value of individual predictors and the interaction terms.

Results

Table 2B presents the descriptive statistics for maternal and infant variables. Five mothers (23.8%) of late preterm infants had a PSDI score ≥ 1.7 (cut-off point to be considered as having an emotional disturbance) in comparison to none of the mothers in the full term group. Concerning maternal behaviors in the interaction with their infant, five mothers (23.8%) made no mind-related comments in the late preterm group, whereas only three mothers (12.5%) in the full term group did not make any mental reference. Still, late preterm and full term groups did not differ regarding the maternal variables in the Table 2B. In turn, all infants on both groups presented an appropriate mental development in accordance to their age norms.

Table 2B. *Descriptive statistics for maternal and infant variables*

	Late preterm group		Full term group	
	Range	*M* (*SD*)	Range	*M* (*SD*)
Mother				
Psychopathological symptomatology	1 – 2.56	1.33 (0.44)	1 – 1.64	1.25 (0.23)
Mind-related terms	0 – 13	3.48 (3.83)	0 – 12	3.71 (2.87)
Appropriate mind-related comments[a]	.00 – .05	.009 (.01)	.00 – .03	.011 (.01)
Maintaining infant's focus of attention[a]	.03 – .89	.47 (.22)	.15 – .78	.55 (.15)
Infant				
Neonatal risk index	- 0.17 – 1.88	0.50 (0.53)	- 1.18 – - 0.50	- 0.72 (0.20)
Mental development	80.77 – 108.33	93.58 (7.79)	90 – 114	101.36 (6.74)
Joint attention behaviors				
IJA	3 – 50	22.10 (10.55)	5 – 42	20.42 (9.00)
RJA[b]	6.25 – 81.25	38.79 (26.67)	25 – 100	58.77 (21.63)

Notes: [a] Proportional scores; [b] Percentage of correct answers. IJA = Initiating Joint Attention; RJA = Responding to Joint Attention

Correlation analyses between joint attention behaviors and maternal and infant variables are presented at Table 3B. Regarding initiating joint attention (IJA), a marginally significant correlation emerged with infant sex, r_{pb} = .254, p = .093, favoring girls. Neither infant birth status nor maternal interactive behaviors were associated with IJA.

Contrastingly, responding to joint attention (RJA) revealed a very different profile. Several control variables of the infant yielded a significant pattern of association. Thus, being a girl was associated with a better performance on RJA trials, r_{pb} = .376, p = .011. In addition, infant mental development at 12-months was related to more correct answers in responding to joint attention tasks, r = .393, p = .008. A negative significant association also emerged between neonatal risk and infant's

RJA, r_s = - .400, p = .007. Regarding our variables of interest, late preterm birth was associated with significantly lower levels of infant's responses to joint attention bids, r_{pb} = .390, p = .008. In turn, of the two dimensions of mothers' interactive style, only maternal behaviors aimed at maintaining the infant's focus of attention were associated with responding to joint attention. In this regard, infants whose mothers maintained more their focus of attention during the toy-play interaction presented significantly higher levels of correct responses, r = .341, p = .022.

Table 3B. *Correlation analysis between infant and mother variables and joint attention behaviors*

	IJA	RJA
Infant variables		
Sex[a, c]	.254[+]	.376*
Birth order[a, d]	- .131	- .151
Mental development[b]	- .141	.393**
Neonatal risk index	.055	- .400**
Birth status[a, e]	- .088	.390**
Mother variables		
Age	- .067	.169
Educational level[a, f]	.007	.218
Psychopathological symptomatology	.183	- .051
Appropriate mind-related comments	.038	.141
Maintaining infant's focus of attention[b]	.049	.341*

^+p < .10; *p < .05; **p < .01

Notes: [a]Point-Biserial Correlation Coefficient; [b]Pearson Correlation Coefficient. The remaining are Spearman Correlation Coefficients. [c]0 = Male vs. 1 = Female; [d]0 = Not first-born vs. 1 = First-born; [e] 0 = Late preterm birth vs. 1 = Full term birth. IJA = Initiating Joint Attention; RJA = Responding to Joint Attention.

On the other hand, mothers' psychopathological symptomatology was not associated with their interactive behavior when playing with the infant. A non-significant result also emerged between initiating and responding to joint attention, $r = -.043$, $p = .777$.

Given that no maternal interaction variable was significantly correlated with IJA, no regression analysis was run for this index of infant joint attention. On the other hand, a hierarchical regression model was run using responding to joint attention as the dependent variable (cf. Table 4B). In order to avoid multicollinearity, neonatal risk index was excluded from the model as it was highly correlated to the infant birth status, $r_{pb} = -.847$, $p < .001$. The following structure was used: Step 1 included the variables infant sex and mental development; Step 2 tested the independent effects of infant's birth status and maternal behavior of maintaining infant's focus of attention; and, lastly, in Step 3, the product of infant's birth status and maternal behavior of maintaining infant's focus of attention was entered to analyze the moderation effect.

The regression model was significant at Step 1, $F(2,44) = 7.43$, $p = .002$, explaining 26% of variance in responding to joint attention. Both infant sex, $\beta = .33$, $t = 2.47$, $p = .018$, and mental development, $\beta = .35$, $t = 2.61$, $p = .012$, were significant predictors. The inclusion of birth status and maternal behavior in Step 2 resulted in a statistically significant improvement in the prediction of RJA, $p = .044$, now explaining 37% of variance, $F(4,44) = 5.82$, $p = .001$. Specifically, infant sex remained a significant predictor, $\beta = .37$, $t = 2.86$, $p = .007$, and, after controlling for potential confound variables, birth status also emerged as a significant predictor, $\beta = .33$, $t = 2.25$, $p = .030$. Thus, being a late preterm was associated with significantly lower levels of responding to joint attention. On the other hand, maternal behavior of maintaining infant's focus of attention did not predict infant's responding, $\beta = .19$, $t = 1.33$, $p = .191$. Finally, the regression model in Step 3 was also significant, $F(5,44) = 4.56$, $p = .002$, but F change from Step 2 did not reach statistical significance, $p = .801$. No moderating effect of mothers' maintaining of infant's focus of attention was observed, $\beta = -.11$, $t = -0.25$, $p = .801$, and only infant sex was retained as a significant predictor, $\beta = .37$, $t = 2.83$, $p = .007$.

Table 4B. *Regression model for Responding to Joint Attention*

Steps and variables	R^2 (Adj. R^2)	*F*	*β*	*F* change
Step 1 (df 2,44)	.26 (.23)	7.43**		7.43**
Infant sex[a]			.33*	
Infant mental development			.35*	
Step 2 (df 4,44)	.37 (.31)	5.82**		3.38*
Infant sex			.37**	
Infant mental development			.10	
Infant birth status[b]			.33*	
Mother maintaining of infant's focus of attention			.19	
Step 3 (df 5,44)	.37 (.29)	4.56**		0.064
Infant sex			.37**	
Infant mental development			.10	
Infant birth status			.43	
Mother maintaining of infant's focus of attention			.21	
Infant birth status X Mother maintaining of infant's focus of attention			- .11	

*$p < .05$; **$p < .01$.

Notes: [a]0 = Male vs. 1 = Female; [b]0 = Late preterm birth vs. 1 = Full term birth.

Discussion

Joint attention abilities were assessed in late preterm and full term infants in order to analyze the predictive value of birth status and mothers' behaviors – maintaining infant's focus of attention and use of appropriate mind-related comments – on infant's joint attention abilities. Simultaneously, we examined the role of maternal interactive behavior as a potential moderator of the negative effect of prematurity on responding to joint attention. Results indicated that neither birth status nor maternal behaviors were associated with infants' initiating joint attention behaviors. On the contrary, infant birth status was a significant predictor of responding to joint attention, after controlling for infant sex and mental development. Thus, late preterm infants presented significantly fewer correct responses to joint attention bids when compared to their full term peers. Maternal efforts to maintain the infant's focus of attention, though, did not predict nor moderated the effect of preterm birth on responding to joint attention. Our findings provide support to the hypothesis that different behavioral dimensions of joint attention may yield specific patterns of association and involve common, but also distinct mental processes (Mundy et al., 2007; Mundy et al., 2000). Possible explanatory hypotheses will be advanced separately for initiating joint attention (IJA) and responding to joint attention (RJA).

Regarding IJA, results are consistent with previous studies (De Schuymer et al., 2011; Sperotto, 2015) that found no differences between preterm infants and their full term counterparts in this specific dimension of joint attention. The tendency to spontaneously seek to share our interest on some event/object or a meaningful affective social experience with others seems to serve a socio-emotional function (Mundy, 1995). Not only does the infant direct social behaviors (e.g., eye contact, pointing gestures) towards a partner, but also exchanges an emotional state regarding an object/toy (e.g., pleasure, surprise, joy) (Mundy, 1995; Mundy & Sigman, 2006). Indeed, IJA seems to specifically recruit frontal regions of the brain, namely orbitofrontal and dorsal-medial-frontal activity (Caplan et al., 1993; Henderson, Yoder, Yale, & McDuffie, 2002; Mundy et al., 2000; Mundy & Newell, 2007; Mundy & Sigman, 2006). Thus, supported by the anterior attention system, self-initiated bids for joint attention reflect the influence of volitional, executive and motivational processes (Mundy et al., 2000; Mundy & Newell, 2007; Rothbart, Posner, & Rosicky, 1994). Mounting evidence strongly suggests that IJA is determined by a positive affective experience (Gangi, Ibañez, & Messinger, 2014; Kasari, Sigman, Mundy, & Yirmiya, 1990; Mundy, Kasari, & Sigman, 1992; Venezia, Messinger, Thorp, & Mundy, 2004) and the perceived reward value and interest in the social stimulus (Adamson, Deckner, & Bakeman, 2010; Dawson et al., 2002; Nichols, Fox, & Mundy, 2005). This way, individual differences in initiating joint attention may reflect variability in infants' affective state and motivational tendencies that are likely to be influenced by the quality of caregiving conditions (e.g., Garner & Landry, 1994; Landry, Garner, Swank & Baldwin, 1996; MacLean et al., 2014; Mundy & Sigman, 2006), which might explain why prematurity did not affect this particular dimension of joint attention.

In our investigation, we found no association between the two specific interactive components – maintaining of the infant's focus and appropriate mind-related comments – and initiating joint attention behaviors. However, this should not be taken as an argument against the importance of the quality of mother-infant interaction for social development, namely infants' motivation to share experiences and interests with others. Ample evidence supports the notion that since the first months of life, dyadic interactions allow the infant to directly engage with an adult, by exchanging behaviors and emotions that will support more advanced self-initiated communicative acts (Adamson & Bakeman, 1985; Garner & Landry, 1992; Trevarthen & Aitken, 2001). Based on our results we speculate that maternal behaviors may have a differential impact at distinct stages of IJA development, being less determinant as the infant's spontaneous attempts to direct the other's attention become more frequent and consolidated in their behavioral repertoire. Therefore, future research should address this question, analyzing the contribution of maternal interactive behaviors to IJA pattern of change over time (e.g., Landry et al., 1997), and, simultaneously, include earlier manifestations of infant's engagement with the social environment. For example, a recent study by Salley and colleagues (2016) found that infant's visual attention and orientation to stimuli and dyadic social engagement (e.g., gaze, facial expression) as early as 1 and 4 months of age, respectively, predicted later initiating joint attention behaviors, suggesting a more active role of the infant in the development of his/her intentional communication. It would also be interesting to explore the influence of maternal behaviors on these potential individual precursors of infant's later tendency to intentionally share attention.

In turn, responding to joint attention (RJA), less affected by affective sharing, is more related to information processing (perception and encoding) and attentional processes (engaging, disengaging, and shifting of attention) that allow the infant to attend to another person's focus of attention (Mundy & Sigman, 2006). In this case, greater brain activation can be observed in temporal and parietal regions (Itier & Batty, 2009; Mundy et al., 2000; Mundy & Newell, 2007), which are recruited in face processing, detection of others' gaze direction or head orientation, and regulation of attention, by orienting, disengaging or shifting attention between different locations (Kingstone, Friesen, & Gazzaniga, 2000; Mundy et al., 2000; Puce, Allison, Bentin, Gore, & McCarthy, 1998; Rothbart, Posner, & Rosicky, 1994). Thus, it is possible that RJA becomes particularly vulnerable to the negative effects of prematurity through the impact it may have on infant's attentional skills, which might explain the result found in our study as late preterm birth predicted significantly lower levels of responding to joint attention bids. Empirical evidence suggests that premature infants show less mature attentional skills, such as shorter fixation times to social stimuli (Telford et al., 2016), less frequent and slower shifting of attention (Rose, Feldman, & Jankowski, 2001; 2009), and problems in regulating their attention (Weijer-Bergsma, Wijnroks, & Jongmans, 2008). In addition, successful gaze following also depends on a range of variables, such as whether gaze is accompanied by gestures and verbalizations, location and target salience, competing stimuli, and head turn movement (Deák, Flom, & Pick, 2000; Flom, Deák, Phill, & Pick, 2004; Moore, 2008; Moore, Angelopoulos, & Bennett, 1997). Thus, perhaps late preterm infants' higher risk of difficulties in attention regulation become more evident in situations that require the use of several attentional processes, as it is the case of responding to joint attention, thus affecting their performance. In addition, late preterm infants might benefit from more and redundant cues in the environment to detect the correct location of the target and successfully follow their partners' gaze or pointing gestures.

Regarding the contribution of maternal behaviors, and specifically a moderation effect, despite the initial correlational pattern between RJA and mother's maintaining of infant's focus of attention, the regression model revealed no significant predictive value of this maternal interactive component or in interaction with infant's birth status, failing to support our hypothesis. This result is partly in line with a previous study from Landry and colleagues (1998), who found that maternal maintaining of the infant's focus of attention had a global positive effect on infants' social response, regardless of their birth status (high-risk preterm, low-risk preterm or term). More recently, two other investigations found inconsistent findings regarding the potential compensatory effect of positive parenting behaviors on preterm infant's social competence. Shah and colleagues (2013) found no interaction between degree of prematurity and maternal interactive behaviors on children's behavioral outcomes at age 36 months. On the other hand, another study suggested a differential susceptibility on social functioning, such that 12 month-old premature infants performed significantly worse when exposed to low quality of parent-infant interaction, but outperformed full term infants when the quality of interaction was high (Gueron-Sela, Atzaba-Poria, Meiri, & Marks, 2015). Therefore, findings are far from being consensual and require further investigation, namely examining the effect of quality of parenting behaviors across varying levels of prematurity. Alternatively, as we previously suggested in the discussion of IJA findings, it is possible that the quality of maternal behaviors may have a differential effect depending on the age of the infant, with greater impact when joint attention abilities are still emerging (Gaffan et al., 2010; Legerstee et al., 2007; Mendive et al., 2013; Osório et al., 2011) and decreasing their influence as infants become more proficient in intentional communicative acts – as might have been the case at the age of testing.

In turn, maternal mind-mindedness yielded no association with any of the joint attention dimensions, in accordance to previous findings of Slaughter and collaborators (2009). A possible explanation lies in the fact that mind-related terms corresponded to only a maximum of 5% of mother's discourse while interacting with her infant, suggesting that it is not yet a common practice for these mothers to verbalize their infant's inner states at 12-months. Therefore, it is reasonable to think that at younger ages, when understanding of intentionality is mostly behavior-based, maternal interactive styles characterized by more overt behaviors rather than verbal comments about infants' current activity would create more opportunities for infant's joint engagement.

Although it was not part of our main goals, an effect of infant's sex could be found in our study. Similarly to previous studies (Mundy et al., 2007; Olafsen et al., 2006), our results showed that girls outperformed boys on both socio-communicative dimensions, drawing attention to the need of taking sex into account in future investigations, namely when assessing developmental outcomes in premature infants.

The current research has several limitations that deserve our attention and should be considered in future investigations. First, the sample size of our study limits interpretation and generalization of the results. Due to constraints unrelated to the researcher, such as mothers failing the evaluation and infants getting tired or fussy (which interfered with the administration of all observational tasks), only data of approximately one-third of the late preterm infants participating in the larger longitudinal investigation could be included in the analyses presented above. Although no differences were found for several control variables between those late preterm infants who were included and excluded from the analyses, a replication study with a larger sample size is needed. Additionally, considering the current sample size of participants included and the number of predictors targeted in the statistical analyses, only large effect sizes could be detected (Field, 2009). Thus, future replication studies with larger sample sizes may be particularly relevant for the detection of moderating effects, at least of medium magnitude (Whisman & McClelland, 2005).

Furthermore, the quality of mother-infant interaction based on two interactive dimensions likely provided a restricted view of the mother's ability to act sensitively and promote her infant's social engagement. In this line, several characteristics of maternal behaviors that may better reflect the dynamics of parent-child relationships should be investigated, such as mothers' positive affect, scaffolding and cooperation (e.g., Steelman et al., 2002). Another interesting suggestion is to analyze the paternal influence on premature infants' joint attention abilities. Previous studies have highlighted the specific contribution of fathers' interactive behavior to their infants' shared attention (Kmita et al., 2014; Martins, Mateus, Osório, Martins, & Soares, 2014). Most importantly, parents' interactive style should be followed over time, specifically how parents adapt their behavior to infants' increased capacity for intentional communication.

Finally, as already discussed, several infant individual processes could have elucidated us on our findings, namely infant's prior attentional capabilities, positive affect, level of interest for engagement with social stimuli, or behavioral self-regulation. In the case of premature infants, information on these variables may be particularly valuable in explaining differences on developmental outcomes when compared to their full term counterparts, but also in examining distinct paths of adaptive trajectories within the group of premature infants.

The present study extends literature on joint attention abilities and their potential correlates in premature infants, particularly in the late preterm group, which has often been underestimated in terms of the vulnerabilities they may present for being premature. Our results suggest that, indeed, being born a few weeks earlier (> 34 weeks of gestation) matters for some socio-communicative abilities – particularly responding to joint attention. These findings bring important implications for public health policies. In the last decades, elective C-sections with no medical indication were suggested to account for an increased rate of late preterm births in the USA (Engle & Kominiarek, 2008; Reddy, Ko, Raju, & Willinger, 2009), prompting the American College of Obstetricians and Gynecologists (2013) to discourage delivery before 39 weeks of gestation, unless under accepted medical or obstetric recommendation. On the other hand, early intervention programs should equally be available to late preterm infants, specifically in terms of assessment of relevant socio-cognitive abilities that develop during infancy, as the case of joint attention. Furthermore, the longitudinal trajectory of joint attention abilities through the second year of life should be investigated in late preterm infants, with particular emphasis on the developmental link with subsequent cognitive, social, and behavioral outcomes.

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CHAPTER 4

Contributions of infant vagal regulation at one month to subsequent joint attention abilities

Contributions of infant vagal regulation at one month to subsequent joint attention abilities[3]

Abstract

Since birth, humans develop an ability to regulate their inner states and behaviors, when facing demanding situations, in order to restore calmness and engage with other persons and the surrounding environment. The present study analyzed whether one-month infant vagal regulation to auditory stimuli was associated with later joint attention abilities – responding to and initiating joint attention –, in interaction with their mothers. Twenty-three infants were assessed and measures of respiratory sinus arrhythmia – RSA (baseline and vagal tone change during auditory stimulation) were used as index of vagal regulation. At 12-months, joint attention behaviors were assessed in a 10-min toy-play mother-infant interaction. Correlational analyses showed that lower baseline RSA and larger increases in vagal tone during auditory stimulation were related to more instances of joint attention behaviors at 12 months, especially responding to joint attention. Results suggest that distinct profiles of autonomic functioning may contribute to joint attention skills.

Key words: vagal regulation; RSA; auditory stimuli; responding to joint attention; initiating joint attention

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[3] Mateus, V., Cruz, S., Ferreira-Santos, F., Osório, A., Sampaio, A., & Martins, C. (2018). Contributions of infant vagal regulation at 1 month to subsequent joint attention abilities. *Developmental Psychobiology*, *60*, 111-117. doi: 10.1002/dev.21582

Introduction

Various neurophysiological processes influence, from early on in development, the ability to engage with the environment and other individuals. Since birth, humans need to learn to regulate their own physiological states in order to successfully respond to the environmental demands and develop more adaptive social skills (Porges, 2001; Porges, Doussard-Roosevelt, Portales, & Greenspan, 1996; Porges & Furman, 2011). A key neurophysiological mechanism for social engagement is the vagal regulation of the heart, which regards the control exerted by the vagus nerve on cardiac activity, enabling us to rapidly self-soothe and regulate our visceral state, and to foster engagement behaviors with objects and other individuals (Porges, 2007; Porges et al., 1996).

According to the Polyvagal Theory (Porges, 2001, 2003, 2007), the vagus nerve is a critical component to understand the linkage between physiological functioning and social behavior, via the impact of two intertwined branches of the vagus on the regulation of cardiac activity and muscles of the head and face (e.g., eyelids, facial muscles, middle ear muscles). Functionally, these muscles process social cues from the environment and determine the individual's social engagement (Porges, 2003). Thus, an adequate vagal regulation on the heart will support a state of calmness and encourage positive oriented behaviors to explore the social environment, as determining facial expressions, increase eye contact, head movements, orientation gestures, use of vocalizations, as well as processing and extraction of human voice from background sound (Porges, 2007; Porges & Lewis, 2009).

The vagal influence on the heart may be quantified by measuring the beat-to-beat heart rate pattern that oscillates at the frequency of spontaneous breathing, an index known as Respiratory Sinus Arrhythmia (RSA) (Porges, 1995, 2001, 2007), which can be measured during steady states (i.e., baseline) or during stressful and challenging conditions. When vagal output to the heart is high, it acts like a "brake", inhibiting sympathetic activity and potentially slowing down heart rate. On the other hand, the release of the "vagal brake" results in a relative increase of the sympathetic influences and, therefore, in heart rate (Porges et al., 1996). Greater levels of baseline RSA (Huffman et al., 1998; Patriquin, Scarpa, Friedman, & Porges, 2013; Van Hecke et al., 2009) and RSA suppression (i.e., decrease in the vagal tone from the baseline to the challenging condition) are reported to indicate better vagal regulation and, therefore, reflect adequate social functioning (Huffman et al., 1998; Porges, 2007; Porges et al., 1996). Specifically, in the first years of life, this pattern of physiological response (i.e., higher basal RSA and greater levels of RSA suppression) have been linked to better social outcomes, as more attentional control and soothability (Huffman et al., 1998), more positive and responsive behaviors (Stifler & Corey, 2001; Van Hecke et al. 2009), and fewer behavioral problems (Calkins & Dedmon, 2000; Calkins & Keane, 2004; Graziano & Derefinko, 2013; Porges et al., 1996; Van Hecke et al. 2009). However, the physiological states and consequent behavioral strategies adopted by the infant seem to be context-specific, depending on the evaluation of risk in the environment (Porges, 2003, 2007). In fact, when the individual perceives the environment as safe, an adaptive and appropriate response through an increased vagal influence should inhibit defensive structures (e.g., fight/flight response) and promote visceral homeostasis, allowing for the expression of positive social behaviors (e.g., physical proximity) (Porges, 2007). In this regard, previous studies reported an RSA augmentation during tasks that would be considered non-threatening or safe (e.g., presentation of toys or pictures, social interaction tasks), which, in turn, was associated with infants' positive engagement (Bazhenova, Plonskaia, & Porges, 2001), more sophisticated exploratory behaviors with toys (DiPietro, Porges, & Uhly, 1992), better self-regulation and less behavioral problems (Hastings et al., 2008).

One important index of social behavior is joint attention, or the infant's ability to coordinate attention with a social partner towards an external event/object of interest (e.g., a toy), that emerges in the last trimester of the first year of life (Bakeman & Adamson, 1984). This relevant social-cognitive milestone has been associated with subsequent language development (Morales et al., 2000; Tomasello & Farrar, 1986), social competence (Sheinkopf, Mundy, Claussen, & Willoughby, 2004; Vaughan van Hecke et al., 2007), and Theory of Mind (Charman et al., 2000; Nelson, Adamson, & Bakeman, 2008). Thus, studying the impact of vagal regulation on joint attention may be particularly relevant given that the individual must process the salient stimulus in the environment, and regulate his/her behavior and attention in order to get socially engaged and attend with a social partner to the event/object of interest.

Very few studies have investigated the association between vagal response and joint attention. In this regard, Heilman and colleagues (2007) found that baseline RSA was positively associated with the frequency of eye gaze towards an unfamiliar person, in typically developing children. Complementary evidence derives from studies with participants with an autism spectrum disorder (ASD), a condition well-known for significant impairments in joint attention abilities (e.g., Dawson et al., 2004), who presented lower baseline RSA and poorer vagal regulation during demanding tasks (Guy, Souders, Bradstreet, DeLussey, & Herrington, 2014; Neuhaus, Bernier, & Beauchaine, 2014; Porges et al., 2013; Van Hecke et al., 2009). More specifically, children with ASD that displayed higher basal RSA also presented more instances of joint attention (e.g., eye contact) when interacting with the researcher (Patriquin et al., 2013). However, these studies assessed the physiological response patterns and attention sharing behaviors in older children as preschoolers and school age children using a cross-sectional design. It remains unclear how earlier physiological vagal regulation in the first few months of life would relate to subsequent joint attention, an important indicator of positive social functioning. Thus, the present study aimed to investigate whether infants' vagal response pattern at rest and during auditory stimulation at one-month of age contributes to joint attention behaviors in interaction with the mother at 12 months. The option for auditory stimulation relates to the importance of this sensory modality for decoding and processing information from the social environment (e.g., emotional prosody) (Ethofer, Van De Ville, Scherer, & Vuilleumier, 2009) and how altered auditory processing may impact on social interactions, as the case of individuals with ASD (Jeste & Nelson, 2009). Considering that the auditory context was expected to be safe and non-threatening for the infant, we hypothesized that higher basal RSA and increased vagal influence during the auditory stimulation condition (RSA augmentation) would promote more instances of responding to and initiating joint attention.

Method

Participants

Families were recruited at their infant's birth and should met the following criteria in order to participate in the present study: a) infants were born full term (≥ 37 weeks of gestation), birth weight > 2500 grams, 10-min Apgar score equal to 10, and had no diagnosis of sensorial deficits; and b) mothers were older than 18 years of age and had a singleton pregnancy. Thus, participants were 23 mother-infant dyads (8 girls, 34.8%). Infants were Caucasian and healthy full-terms. The physiological assessment was carried out at age one-month (M = 33.91 days, SD = 7.10) and, when infants completed 12-months of age (M = 12.64 months, SD = 0.47), families were invited to return to the hospital for a reassessment. Mothers were aged 18 to 40 years (M = 31.48, SD = 5.30). For this study, we only included participants with complete behavioral and physiological data at both time points. From an initial sample of 28 infants, five of them did not have joint attention assessment at 12-months and were excluded from the analysis. No differences were found on gestational age, infant age at one-month-old assessment and RSA variables, when considering both samples (23 and 28 infants). This study was reviewed and approved by the institutional ethics committee.

Procedure

Families were recruited at birth in a hospital in the north of Portugal. At the one-month-old appointment, the researcher explained the study objectives and procedures, and written informed consent was obtained. The physiological assessment (electrocardiogram – ECG and respiratory rate recordings) was carried out in a room with adequate temperature and controlled luminosity and sound. Mothers were asked to place the infant on their lap and to keep them still. Then, the researcher delivered the auditory stimuli via two speakers held at approximately 20 cm from each of the infant's ears. The physiological data collection lasted approximately 10 minutes.

At 12-months of age, mothers returned to the hospital for the interaction task assessment. They were asked to play freely with their infants for 10 minutes, as they would normally do at home, using a set of toys provided by the researcher. This procedure was video-recorded and later coded for infant's joint attention abilities.

Auditory stimuli

Two simple tone auditory stimulus intensities were created in Audacity software (version 1.3.6 for OS X, www.audacityteam.org), at 900Hz frequency: a higher intensity (70dB) and a lower intensity (50dB) – generated by reducing the sound pressure level by 20dB (Schmidt & Segalowitz, 2008). Each stimulus was a click-like sound, constituted by epochs lasting 1 second (duration – 100ms; 900ms inter-stimulus interval). The stimuli were delivered with Presentation® software (Version 0.61.3, www.neurobs.com) in a block paradigm, considering stimulus intensity – one block consisted of sixty 50dB auditory stimuli and the other of sixty 70dB stimuli. Each block was presented once and offered for 1 minute (1 stimulus per second, with a 20-second interval between blocks). The presentation order of the blocks was counterbalanced across participants.

Physiological assessment at one month of age

After cleaning the infant's chest with distilled water, three pre-gelled hypoallergenic Ag/AgCl electrodes were positioned at the right, left, and medial zones of the chest, in a modified Lead II electrode configuration, in order to record cardiac activity. A respiratory band was placed around the infant's stomach as, at this age, respiration is mainly occurring at the abdominal level (Schmidt & Segalowitz, 2008). The signal traces were visually inspected to warrant the quality of the signal before recording. After recording a 5-minute baseline, the auditory stimuli were delivered. Recordings were conducted with Biopac MP-150 equipment (Biopac System, Santa Barbara, CA, USA), coupled with

ECG100C and DA100C modules for registration of cardiac and respiratory activities, respectively. The Biopac amplifier was connected to a computer equipped with AcqKnowledge software (Biopac), used to define the acquisition parameters, store, and preprocess the physiological data. Physiological signals were amplified 1000 times and digitized at a sampling rate of 500 Hz (bandpass filtered 0.05-100 Hz).

Electrocardiogram (ECG) recordings were exported from AcqKnowledge into QRSTool/CMteX (version 1.2.2; Allen, Chambers & Towers, 2007) for automatic R peak detection, calculation of the inter-beat interval (IBI) series (misidentifications were manually corrected by scoring the actual R peak following visual inspection), and computation of RSA (calculated as the log variance of the IBI series after bandpass filtering in the canonical infant respiratory frequency band of 0.24-1.04 Hz; Allen et al., 2007). Visual inspection of the respiratory power spectra (obtained using in-house scripts in Matlab – The MathWorks, Natick, MA, USA) ensured that the peak respiratory frequency of all infants was included in the interval used for RSA filtering (Berntson et al., 1997).

For the statistical analysis, baseline RSA was extracted from the first good 1-minute of data from the 5-minute baseline collected, in order to be equivalent to the duration of each auditory stimulus block. Afterwards, vagal reactivity was calculated by subtracting the auditory stimulus RSA raw score on each condition (lower and higher intensity) from the baseline RSA. Thus, negative scores would reflect RSA augmentation. Henceforward, in the statistical analyses, measures of baseline RSA and vagal tone change during lower and higher auditory intensity are used as indexes of vagal regulation.

Joint attention behaviors

Mother-infant free toy-play interaction at 12-months of age was assessed using a coding scheme designed by Martins (2003), focused on the infant's response to maternal bids for joint attention and their own initiatives to draw the mother's attention to a target (usually a toy) (for further detail see Osório, Martins, Meins, Martins, & Soares, 2011).

Infant's responses to each maternal behaviors received one of two possible codings: *responds to joint attention bids* (by following the mother's action on the toy and, at the same time, alternating gaze between the toy and the mother) or *no response to joint attention bids* (when the infant ignores mother's action revealing no interest in the toy or follows mother's action on the toy, but never alternates gaze between the mother and the toy). Responding to joint attention was scored as the proportion of infant's instances of involvement in joint attention, divided by the total number of mother's bids.

Initiating joint attention was coded in terms of three types of behaviors used by the infant to spontaneously direct the mother's attention: animating a toy, offering a toy, and pointing. All behaviors required the infant to look at the mother's face at some point during the action, except for pointing (which could be scored even if the infant did not alternate gaze). The frequency of all three behaviors was collapsed into an overall score.

A second trained judge coded a random 20% of the mother-infant interactions. Inter-rater reliability was calculated using Cohen's kappa and revealed to be adequate (Responding to joint attention = .73; Initiating joint attention = .81).

Results

Repeated-measures analyses of variance indicated no significant differences in infant's RSA response from baseline to lower and higher auditory intensity, $F(2, 44) = 0.73$, $p = .487$, $\eta^2_p = .032$. Infants' sex had no effect on vagal response (Greenhouse-Geisser corrected), $F(2, 42) = 1.22$, $\varepsilon = .75$, $p = .299$, $\eta^2_p = .055$. Additionally, infants produced an identical response to the baseline and auditory stimulation intensities regardless of their alertness state (sleeping or awake), $F(2, 42) = 0.12$, $p = .884$, $\eta^2_p = .006$. Regarding joint attention variables, girls and boys did not differ in their response to mother's bids, $t(21) = 0.593$, $p = .560$, $d = 0.28$, nor in their initiating joint attention behaviors, $U = 41.0$, $p = .212$, $r = -.26$.

The descriptive statistics for infant physiological responses during baseline and auditory stimulation and joint attention behaviors are presented in Table 1C.

Table 1C. *Infant joint attention behaviors and physiological measures*

	Min – Max	*M* (*SD*)
Joint attention behaviors		
Responding to joint attention	0 – .13	.04 (.03)
Initiating joint attention	0 – 15	4.09 (3.75)
Physiological measures (RSA)		
Baseline	1.34 – 5.68	3.11 (1.24)
Lower auditory intensity	1.47 – 5.50	3.41 (1.02)
Higher auditory intensity	0.85 – 5.46	3.16 (1.04)

Correlation analyses were conducted to determine whether infant basal levels and vagal reactivity during auditory stimulation, assessed at one-month-old, would relate to later joint attention skills in interaction with the caregiver (Table 2C).

Regarding responding to joint attention, results indicated that lower baseline RSA amplitude was significantly correlated with higher levels of infant's response to mothers' bids, r_s = - .51, p = .012. Similarly, a significant association was found with RSA change from baseline to lower, r_s = - .61, p = .002, and higher auditory intensity, r_s = - .48, p = .020, such that increases in RSA during auditory stimulation were associated with more responding to joint attention.

Table 2C. *Spearman correlation between vagal response and infants' joint attention behaviors*

	RJA	IJA
Baseline RSA	- .51*	- .35^{+}
Lower auditory intensity RSA[a]	- .61**	- .15
Higher auditory intensity RSA[a]	- .48*	- .52*

^{+}p < .10; *p < .05; **p < .01

Note: RSA = Respiratory Sinus Arrhythmia; RJA = Responding to Joint Attention; IJA = Initiating Joint Attention. [a]RSA change score = baseline RSA minus RSA during auditory stimulation condition.

Regarding the pattern of association between RSA and initiating joint attention, baseline RSA yielded a marginally significant correlation, r_s = - .35, p = .099, and no association was found between lower auditory stimuli intensity and later initiating joint attention behaviors, r_s = - .15, p = .503. On the other hand, a significant correlation was found with the higher auditory intensity, r_s = - .52, p = .010. Once again, increases in RSA during higher intensity of auditory stimulation were related to more infants' attempts to draw their mothers' attention.

Finally, measures of joint attention were not associated with each other, r_s = .28, p = .201.

Discussion

From an evolutionary perspective, the regulation of the cardiac activity, via the control exerted by the vagus on the heart, will assist the individual to adapt its behavior in order to deal with environmental challenges. Based on previous processing of environment features to evaluate risk, the influence of the vagus on the heart may recruit different classes of behaviors: defensive and mobilization strategies (i.e., decreased influence of the vagus) or self-soothing and social engagement behaviors (i.e., increased influence of the vagus) (Porges, 2001, 2007). Indeed, the maturation of the autonomic nervous system during the first years of life, characterized by age-related increases in vagal tone (Izard et al., 1991; Patriquin, Lorenzi, Scarpa, & Bell, 2014; Porter, Bryan, & Hsu, 1995), parallels infants' ability to regulate their behavior and visceral states through the dynamic interaction with another person (Porges & Furman, 2011).

In this sense, the present study aimed to investigate the contribution of infant physiological functioning at one-month, during baseline and in response to auditory stimulation, to later joint attention abilities at 12-months. Our findings partially confirmed our hypothesis, so that lower baseline RSA and increases in RSA during auditory stimulation (RSA augmentation), at age one-month, were correlated with more instances of joint attention behaviors. More specifically, infant vagal response was more strongly associated with infant responding to maternal bids for joint attention than to initiating joint attention behaviors.

As opposed to previous studies (e.g., Huffman et al., 1998), we found that lower RSA baseline was associated with better social outcome at 12-months. At age one-month, when the autonomic system is still immature, infants are mostly dependent on their caregiver to be soothed and behaviorally regulated. Thus, we may speculate that, at very young ages, regulatory challenges may create opportunities for interaction with the caregiver. These opportunities not only help the infant to learn how to regulate their physiological state, but may also foster the development of social skills emerging in the context of dyadic interactions, such as the case of joint attention. In addition, infant's difficulties in maintaining visceral homeostasis, expressed in lower RSA baseline, may be translated into increased sensitivity (i.e., higher reactivity) to social and non-social stimuli in the environment. This may explain our results, as the infant is likely to respond and engage with the social partner as they detect adults' bids for joint attention.

On the other hand, infant's vagal response to auditory stimulation corroborated previous findings of increases in vagal influence as indicative of an adaptive response to safe environments, and, consequently, promoter of more positive behaviors and social engagement (e.g., Bazhenova et al., 2001). More specifically, lower intensity auditory stimuli resemble the speech sound produced in a normal conversation and usually present in infant-directed speech. The literature has highlighted infants' preference for this type of speech register (e.g., Cooper, Abraham, Berman, & Staska, 1997; Leibold & Werner, 2007) that conveys positive affect and modulates infant's attention to the environment (Fernald, 1992). This may have impelled the infant to react to the stimuli and may explain the unique association with later responding to joint attention.

Taken together, these results suggest that even at earlier ages infant's patterns of autonomic regulation may lay the foundation for the development of social abilities that emerge later on. Additionally, it is possible that no single unidirectional profile of physiological functioning influences social outcomes, and in particular joint attention abilities. Instead, this may depend on the age period and on environmental conditions, namely risk assessment. Another interesting finding concerns the specific pattern of association with measures of joint attention, providing support to the hypothesis that different behavioral dimensions of joint attention may reflect common but also distinct correlates (Mundy et al., 2007). Responding to joint attention requires the infant to be capable of regulate his/her own behavior and attention, in order to detect, engage, disengage and shift attention between distinct targets. Therefore, autonomic functioning may be particularly relevant to responding to bids for joint attention, rather than initiating joint attention, due to the impact on behavioral regulation, detection of stimulus in the environment, and mobilization of attentional resources.

The current research has several limitations that merit attention and should be considered in future investigations. First, due to the small sample size, caution is needed in the interpretation and generalization of the results. A replication study with a larger sample size is needed, so we could test a multiple regression model and analyze the variance explained in joint attention behaviors by baseline RSA and each RSA change score to auditory stimulation. Secondly, physiological data was only collected at age one-month. Since RSA response patterns change over time, it would be important to have additional records of infant's autonomic functioning at 12-months, when joint attention behaviors were assessed. Finally, we did not evaluate the quality of maternal interactive style (e.g., sensitivity, intrusiveness) and other infant variables (e.g., temperamental characteristics) that could provide us with valuable information in explaining our results. Indeed, a high quality caregiving environment (e.g., Calkins, Smith, Gill, & Johnson, 1998; Hastings et al., 2008; Waters & Mendes, 2016) seems to facilitate the acquisition of better autonomic functioning and self-regulatory skills during infancy and preschool years. Thus, future studies should also take into consideration parenting variables in order to better understand infants' individual differences in physiological regulation and its association with subsequent social outcomes.

This study advances extant literature on the contributions of early autonomic functioning to later social outcomes, namely joint attention, giving support to the assumption that distinct profiles of physiological regulation may promote social development, depending on infant's perceived safety or threat in the environment. Further research should be conducted to clarify the interactions between physiological processes and social developmental outcomes, in typically developing infants, but also at-risk groups such as preterm infants. Indeed, prematurity seems to pose additional challenges to infant regulation of their visceral states (e.g., Feldman, 2006) and has been linked to socio-emotional problems in general (e.g., Clark, Woodward, Horwood, & Moor, 2008), as well as decreased joint attention abilities (e.g., Olafsen et al., 2006).

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CHAPTER 5

CONCLUSION

Joint attention in infancy: What we know and what remains to be known

Joint attention is a significant milestone in infants' socio-cognitive development, with links to later language ability (e.g., Morales et al., 2000a), social competence (e.g., Sheinkopf, Mundy, Claussen, & Willoughby, 2004), and Theory of Mind (e.g., Nelson, Adamson, & Bakeman, 2008). In the last decades, research on individual and environmental factors that influence joint attention contributed to a deeper understanding of infants' inter-individual differences in this important capacity and their impact on subsequent development. However, some questions required further investigation, namely the effect of infant's gestational age, physiological regulation, and maternal interactive behaviors on the emergence of joint attention, which we sought to address in the present doctoral dissertation. Specifically, we examined to what extent preterm birth affected distinct behavioral dimensions of joint attention abilities, by means of meta-analytic techniques. In addition, we clarified whether late prematurity (34 – <37 weeks of gestation) would compromise the development of infants' joint attention. Simultaneously, we explored the independent contribution of maternal interactive style to concurrent joint attention abilities and whether they would buffer the negative effects of biological immaturity. Finally, we explored a potential longitudinal link between infant's early physiological functioning, at one-month of age, and joint engagement behaviors by the end of first year of life, in a sample of typically developing infants.

Thus, a summary of our main results is presented in the next paragraphs.

Summary of empirical findings

Paper 1 reports a meta-analytic study investigating whether preterm birth systematically affects distinct dimensions of joint attention – initiating joint attention, responding to joint attention, and episodes of joint attention. In addition, we attempted to examine the role of preterm infants' gestational age in explaining the results. Literature on joint attention development in premature infants presents mixed findings, either suggesting no differences between preterm and their full term peers (e.g., De Schuymer, De Groote, Beyers, Striano, & Roeyers, 2011), or significant impairments in preterm infants (e.g., Garner, Landry, & Richardson, 1991), or yet distinct results across different dimensions of joint attention (e.g., Sperotto, 2015). Thus, the fact that premature infants vary highly in gestational age and neonatal/medical risks (March of Dimes, PMNCH, Save the Children, & WHO, 2012), allied to the assumption that distinct behavioral manifestations of joint attention may reflect specific patterns of brain activation and mental processes (Mundy et al., 2007; Mundy, Card, & Fox, 2000), dictated the need for a meta-analytical approach for combining the results from different studies in order to clarify the effect of prematurity on joint attention abilities.

Our findings showed that, overall, no significant differences were found between preterm and full term infants in all three variables assessed. However, when preterm infants' mean gestational age was considered, we found that specific dimensions of joint attention, namely responding to joint attention and episodes of joint attention, were particularly vulnerable to varying levels of prematurity. In this regard, we suggest that understanding the mental processes, as well as the cortical and attentional networks involved in different behavioral manifestations of joint attention may elucidate us on how these might be affected by premature birth.

Despite the small number of studies included, this paper represents an initial effort to synthesize the existing literature and shed some light on this relevant topic. Additionally, we drew attention to some issues that should be addressed in future investigations, namely the impact of parenting behaviors, and the need to focus on the specific needs of late preterm infants, still an understudied group among the premature population.

In **Paper 2**, we investigated joint attention abilities in a sample of late preterm and full term infants at 12-months chronological age. We examined whether infant birth status (late preterm vs. full term) and two dimensions of maternal interactive style – maintaining infant's focus of attention and appropriate mind-related comments – would predict joint attention behaviors. Additionally, we tested whether the quality of maternal interaction could moderate the effect of prematurity on responding to joint attention.

Our results were in accordance to our main reasoning in the discussion of the meta-analysis, raising the possibility that preterm birth may have a differential effect on specific behavioral dimensions of joint attention. Whereas late preterm birth predicted significantly lower levels of responding to joint attention, after controlling for infant sex and mental development, no association was found with initiating joint attention behaviors. We conjectured that preterm infant's difficulties in regulating their attention (Weijer-Bergsma, Wijnroks, & Jongmans, 2008) may become more evident in skills that require the use of attentional resources, such as responding to joint attention. In turn, initiating joint attention would be more influenced by affective (e.g., Kasari, Sigman, Mundy, & Yirmiya, 1990) and motivational processes (e.g., Adamson, Deckner, & Bakeman, 2010), that we believe to be promoted within the context of early dyadic interactions and less affected by prematurity.

Contrary to our expectations, maternal interactive behavior did not independently predict or moderate the effect of preterm birth on responding to joint attention. However, we do not rule out the beneficial effects of positive parenting behaviors, which have been demonstrated in the literature to foster infant's optimal developmental outcomes (e.g., Landry, Smith, Swank, & Miller-Loncar, 2000; Page, Wilhelm, Gamble, & Card, 2010) and, in particular, infant's engagement in coordinated attention (e.g., Mendive, Bornstein, & Sebastián, 2013; Vaughan et al., 2003). Alternatively, we suggested that maternal behaviors may be more influential when the capacity is still emerging, but not after infants become more skilled and intentional in social engagement (as is likely the case at 12 months). In this case, infants' own characteristics (e.g., motivations, temperament, attentional capabilities, and interactive behavior) may, perhaps, better explain inter-individual differences in joint attention during the second year of life. On the other hand, previous findings regarding the role of positive parental interactive behaviors as a buffer of the adverse effects of prematurity on infants' social competence are not consistent, either showing no interaction between caregivers' interactive style and degree of prematurity (Shah, Robbins, Coelho, & Poehlmann, 2013) or suggesting a possible differential susceptibility of preterm infants to the quality of caregiving conditions (Gueron-Sela, Atzaba-Poria, Meiri, & Marks, 2015). Therefore, further investigation is needed in order to clarify this specific subject. Finally, other maternal interactive behaviors that tap on important components of social interactions, such as emotional support, positive affect, scaffolding or responsiveness, could make a more significant contribution to the interactional dynamics during infancy, particularly in what concerns social development in late premature infants.

An interesting finding that was stable in our study was the role of infant sex in predicting joint attention behaviors, with girls outperforming boys in all dimensions. This result is in line with previous work indicating that girls are apparently ahead of boys in joint attention measures in typically developing (Mundy et al., 2007) and premature infants (Olafsen et al., 2006). This sex-specific advantage tends to persist through time and expand to subsequent related outcomes, such as language ability (Eriksson et al., 2012; Simonsen, Kristoffersen, Bleses, Wehberg, & Jørgensen, 2014), and Theory of Mind (Calero, Salles, Semelman, & Sigman, 2013; Charman, Ruffman, & Clements, 2002). In this sense, future studies should address this variable and clarify its relevance to the development of joint attention in typically developing and premature infants, examining a potential female advantage on socio-cognitive development since early on.

Overall, our findings in paper 2 expand previous literature on the development of joint attention abilities by investigating a group of infants often understudied among the preterm population – late preterm infants.

In turn, **Paper 3** extended previous research that relates infant's regulation of visceral states to adaptive social skills. More specifically, we explored the presence of a longitudinal link between infant's vagal regulation at 1-month of age – measured by Respiratory Sinus Arrhythmia (RSA) – and joint attention abilities during a mother-infant interaction at 12-months, in a sample of healthy full term infants. Infant's physiological functioning was assessed at rest and in response to auditory stimulation of varied intensities. Results did not support the hypothesis that higher RSA baseline would be associated with better social outcomes. Instead, we found that infant's lower RSA baseline, reflecting difficulties in regulating internal states, was associated with higher levels of responding to mother's bids for joint attention. On the other hand, vagal reactivity, expressed as increases in RSA from baseline to auditory stimuli, promoted more instances of responding and initiating joint attention. This second result indicated an adaptive response of the individual to non-threatening contexts, as it was the case of auditory stimulation, and confirmed previous findings of the association between RSA augmentation in safe environments and positive social engagement (e.g., Bazhenova, Plonskaia, & Porges, 2001). Thus, depending on the infant's evaluation of risk in the environment, different profiles of physiological regulation may facilitate social development, and particularly joint attention engagement. Age also seems to be an important factor, as very young infants depend on caregivers to regulate their physiological states. Therefore, regulatory difficulties may provide opportunities of interaction between mother and infant, possibly resulting in additional benefits to social skills developed within dyadic contexts, as the case of joint attention. Additionally, it is possible that infants' heightened alertness to social and non-social stimuli in the surrounding environment, expressed in lower basal RSA, may also trigger their ability to better detect adults' bids for joint attention and, thus, increase the likelihood of infant's engagement. A unique association was found between vagal reactivity to lower auditory intensity stimuli and responding to joint attention, which may be due to the resemblance of such stimuli to infant-directed speech (often occurring in infant-adult joint attention exchanges).

Concluding, our results from paper 3 underlined the important role of infant's early physiological functioning to social abilities that emerge later on, likely through its impact on core features such as behavioral regulation, detection and processing of social stimuli in the environment, and mobilization of attentional resources. This might explain the consistently stronger pattern of associations observed with responding to bids for joint attention rather than initiating joint attention, providing support to the notion of distinct correlates underlying different manifestations of joint attention (e.g., Mundy et al., 2007). By clarifying this link between autonomic functioning and joint attention in typically developing infants, fruitful new research avenues may emerge, aimed at elucidating us on the development of joint attention abilities in infants at risk for difficulties in regulating their visceral states, such as preterm infants (e.g., Feldman, 2006). In line with recent evidence (Salley et al., 2016), findings from paper 3 raise the possibility that, despite joint attention emerging around 9 months, the path for successful social engagement maybe begin to take shape as early as one month of age.

Strengths of the present investigation

This doctoral dissertation aimed to explore the relevance of three variables – prematurity, maternal interactive behaviors, and infant physiological regulation – to infants' social development, specifically joint attention. With a combination of meta-analytical techniques applied to a set of carefully selected empirical studies using observational methodology (so as to provide a more ecologically valid overview of infant and mother behaviors), we sought to disentangle the effect of preterm birth on distinct behavioral dimensions of joint attention. Simultaneously, we analyzed the role of varying levels of prematurity in explaining the results. Then, joint attention abilities were examined in an often understudied group of premature infants – late preterm – and the positive effect of quality of maternal behaviors on infants' joint attention was examined, namely its potential role in moderating the negative effect of prematurity. Finally, we investigated the link between infant physiological regulation at one-month of age and later joint attention capacity in full term infants. The findings of this latter study might open new research avenues in the development of shared attention in premature infants, who are also at risk of difficulties in regulating their physiological states.

Limitations of the present investigation

One aspect common to all three studies is sample size – the number of studies included in the meta-analysis on the one hand, and the number of participants in both empirical studies, on the other hand. The number of studies included in the meta-analytical investigation of paper 1 was limited by our stringent inclusion criteria, as well as the unfortunate no-response from some of the authors whose investigation should have been included. In our view, and even though recognizing the benefit of running a broader meta-analysis in the future, both aspects did not preclude us from providing a first window to the effects of prematurity on joint attention by combining the empirical studies carried out so far. As to the sample size of our longitudinal empirical studies, and even if that was well within the average in similar reports on early child development (e.g., Garner et al., 1991; Heilman, Bal, Bazhenova, & Porges, 2007; Mendive et al., 2013; Mundy & Gomes, 1998; Nichols, Martin, & Fox, 2005; Osório, Martins, Meins, Martins, & Soares, 2011; Patriquin, Scarpa, Friedman, & Porges, 2013; Sansavini et al., 2015; Suttora & Salerni, 2012), benefits can definitely be drawn if replication studies are carried in larger samples.

Implications for future research

The findings of the studies included in this doctoral dissertation, while trying to address several gaps in the literature, also raised interesting research questions that may guide future investigations. When attempting to understand the developmental trajectories of joint attention in typically developing and at-risk infants, we should consider the interplay between infant brain development and behavioral characteristics, as well as the social partner's interactive style. Thus, examining aspects of these three domains should provide more complete and comprehensive explanations of early social development and provide the scientific community with a broader, ecological approach to the study of socio-cognitive development,

In our studies, initiating and responding to joint attention were not significantly intercorrelated, suggesting that different behavioral manifestations of joint attention may reflect distinct mental processes and patterns of association, as proposed by the Multiple Process Model (Mundy et al., 2000). One of the main assumptions of this model is the fact that different dimensions of joint attention recruit specific attentional networks (Posner & Petersen, 1990), and areas of the brain (e.g., Mundy et al., 2000). Very preterm (< 32 weeks of gestation) and very low birth weight (< 1500g) infants seem to present important brain alterations at term-equivalent age, compared to full term peers, namely white matter and grey matter reduced volumes (e.g., Keunen et al., 2012; Monson et al., 2016; Thompson et al., 2007; Zhang et al., 2015). Although late prematurity (34 – < 37 weeks of gestation) is generally considered less disruptive of overall infant development, it still occurs in a critical period of brain growth and maturation, especially regarding the development of white matter and grey matter tissues (Adams-Chapman, 2006). In this regard, white matter abnormalities have been associated with poorer performance on attention tasks and processing speed (Murray et al., 2014; 2016), executive functions (Thompson et al., 2014), motor skills (Monson et al., 2016; Thompson et al., 2014), and measures of cognitive/linguistic development (Monson et al., 2016; Northam, Liégeois, Chong, Wyatt, & Baldeweg, 2011; Reidy et al., 2013) at later ages. Similarly, reduced volumes of grey matter have been related to deficits in several subsequent chidren neurodevelopmental outcomes, such as cognitive ability (Monson et al., 2016), motor functioning (Monson et al., 2016), memory (Omizzolo et al., 2014), and attention measures (Murray et al., 2014). Thus, we wonder what the implications of premature infants' brain alterations are to the specific cortical regions associated with joint attention behaviors. To what extent could these brain alterations vary as a function of prematurity and how they may help to explain preterm infants' increased risk for impairments – specifically in responding to joint attention?

On the other hand, another challenging research avenue concerns the early identification of specific infant abilities, prior to the emergence of joint attention, which may potentially stimulate a cascading effect of increasing interest to participate in social exchanges and share experiences with others. Several individual characteristics of the infant may be particularly relevant to investigate to the extent they measure infant's engagement with objects and/or other persons. In this regard, factors such as infant's attentional capabilities (Morales et al., 2000b; Mundy et al., 2000; Salley et al., 2016), social engagement with others (Salley et al., 2016; Striano & Rochat, 1999), positive affect (Gangi, Ibañez, & Messinger, 2014; Kasari et al., 1990; Nichols et al., 2005; Striano & Bertin, 2005; Vaughan et al., 2003), or exploratory behaviors with toys (Bigelow, MacLean, & Proctor, 2004), have been positively associated with infant's joint engagement. It would be interesting to understand how early on in development these infant abilities may predict later joint attention development, as well as its additional value in explaining impairments in at-risk samples. Identifying potential precursors of subsequent social competence, and joint attentions skills in particular, is of the utmost importance for the development of early intervention programs tailored to the specific vulnerabilities of each at-risk group, such as preterm infants.

Finally, the role of parenting behaviors on infants' capacity for sharing attention requires further research, specifically whether the influence of distinct classes of behaviors is age-specific. Given that infants face dynamic challenges throughout development it is also possible that the most beneficial parental behaviors may change accordingly. Even though concurrent maternal interactive behaviors – such as sensitivity, maintaining infant's focus of interest – seem to account for inter-individual differences in emerging joint attention abilities (around 9-10 months of age) (e.g., Gaffan, Martins, Healy, & Murray, 2010; Osório et al., 2011; Mendive et al., 2013), the quality and history of parent-infant relationships before this age period are also of interest, as early reciprocal interactions contribute to future relational experiences and developmental outcomes of the infant (Smith, 2010). In this line of thought, previous investigations have shown that high quality parent-infant interactions at 6 months are predictive of better social outcomes at later ages (including joint attention) (Gaffan et al., 2010; Gueron-Sela et al., 2015). Complementary evidence also derives from intervention programs implemented in the first months of life, aiming to improve parents' responsiveness and sensitivity to their preterm infants' signals. Results demonstrated a significant beneficial effect for premature infants whose parents participated in the intervention, when compared to the preterm control group, in terms of more positive social engagement (e.g., more attentiveness, alertness and approaching behaviors, as well as more initiating joint attention) (Landry, Smith, & Swank, 2006; Newnham, Milgrom, & Skouteris, 2009, Olafsen et al., 2006). Therefore, future studies may benefit from longitudinal designs, so that we might equally address parents' adaptation to their infant's increased level of social competence.

Some of these future avenues of research may be answered, for example, by adopting a methodological design similar to the larger longitudinal project of which paper 2 is part, with multiple assessment time points and, simultaneously, including variables of the infant and the caregiver.

In sum, our papers extend previous literature on the development of joint attention abilities, by examining the effect of prematurity, specific dimensions of maternal interactive style, and infants' physiological regulation, and discussing the results in light of extant empirical evidence and distinct sources of influences (individual brain and behavior and environmental factors), which may advise future investigation on this field.

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