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It's You and Me: Infants' cross-modal communicative signals and mother-infant interactive behavior predict infant regulatory patterns in the still-face paradigm at 3 months

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ABSTRACT

Infant regulatory behavior develops since birth and impacts their early social interactions. Infants differ in the relative coherence and incoherence of their cross-modal communicative signals during *en-face* infant-caregiver interactions. We expand this research by evaluating whether different infant regulatory patterns observed during the Face-to-Face Still-Face (FFSF) at 3 months are associated with the coherence or incoherence of infants' cross-modal communicative behaviors during *en-face* interactions or with multiple dimensions of mother-infant interactive behavior during free-play. Analyses were based on data collected from 100 mother-infant dyads from urban, working- and middle-class backgrounds in Portugal who were videotaped during the FFSF and free play at 3 months. Results confirm that infants' different regulatory behavior patterns in the FFSF at 3 months are associated with the coherence and incoherence of their cross-modal interactive behaviors and specific aspects of mother-infant interaction. Infants with a Social-Positive oriented regulatory pattern during the FFSF displayed more coherent and less incoherent communicative behaviors with their mothers and were more cooperative during free play. In turn, their mothers were more sensitive. Our findings support the perspective that infants' regulatory behavior strategies in the context of caregiver regulatory support and sensitivity are likely to increase dyadic correspondence and infant ability to engage with the world.

1. Introduction

Early in the first year, infants begin to develop interactive and regulatory abilities that impact their social and emotional development (Sameroff & Fiese, 2000; Sroufe, 1997). These regulatory processes have roots in the prenatal period and rapidly evolve into a more sophisticated organization across the first year and beyond (Tronick et al., 2020). Despite their immaturity, most three-month-old infants already display an organized pattern of regulatory responses when confronted with socioemotional interactive challenges (Barbosa et al., 2018; Fuertes et al., 2022; Montirosso et al., 2010; Tronick & Cohn, 1989). Yet young infants vary in how

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successful they are in regulating their emotional arousal during early *en-face* interactions. These variations reflect, in part, individual differences in infants' ability to regulate their own internal physiological, perceptual, behavioral, and affective states (e.g., Carter et al., 1990; Cohn et al., 1991; Tronick et al., 1982). Because the capacity for regulation reflects the interplay of multiple transacting biopsychosocial systems, which only gradually become hierarchically organized and coordinated, three-month-old infants often have difficulty regulating their emotional arousal.

Infants' interactive and regulatory capacities also reflect the quality and consistency of regulatory support and sensitivity they receive from their caregivers (Feldman, 2007; Tronick & Beeghly, 2011). Thus, the regulatory capacities of young infants emerge in a dyadic context. Perhaps consequently, infants' early emerging regulatory abilities are linked to their attachment organization by the end of the first year (McElwain et al., 2003) and predict other aspects of their socioemotional development. For instance, infants' difficulties in early emotional regulation are linked to posterior outcomes (e.g., social withdrawal, aggressive behavior, and attention disorders) for a review, see Calkins and Fox, (2002).

One possible reason for these cross-time associations might be that young infants differ in their ability to convey their communicative needs and goals to their caregivers clearly and coherently. During early infant-caregiver interactions, young preverbal infants exhibit flexibly organized configurations of facial, vocal, affective, and motor behavior that convey convergent messages about their internal states and desires to caregivers (Beebe et al., 2010; Beebe et al., 2014; Weinberg & Tronick, 1996). When infants' cross-modal configurations of interactive behaviors are coherent (e.g., infants look and smile at their parent while also reaching out their arms for them), they convey clear and convergent information to the parent about their current states and needs (*cross-modal coherence*). In recent longitudinal research (Beebe et al., 2010; Fuertes et al., under review), infants who displayed coherent cross-modal interactive behaviors about their states and needs more frequently during *en-face* infant-caregiver social interactions were more likely to form a secure attachment relationship with their caregiver by the end of the first year. This may be because greater cross-modal coherence in infants' interactive behaviors is easier for caregivers to read and respond to accurately. Thus, the capacity for greater cross-modal coherence may afford infants greater efficacy in attaining their interactive and regulatory needs, which in turn supports their attachment goal-corrected responses, building felt security and basic trust (Beebe et al., 2014).

In contrast, early cross-modal configurations of interactive behavior that are temporally delayed, discrepant, mixed, or contradictory, such as reaching for the caregiver while gaze averting, may contribute to *cross-modal incoherence.* Incoherent social communicative configurations can be misinterpreted by caregivers, which may undermine caregivers' ability to effectively scaffold and soothe infant distress, prolonging infants' emotion dysregulation and disengagement. If such interactive mismatches are prolonged and occur often, they could undermine the quality of infant-caregiver interactions and eventually lead to the formation of insecure attachment (Barbosa et al., 2020). In support of this notion, work by Beebe et al. (2010) shows that greater cross-modal discrepancy in infants' interactive behaviors at 4 months is associated with a higher prevalence of disorganized attachment at 12 months. Other research found, in a study including infants born full-term and very preterm, that infants' coherence of their cross-modal communicative signals during *en-face* infant-caregiver interactions at 3 months was associated with secure attachment and infants' incoherence associated with insecure attachment (Fuertes et al., 2023).

How infants organize their interactive and regulatory behaviors is thought to be flexible, varying according to internal and external cues. Infants' capacity for exhibiting cross-modal coherence or incoherence in their interactive behaviors during *en-face* interactions also likely reflects their current repertoire of regulatory skills, which contributes to either positive and reciprocal, or negative and mismatched, caregiver-infant interactions.

Infants who are skilled at internal regulation become increasingly capable of accomplishing their goals with external environmental inputs. According to Sander (1975), this development process starts with preempted physiological states which move to regulatory abilities, often focused on establishing and maintaining reciprocal relationships with caregivers. Gradually, these regulatory skills contribute to attachment organization and the formation of self.

Although young infants do not depend solely on caregivers to regulate their states and behaviors, caregivers' regulatory support is crucial in facilitating infants' successful regulation, especially in stressful situations (Beeghly et al., 2010). During infant-caregiver interactions, infants possess a repertory of age-possible regulatory behaviors such as gaze aversion, turning away from the distressing stimulus (distancing), engaging in self-comforting behaviors such as thumb-sucking or engaging in object exploration (distraction) (Weinberg & Tronick, 1994). The caregiver's ability to read these "cues" regarding their infant's current state and interactive goals allow them to soothe their infants more effectively or redirect their infant's attention behavior so that regulation and social engagement are restored. Thus, infant regulatory capacities reflect dyadic mutual regulatory processes that are fundamental in facilitating infants' ability to re-engage in social interaction and accomplish their social and affective goals.

The present study attempts to shed further light on infants' early regulatory patterns observed during the FFSF (Face to Face Still-Face) at 3 months by investigating whether they are associated with infant or maternal interactive behavior in other contexts, including the relative coherence or incoherence of infants' communicative behaviors during *en-face* interactions, or with multiple dimensions of maternal and infant interactive behavior observed during an independent free play session at 3 months. Specifically, we evaluated whether infants who display fewer positive patterns of emotional regulation during the FFSF at 3 months would also exhibit more incoherent cross-modal interactive behaviors during *en*-face interactions and receive less maternal sensitivity during infant-caregiver interactions in other contexts. This understudied topic is significant because infants with less optimal regulator strategies may be at heightened risk for developing an insecure attachment organization by the end of the first year, if not compensated for by sensitive caregiving and regulatory support.

2. Infant regulatory behavior patterns in the FFSF at 3 months

The FFSF (Tronick et al., 1978) is frequently used to investigate individual differences in infants' regulatory behavior in response to temporary maternal emotional unavailability and provides a reliable window for examining infants' emerging regulatory abilities from 2 months on (Adamson & Frick, 2003). When confronted with a still-faced parent following a period of reciprocal infant-parent social interaction, infants typically exhibit a robust "still-face effect", characterized by a decrease in positive affect relative to baseline and an increase in negative arousal and self-comforting behaviors (Cohn & Tronick, 1989; Gianino & Tronick, 1988; Mayes & Carter, 1990; Toda & Fogel, 1993; Tronick et al., 1978; Weinberg & Tronick, 1994). During the reunion episode of the FFSF, when the parent resumes regular interactive play, infants typically exhibit a "reunion effect" characterized by a rebound of positive affect along with a partial carry-over of negative affect (Mesman et al., 2009).

However, not all infants react similarly to the social stressors encountered in the FFSF. An extensive line of research shows that infants vary in their regulatory responses to the maternal still-face and across all FFSF episodes. For example, in their pioneering work, Cohn and Tronick (1989) showed that infants differ in the amount of positive responses they display in both the Still-Face and reunion episodes of the FFSF. Similarly, Mayes and Carter (1990) noted that some three months old infants in their study exhibited high positive behaviors and a low incidence of negative behaviors during the still-face episode, SF, while others appeared to be present the typical still-face effect (i.e., highly distressed and inconsolable during still-face).

In early work, Gianino and Tronick (1988) identified two regulatory strategies utilized by infants: orientation towards the other ("other-directed regulatory behaviors") and orientation towards self-repair ("self-directed regulatory behaviors"). In the first case, infants communicate their states and emotions to their caregiver, which guides the caregiver's responses. In the second case, the infant seeks to regulate their negative emotions by engaging in self-comforting, or by avoiding or distancing themselves from the caregiver, or by engaging in distraction, such as attending to objects and other forms of exploratory behavior (Cohn & Tronick, 1989; Gianino & Tronick, 1988; Tronick & Cohn, 1989).

In subsequent micro-analytic research, other investigators (Fuertes et al., 2006; 2009) identified three patterns of infant regulatory behavior during the FFSF from cluster analysis: (i) a Socially Positive Orientation; (ii) Socially Negative Orientation; and (iii) a Self-Comfort Orientation. However, this typology only considered the quality (positive, negative, and self-comfort behaviors) and intensity of these behaviors. More recently, several studies produced typologies to describe infant regulatory behavior patterns during the FFSF paradigm (e.g., Barbosa et al., 2018; Fuertes et al., 2021; Ham & Tronick, 2006; Montirosso et al. 2015; Papousek, 2007; Ribeiro et al., 2020; Seixas et al., 2017). Taking into consideration these typologies and related findings from prior research and based on the infants' behavior during the FFSF, Fuertes, and Lopes-Santos (2009) identified 3 patterns of infant regulatory behavior across all episodes of the FFSF that were based on: (a) infants' specific behavior organization (e.g., the infant exhibits predominantly socially positive behavior, distress, or self-comforting behavior, or mixed behavior); (b) the intensity of infants' exhibited behavior (e.g., the infant displays prolonged and intense crying); (c) quality of infant behaviors (e.g., the infant reacts by displaying communicative signals to the caregiver denoting pleasure such as smiles or laughter, and engages in reciprocal neutral or positive vocalizations); and (d) infants' ability to recover from negative affect during the reunion episode of the FFSF. These regulatory patterns include: (a) a *Social-Positive Oriented regulatory pattern,* which is characterized predominantly by positive affect during high/moderate reciprocal interactions with their caregiver. Interactive mismatches are easily repaired, and infants tend to recover quickly from the stress of the still-face episode during the reunion episode; (b) a *Distressed-Inconsolable Oriented* regulatory pattern, in which infants exhibit periods of disengagement or moderate negative affect in the first episode followed by intense negative affect during the still-face episode that continues or even increases during the reunion episode; and (c) a *Self-Comfort Oriented* regulatory pattern, in which infants exhibit apparent avoidance of the adult (e.g., gaze aversion and distancing) in the first and third interactive episodes, and engage in frequent self-comforting behaviors such as thumb-sucking across all episodes. Only this last typology was used in this study. However, further studies are needed to understand the overlap between the various typologies of regulatory patterns observed in FFSF.

The Social-Positive Oriented, Distressed-Inconsolable Oriented and Self-Comfort Oriented regulatory patterns have been observed in a variety of different samples, including infants varying in biological risk, including infants born full-term (Barbosa et al., 2018; Fuertes et al., 2022; Seixas et al., 2017), infants born moderate-to-late preterm (Fuertes et al., 2022), and infants born very preterm (Antunes et al., 2023). Moreover, these patterns have been identified in both Portuguese and Brazilian samples (Fuertes et al., 2021; Ribeiro et al., 2020). Other research shows that these three patterns are relatively stable from 3 to 9 months of age and are associated with markers of infant physiological reactivity during the FFSF (Barbosa et al., 2018), and are linked to infants' later attachment organization in the Strange Situation (Barbosa et al., 2020). Specifically, infants who exhibited a Social-Positive Oriented regulatory pattern during the FFSF at 3 months of age were more likely to be classified as securely attached at 12 months. In contrast, infants who showed a Distressed-Inconsolable pattern were more likely to be classified as insecure-ambivalent. In contrast, infants who exhibited a Self-Comfort Oriented regulatory pattern were more likely to be classified as insecure-avoidant (e.g., Barbosa et al., 2020).

2.1. Factors associated with infant interactive behavior and regulatory patterns in the FFSF

Coherence and incoherence of infants' cross-modal interactive behavior. Several studies found significant associations between different dimensions of infants' cross-modal interactive behavior (e.g., direction of gaze, facial affect, vocalizations, motor movements) during the FFSF, the quality of parental interactive behavior, and infants' regulatory behavior patterns. For instance, 6 months old infants, whose parents were highly responsive and more contingent in their responses to them, looked more at their parents during play and reunion episodes of FSFF and appeared less upset during the reunion episode, compared to infants whose parents were less responsive and contingent (Haley & Stansbury, 2003). This suggests that infants' cross-modal interactive behaviors in the FFSF reflect their

current social orientation and regulatory style. However, according to our best knowledge, no prior studies have linked the coherence and incoherence of infants' cross-modal interactive behaviors during infant-parent *en-face* interactions with the three infant regulatory behavior patterns.

Maternal and infant interactive behavior in other contexts. Several dimensions of maternal behavior, such as responsiveness, sensitivity, and positivity, are associated with infants' regulatory behavior during the FFSF. Tronick et al. (1982) found that maternal sensitivity to 9-month-old infants' cues during the first baseline episode of the FFSF was associated with infants' more frequent positive bids to the mother during the still-face episode. Similarly, Kogan and Carter (1996) reported that 4-month-old infants who exhibited more positive affective behavior during the still-face episode of the FFSF had mothers who were more sensitive and responsive to them during the reunion episode.

Maternal interactive behavior evaluated outside the FFSF is also linked to infants' responses during the FFSF. Carter et al. (1990) found that parents' display of positive affect during parent-infant free play interactions is associated with their infants' greater tendency to look at the mother during the FFSF. Consistent with these results, Braungart-Rieker (1998) report that parents' appropriate responses to their infant's behavioral cues are associated with less infant negative affect and more frequent social gazing at the mother during the still-face episode of the FFSF. These results suggest that the quality of maternal interactive behavior experienced by infants (both outside and inside the FFSF) is associated with differences in infants' emotional regulatory behaviors during the FFSF. Consistent with this perspective, recent research shows that greater maternal sensitivity to infants during free play at 3 months is higher among dyads in which infants displayed a Social-Positive Oriented regulatory pattern in the FFSF (e.g., Barbosa et al., 2019; Fuertes et al., 2011; Fuertes et al., 2022).

Given that infants' regulatory patterns are typically identified during the FFSF, an interactive context, and are linked to maternal interactive behavior in other contexts, infants' regulatory patterns should be interpreted from a dyadic perspective. That is, infants' regulatory behavior patterns likely transact with caregivers' interactive behavior in a bidirectional manner. In the current study, we hypothesize that infants who express themselves with positive patterns of regulatory behavior during the FFSF will be more likely to exhibit more coherent cross-modal communicative behaviors to their caregivers. In turn, greater coherence in infants' cross-modal interactive behaviors during *face-to-face interactions makes it easier for caregivers to read and respond* accurately. Even when these infants exhibit negative behaviors, they do so coherently, and those behaviors can be easily read in the context (e.g., an infant is likely to be distressed when hungry or tired). We therefore expect that infants who experience higher levels of maternal sensitivity during free play interactions at 3 months will also be more likely to exhibit a Social-Positive Oriented regulatory pattern in the FFSF, a pattern that is associated with a more reciprocal and engaged dyadic interaction. A primary goal of the current study is to evaluate and describe these understudied associations to learn more about maternal and infant interactive behavior and their links to infants' early regulatory patterns.

2.2. Goals of this study

The current study's overarching goal is to better understand the nature and correlates of infants' early regulatory patterns in a full-term sample of Portuguese 3-month-old infants and their mothers. We addressed this goal by investigating four specific study aims.

The first was to evaluate whether the coherence or incoherence of infants' interactive behaviors, scored microanalytically during *en-face* play at 3 months (the baseline episode of the FFSF) were associated with infants' regulatory patterns observed across all FFSF episodes (Social-Positive Oriented, Distressed-Inconsolable, or Self-Comfort oriented). The second aim was to determine whether multiple dimensions of maternal and infant interactive behavior observed during an independent free play session at 3 months were associated with the three infant regulatory behavior patterns in the FFSF. We also evaluated the associations between the three infant regulatory behavior patterns in the FFSF and demographic factors.

The third aim was to evaluate correlations between infants' coherent and incoherent cross-modal interactive behavior at 3 months during the first episode of FFSF, and maternal and infant interactive behaviors during free play at 3 months in free-play. Also, we tested the association between those factors (infants' coherent and incoherent cross-modal interactive behavior, maternal and infant interactive behaviors) with demographic variables.

The fourth exploratory aim was to conduct covariate-controlled multinomial logistic regressions, to identify specific predictors of infants' regulatory patterns in the FFSF, including the coherence and incoherence of infants' cross-modal interactive behavior, maternal and infant interactive behaviors in free play. It is our hope that addressing these aims will help shed more light on maternal, infant, and demographic contributions to infants' early emotional regulation strategies.

3. Methods

3.1. Sample characteristics

Participants were 100 infants (48 girls; 52 boys, 50 firstborn) and their mothers ($M_{\text{maternal age}} = 31.61$ years, $SD = 4.09$, range: 20–39) from urban working- to middle-class backgrounds in Portugal. All infants were healthy, full-term, and clinically normal at delivery as determined by pediatric examination. Infants' birth weight ranged from 2000 to 4350 g ($M = 3295.75$, $SD = 429.85$), and their gestational age at delivery ranged from 37 to 42 weeks ($M = 39.52$ weeks, $SD = 1.07$). Infants' first-minute Apgar scores ranged from 5 to 10 (M=9.07, SD=.64), and fifth-minute Apgar scores ranged from 9 to 10 (M=9.95, SD=.22), denoting good health and recovery from the stresses of labor and delivery. According to health records, no infants had any known sensory or motor impairments, serious illnesses, or congenital anomalies at delivery. No parents had any known mental health or drug/alcohol addiction problems. All

eligible dyads, whose infants were born during the research timeline at the selected hospital, were contacted, resulting in a total of 166 infants (the population). Out of these, 66 either dropped out or did not agree to participate in the project. Therefore, based on Fisher Formula, the expected sample size is 100 for a 95% confidence interval and a population proportion of 80%.

Of the 100 mothers, 93 were Portuguese-born and seven were born in other countries (Spain, France, South-Africa, Guinea, or Brazil). Most mothers had completed high school ($M_{\text{maternal formal education}} = 14.73$ years, $SD = 3.49$, range: 6–23). According to the latest available data from the National Statistical Institute (INE, 2020), this maternal education level falls slightly above national indices. Regarding employment status, 72% of the mothers had full-time jobs, 15% worked part-time, and 13% were unemployed. This distribution falls somewhat above the Portuguese employment rate for women with children under age two (about 68%; INE, 2022). Eighty-five of the 100 infants in the current sample lived with both parents co-residing as couples in the same household, and 41 couples were formally married.

3.2. Procedures

All procedures in this study were conducted according to the ethical guidelines presented in the Declaration of Helsinki, with written informed consent obtained from all mothers before any assessment or data collection took place. All procedures were approved by the Ethics Committees of all Health Units and Hospitals involved and by the Portuguese Data Protection Commission.

Recruitment and Inclusion Criteria. Recruitment took place in hospitals in metro Lisbon (an urban area) and was carried out by three trained researchers. To be eligible to participate in this study, infants had to meet the following inclusion criteria: i) delivery at 37 weeks gestational age or more; ii) no evidence of sensory or neuromotor impairments; iii) absence of severe health conditions (e.g., chronic lung disease) or congenital anomalies, at the time of recruitment. Mothers to be eligible had to be free of any clinical mental health problems or drug/alcohol dependence, as determined by medical record and maternal self-report. Mother-infant dyads who met inclusion criteria were invited to participate. All procedures were approved by the Ethics Committees of all Health Units and Hospitals involved and by the Portuguese Data Protection Commission according to the ethical guidelines presented in the Declaration of Helsinki. All eligible, recruited mothers and fathers (except single mothers) provided written informed consent to their and their infant's participation before any assessment or data collection occurred.

3.3. 3-month laboratory visit

At 3 months postpartum, recruited, eligible mothers were recontacted to schedule a follow-up visit to the laboratory with their infant. Mother-infant dyads were videotaped during this visit during an unstructured free-play session followed by the FFSF.

Free play interaction. Following the instructions of the CARE-Index manual (Crittenden, 2003), each dyad was videotaped for 5 min during an unstructured play session. Mothers were invited to play with the infant as they normally would at home but were given no specific instructions about how.but mothers were free to use or not use the toys as they wished. Additionally, a chair was provided for mothers who wished to play with their infant while sitting and holding the infant in their lap.

Face-to-Face Still-Face paradigm (FFSF, Tronick, et al., 1978). The FFSF paradigm includes three successive three-minute episodes: (a) a face-to-face baseline interaction during which mothers were instructed to play with their infants as they normally would at home without using toys or pacifiers; (b) a still-face perturbation, during which mothers were instructed to keep a *"poker face"* while looking at the infants, and to refrain from smiling, talking, or touching the infant; and (c) a reunion episode, during which mothers were instructed to resume their typical play interaction with the infant. Mothers and infants were sitting in separate chairs facing each other during all three episodes of the FFSF, at the mother arm reaching distance. To mark the beginning and end of each episode for scoring purposes, each episode was separated by a 15-second interval during which the mother was asked to turn away from the infant.

Mothers and infants were videotaped during the FFSF using two cameras, one focused on the mother's face and upper torso, and the other focused on the infant's face and body. Both cameras were connected to an image mixer software that generated a time-synchronized split-screen image of each partner on a single video record.

3.4. Measures

3.4.1. Infant regulatory patterns during the FFSF

The Coding System for Infant Regulatory Behavior Patterns in the FFSF (CoIRBP, Fuertes & Lopes-dos-Santos, 2009) was used to score infants' regulatory organized patterns from videotapes of the FFSF at 3 months. This coding system describes three patterns of infants' regulatory behavior: Social-Positive Oriented, Distressed-Inconsolable, and Self-Comfort Oriented, that were derived from four dimensions of infants' behavior and affective facial expressions across all three episodes of the FFSF paradigm: (a) behavior organization (e.g., the infant exhibits predominantly positive social behavior, distressed behavior, or self-comforting behavior, or a mixed-pattern behavior); (b) intensity of exhibited behavior (e.g., the infant displays prolonged and intense crying); (c) quality of behavior (e.g., the infant reacts by displaying signals denoting pleasure such as smiles, laughter, and reciprocal neutral or positive vocalizations); and (d) infants' ability to recover from negative affect during the reunion episode of the FFSF.

3.4.2. Coherence and incoherence of infant communicative signals during en-face interaction

The Coding System for Infants' Coherent and Incoherent Cross-Modal Interactive Behavior (CoICIB, Fuertes et al., 2023) was used to score infants' coherent and incoherent cross-modal interactive behavior microanalytically during the first baseline FFSF episode (*en-face* play).

According to this system, *Coherent cross-modal interactive behaviors* included the following three combinations of infant affect and behaviors: (i) Looking at the mother and smiling, ii) Looking at the mother and vocalizing (positive or neutral vocalizations), and iii) Looking at the mother and directing their arms and body in her direction. Each behavioral configuration was computed (present or not present) second-by-second during for each infant in both samples. The frequency of all instances of coherent cross-modal configurations exhibited by each infant was used in the statistical analyses in the current study.

Incoherent (discrepant) cross-modal interactive behaviors included the following six configurations of infant affect and behaviors (all were scored while the mother was trying to engage the infant in interaction): (i) Looking away and smiling as the mother attempts to engage, ii) Looking at an object and smiling as the mother tries to engage, iii) Looking away and vocalizing as the mother tries to engage, iv) Looking at an object and vocalizing as the mother tries to engage, v) Closing eyes and verbally protesting while directing their arms and body in mother's direction; and vi) Looking away turning head, while directing arms in mother's direction. The frequency of incoherent cross-modal behavior combinations was tallied for each infant and used in the statistical analyses in the current study. These behavioral configurations are labeled incongruent because infants response sends contradictory messages, for instance, while seeking proximity or interaction, they exhibit behaviors that communicate otherwise (e.g., close their eyes) or smile without look at mothers in response to the mother solicitations.

In prior research with this system, researchers (Fuertes et al., 2023) describe other coherent (positive and negative) and incoherent cross-modal behavioral configurations, but because these configurations are rare, they were not included in the final version of the system.

Two trained coders who were masked to background variables and the study's hypotheses independently scored a randomly selected set of 40 videotapes for infants' coherent and incoherent cross-modal interactive behaviors to evaluate inter-coder reliability. The average Cohen's kappa coefficient for inter-rater agreement was.74, denoting a very good agreement. To evaluate intra-observer reliability over time (coder drift), the first coder re-scored 20 randomly selected cases after a three-month interval. The average Kappa coefficient (k = .90) indicated excellent reliability.

3.5. Mother-infant interactive behavior during free play

According to the Care-Index manual (Crittenden, 2003), maternal sensitivity is defined as any pattern of behavior that pleases the infant, increases the infant's comfort and attentiveness, and reduces the infant's distress and disengagement.

Multiple dimensions of mother-infant interactive behavior during the 5-minute free play session were scored using the *Child-Adult Relationship Experimental Index* (CARE-Index, Crittenden, 2003). Points are then added to yield seven scale scores, including three independent adult scales (Sensitivity, Control, and Unresponsiveness), and four separate infant scales (Cooperative, Compliant-Compulsive, Difficult, and Passive behaviors). Each maternal and infant scales were scored in terms of facial expressions, verbal expressions, position and body contact, affection, turn-taking, control contingencies, and choice of activity (from 0 to 14 points). Each scale (e.g., maternal sensitivity) includes descriptors for each dimension (e.g., facial expression). To score each scale in each dimension, the coder can attribute 2 points (e.g., total sensitivity in facial expression), split points for mixed behaviors (e.g., 1 point for sensitivity and 1 point for passivity in facial expression) or give no points. A final scale score of 14 points means total quality in all dimensions (facial, verbal, physical, affective, reciprocity, contingency, play).

To score one must attend to each partner's behavior, using a dyadic frame (i.e., considering the mother interactive behavior when scoring the infant and vice-versa). For example, if a child smiles in response to a mother's positive behavior, it is considered cooperative behavior. However, if the child smiles while their mother is upset or intrusive, it is coded as compulsive/compliant behavior.

Two coders trained on the CARE-Index and masked against to study's hypotheses scored the videotaped free-play interactions. Intercoder reliability was evaluated by comparing the two coders' ratings using intraclass correlation coefficients (ICC) (Cicchetti, 1994). The obtained overall average ICC was.81, denoting good reliability.

3.6. Analytic plan

Four sets of statistical analyses were conducted to address the aims of the current study. These are described below.

(1) The first aim was to investigate whether the three infant regulatory patterns observed during the FFSF at 3 months (Social-Positive Oriented, Distressed-Inconsolable, and Self-Comfort Oriented) were associated with the frequency of infants' coherent and incoherent cross-modal interactive behaviors during the first (baseline) scored during the first (baseline) FFSF episode at 3 months. To accomplish this aim, three subsets of analyses were performed. In the first, the distribution of the three infant regulatory patterns (scored across all FFSF episodes) was obtained using univariate frequency analysis. The second set of analyses calculated the frequency of infants' coherent and incoherent cross-modal interactive behaviors during the first FFSF episode. In the third set of analyses, ANOVAs were used to evaluate the associations between the three regulatory patterns and the frequency of infants' cross-modal coherent and incoherent interactive behaviors. When significant overall effects were observed, the differences between specific groups were further explored using Tukey's post hoc tests. Size effect analyses (Eta squared, η^2) were conducted to evaluate the magnitude of the differences among the patterns of regulatory behavior. According to Cohen (1988), a small effect is defined when $\eta^2 = 0.01$, a medium effect when $\eta^2 = 0.06$, and a large effect when $\eta^2 = 0.14$.

(2) The second aim was to determine whether dimensions of maternal and infant interactive behavior during free play at 3 months and demographic factors were associated with the three patterns of infant regulatory behavior in the current sample. These analyses were accomplished using ANOVAs.

(3) The third aim was to test the bivariate associations between infants' coherent and incoherent cross-modal interactive behavior

at 3 months during the first episode of FFSF, maternal and infant interactive behavior at 3 months in free play and demographic variables using Pearson correlations.

To identify potential covariates (see Aim 4), the bivariate associations between candidate infant medical and family demographic variables and the study variables (i.e., infants' regulatory patterns in the FFSF, the coherence and incoherence of infants' cross-modal interactive behaviors during the first FFSF episode, and maternal and infant interactive behavior during free play) were also evaluated. All variables with statistically significant association to the dependent variables (i.e., the three infant regulatory behavior patterns) were identified as a possible covariate for the analyses conducted in Aim 4. Candidate medical covariates included infants' gestational age at delivery, birth weight, and Apgar scores at 1 and 5 min post-delivery. Candidate familial demographic variables included maternal age, maternal education, and the number of siblings living in the household.

(4) The fourth exploratory aim was to conduct covariate-controlled multinomial logistic regression analyses to identify specific interactive predictors of infant regulatory patterns. Candidate predictors included infant cross-modal coherent and incoherent behavior, mother, and infant interactive behaviors during free play. Any qualifying demographic variable identified in Aim 3 was also entered as a covariate. Variables with high collinearity were excluded from the analyses.

All statistical analyses were carried out using SPSS for Windows, version 27. Findings were denoted as statistically significant using an alpha of $< .05$. To carry out the mean difference tests, the assumptions of normality and homogeneity of variances were tested.

4. Results

Aim 1: Are differences in the frequency of infants' coherent and incoherent cross-modal interactive behavior during *en-face* play associated with infants' regulatory behavior patterns in the FFSF?

Distribution of the three patterns of infant regulatory behavior in the FFSF at 3 months. In the current sample, 54 (54.4%) infants presented a Social-Positive Oriented regulatory pattern during the FFSF at 3 months, which was the most frequent pattern. An additional 30 (30.3%) infants exhibited a Distressed-Inconsolable regulatory pattern, whereas 15 (15.2%) infants displayed a Self-Comfort oriented pattern.

Associations between the three regulatory patterns and the frequency of infants' coherent and incoherent cross-modal interactive behaviors. Descriptive statistics and ANOVA results are presented in Table 1. On average, infants with a Social-Positive Oriented regulatory pattern exhibited more frequent coherent cross-modal interactive behaviors with their mother during the first FFSF episode at 3 months, compared to infants with either a Distressed-Inconsolable or a Self-Comfort Oriented regulatory pattern [$F(2) = 8.067$; $p = .001$; $\eta^2 = .146$]. Infants with a Social-Positive Oriented regulatory pattern were also less likely than infants in the other two groups to exhibit more frequent incoherent cross-modal interactive behaviors [$F(2) = 6.282$; $p = .003$; $\eta^2 = .134$].

Regarding specific configurations of *coherent* cross-modal interactive behaviors, infants with a Social-Positive Oriented pattern looked and smiled at their mother more often than infants with other regulatory patterns [$F(2) = 9.615$; $p = .001$; $\eta^2 = .170$]. These infants also looked at their mother while vocalizing more frequently than infants with Self-Comfort Oriented pattern [$F(2) = 4.464$; $p = .014$; $\eta^2 = .087$].

Regarding specific configurations of *incoherent* cross-modal interactive behaviors, infants with a Self-Comfort Oriented regulatory pattern were more likely than infants with a Social-Positive Oriented regulatory pattern to look away and smile as the mother tried to

Table 1
Means, Standard Deviations, and ANOVA Results for Infants' Coherent and Incoherent Cross-Modal Interactive Behaviors, according to Infants' Regulatory Behavior Patterns at 3 Months.

Infant Behavior	Social-Positive Oriented pattern *M (SD)*	Distressed-Inconsolable pattern *M (SD)*	Self-Comfort-oriented pattern *M (SD)*	*F*	*p*	*Tukey HSD*	η^2
Coherent cross-modal interactive behavior							
Looking at the mother and smiling	23.83 (11.55)[a]	15.47 (11.04)[b]	10.46 (12.66)[c]	9.615	.001	a>b,c	.170
Looking at the mother and vocalizing	17.43 (8.89)[a]	14.87 (7.29)[b]	9.54 (10.66)[c]	4.464	.014	a>c	.087
Looking at the mother and directing arms and body in mother's direction	5.59 (5.12)[a]	6.13 (6.04)[b]	5.29 (5.47)[c]	2.780	.067	-	.056
Total of coherent behaviors	46.87 (21.38)[a]	36.47 (18.25)[b]	22.08 (24.75)[c]	8.067	.001	a>b,c	.146
Incoherent cross-modal interactive behavior							
Looking away and smiling as the mother tries to engage	2.18 (3.56)[a]	3.00 (4.68)[b]	7.23 (9.35)[c]	5.331	.006	c>a	.102
Looking at an object and smiling at it as the mother tries to engage	2.87 (4.25)[a]	2.07 (3.49)[b]	7.85 (7.55)[c]	7.645	.001	c>a,b	.140
Looking away and vocalizing as the mother tries to engage	4.28 (4.98)[a]	5.47 (8.78)[b]	9.54 (8.78)[c]	4.290	.016	c>a	.084
Looking at an object and vocalizing as the mother tries to engage	1.74 (3.50)[a]	4.00 (8.27)[b]	8.69 (7.32)[c]	7.355	.001	b,c>a	.135
Closing eyes and verbally protesting while directing arms and body in mother's direction	.39 (1.39)[a]	3.53 (6.82)[b]	2.23 (4.23)[c]	5.555	.005	b>a	.106
Looking away and turning head while directing arms in mother's direction	1.28 (3.78)[a]	5.67 (7.09)[b]	2.61 (6.38)[c]	6.453	.002	b>a	.121
Total of incoherent behaviors	12.98 (13.60)[a]	22.40 (13.99)[b]	26.20 (13.37)[c]	6.282	.003	b,c>a	.134

engage them in interaction [$F(2) = 5.331$; $p = .006$; $\eta^2 = .102$], and to look away and vocalize as the mother tried to engage them [$F(2) = 4.290$; $p = .016$; $\eta^2 = .084$]. Infants with a Self-Comfort Oriented pattern were also more likely than infants in both of the other groups to look and smile at an object while the mother tried to engage them [$F(2) = 7.645$; $p = .001$, $\eta^2 = .140$. In turn, infants with a Distressed-Inconsolable regulatory pattern and infants with a Self-Comfort Oriented pattern were more likely than infants with a Social-Positive Oriented regulatory pattern to look at an object and vocalize while the mother tried to engage with them [$F(2) = 7.355$, $p = .001$, $\eta^2 = .135$]. Also, infants with a Distressed-Inconsolable regulatory pattern were more likely than infants with a Social-Positive Oriented pattern to close their eyes while verbally protesting and directing their arms and body in the mother's direction [$F(2) = 5.555$; $p = .005$ $\eta^2 = .106$], and to look away and turn the head away while directing their arms in the mother's direction [$F(2) = 6.54$, $p = .002$, $\eta^2 = .121$].

Aim 2: Are dimensions of maternal and infant interactive behavior, and demographic variables during free play associated with infants' patterns of regulatory behavior in the FFSF?

Descriptive statistics and ANOVA results for this aim are presented in Table 2. Findings show that infants classified as having a Social-Positive Oriented regulatory pattern in the FFSF were, on average, more cooperative with their mother during free play [$F(2) = 7.352$; $p = .001$; $\eta^2 = .134$] than infants with a Self-Comfort Oriented regulatory pattern in the FFSF. In turn, their mothers were more sensitive to them [$F(2) = 5.511$; $p = .005$; $\eta^2 = .104$]. In turn, infants with a Distressed-Inconsolable regulatory pattern in the FFSF were more difficult during free play with their mother, compared to infants with other regulatory patterns in the FFSF [$F(2) = 5.442$; $p = .006$; $\eta^2 = .103$], and their mothers were more unresponsive to them [$F(2) = 3.615$; $p = .031$; $\eta^2 = .071$]. Lastly, infants with a Self-Comfort Oriented regulatory pattern in the FFSF exhibited more compulsive/compliant behavior with their mother during free play than infants with other regulatory patterns [$F(2) = 17.973$; $p = .001$; $\eta^2 = .275$], and their mothers were more controlling and intrusive with them during free play [$F(2) = 16.858$; $p = .002$; $\eta^2 = .128$].

The ANOVA analyses was used to test the mean differences of infants' patterns of regulatory behavior in the FFSF on a range of demographic variables including gestational weight, gestational age, Apgar scores at first and fifth minute, number of siblings, maternal age, and maternal years of education. With Post-Hoc Tuckey Test, we found that Apgar at first minute was higher in infants classified as having a Social-Positive Oriented regulatory pattern in the FFSF compare to infants with a Self-Comfort Oriented regulatory pattern [$F(2) = 3.859$; $p = .025$; $\eta^2 = .087$]. Therefore, Apgar 1 was included as a covariate in the multinomial logistic regression analyses conducted in Aim 4.

Aim 3: Are maternal and infant interactive behavior, and demographic variables during free play correlated with infants' coherent and incoherent cross-modal interactive behaviors in the first episode of the FFSF?

Results of Pearson correlations indicated that mothers' sensitivity to their infant during free play was positively correlated with infants' more frequent display of coherent cross-modal interactive behaviors during the first FFSF episode ($r = .247$; $p = .015$) and negatively correlated with infants' more frequent display of incoherent cross-modal interactive ($r = -.377$; $p = .001$). Similarly, infants' cooperative behavior with the mother during free play was positively correlated with the frequency of their coherent cross-modal interactive behaviors ($r = .234$; $p = .021$) and negatively correlated with the frequency of their incoherent cross-modal interactive behaviors ($r = -.372$; $p = .001$). In turn, mothers' controlling/intrusive behavior and infant compulsive/compliant behavior during free play were negatively correlated with the frequency of infants' coherent cross-modal interactive behaviors during the first episode of the FFSF ($r_{maternal} = -.204$; $p = .045$; $r_{infant} = -.271$; $p = .007$, respectively) and positively correlated with the frequency of infants' incoherent cross-modal interactive behaviors ($r_{maternal} = .286$; $p = .004$; $r_{infant} = .375$; $p = .001$, respectively).

The correlational results also revealed that most infant and familial demographic variables were not significantly associated with the frequency of infants' coherent or incoherent cross-modal interactive behaviors during *en-face* play. However, infants' 1-minute Apgar score was significantly correlated with infant coherent cross-modal interactive behaviors ($r = .245$; $p = .024$). Maternal education was negatively correlated with maternal sensitivity ($r = -.247$; $p = .014$) and infant passivity ($r = -.206$; $p = .041$), but positively correlated with infant cooperative behavior ($r = .263$; $p = .009$) but was not associated with the coherence/incoherence of infants' cross-modal interactive behaviors.

Aim 4: Identifying specific predictors of infant regulatory behavior patterns in the FFSF at 3 months in covariate-controlled multinomial logistic regressions.

Table 2
Means, Standard Deviations, and ANOVA Results for Maternal and Infant Interactive Behavior during Free Play, according to Patterns of Infant Regulatory Behavior at 3 Months.

Free Play Interactive Behavior	Social-Positive Oriented pattern *M (SD)*	Distressed-Inconsolable pattern *M (SD)*	Self-Comfort Oriented pattern *M (SD)*	*F*	*p*	*Tukey HSD*	η^2
Maternal interactive behavior							
Sensitivity	10.13 (2.50)[a]	9.40 (2.62)[b]	7.53 (3.11)[c]	5.511	.005	a>c	.104
Control/Intrusively	3.32 (2.54)[a]	3.10 (2.44)[b]	6.00 (3.46)[c]	16.858	.002	c>a,b	.128
Unresponsiveness	.66 (1.45)[a]	1.53 (1.64)[b]	.47 (1.61)[c]	3.615	.031	b>a,c	.071
Infant interactive behavior							
Cooperation	10.49 (2.76)[a]	9.37 (2.99)[b]	7.33 (2.94)[c]	7.352	.001	a>c	.134
Compulsivity/Compliance	1.34 (2.19)[a]	.97 (1.70)[b]	5.07 (3.53)[c]	17.973	.001	c>a,b	.275
Difficulty	.62 (1.51)[a]	1.83 (2.76)[b]	.13 (.35)[c]	5.442	.006	b>a,c	.103
Passivity	1.60 (2.12)[a]	1.80 (2.25)[b]	1.87 (2.45)[c]	.123	.884	-	.003

Before conducting the regressions, multicollinearity analyses were carried out. Results indicated high collinearity (VIF above 8) between the multiple dimensions of maternal interactive behavior in free play, infant interactive behavior in free play, and infants' total scores for cross-modal interactive coherence and incoherence in the FFSF. Therefore, only the total scores for infants' coherent cross-modal interactive behaviors were included as a predictor of infant regulatory patterns in the multinominal logistic regressions. From all sub-categories of infants' cross-modal coherence and incoherence, the global scores had the strongest associations with infants' regulatory behavior patterns. Infants' 1-minute Apgar score was also entered as a covariate in these analyses.

Results indicated adequate model fit. The total model fit indices were 117.13 and χ^2 (4) = 20.94, $p < .001$ and Nagelkerk $r^2 = .261$. The coherence model fit indices were 128.73 and χ^2 (4) = 11.60, $p = .003$, and the Apgar at first-minute model fit indices was 127.02 and χ^2 (4) = 9.89, $p = .007$.

Results of the covariate-controlled multivariate logistic regressions are presented in Table 3. Findings indicated that infants' total coherent cross-modal interactive behaviors and 1-minute Apgar scores were each significantly associated with infants' regulatory behavior patterns in the FFSF. Specifically, using Social-Positive Oriented pattern as a reference category, the Distressed-Inconsolable regulatory pattern was predicted by infants' total incongruent cross-modal interactive behaviors ($p = .045$) and 1-minute Apgar score ($p = .020$). Likewise, the Self-Comfort Oriented pattern was predicted by infants' total incoherent cross-modal interactive behaviors ($p = .004$) and marginally associated with 1-minute Apgar score ($p = .057$) (results in Table 3).

5. Discussion

Prior research with full-term and preterm samples demonstrates that infant regulatory patterns observed as early as 3 months in the FFSF are correlated with indices of infants' physiological reactivity (Barbosa et al., 2019; Fuertes et a., 2011) and with mother-infant attachment patterns at 12 months (Barbosa et al., 2018; Fuertes et al., 2022). Moreover, infants' regulatory behavior patterns are stable from 3 to 9 months of age (Barbosa et al., 2018). However, little is known about other maternal and infant interactive behaviors or infant medical and familial demographic factors that may be associated with infants' early regulatory patterns. This information is important to better understand the organization of infants' early infant regulatory patterns.

In the current study, analyses were based on data collected for 100 full-term 3-month-old infants and their mothers from urban working- to middle-class backgrounds in Portugal. Our findings show that both mothers' and infants' interactive behaviors significantly correlate with infants' early regulatory patterns in the FFSF. Specifically, the frequency of infants' coherent and incoherent cross-modal interactive behaviors during infant-mother *en-face* interactions are each highly associated with their regulatory patterns in the FFSF at 3 months of age. Infants with a Social-Positive Oriented pattern exhibit more frequent coherent and less frequent incoherent cross-modal interactive behaviors with their mother, compared to infants with a Distressed-Inconsolable or a Self-Comfort Oriented regulatory pattern. In contrast, infants with Self-Comfort Oriented pattern, compared with infants with a Social-Positive oriented pattern, are more likely to exhibit incoherent cross-modal behaviors, such as looking away from the mother while vocalizing or looking away from the mother and smiling as their mother tries to engage them. These infants also exhibit less frequent coherent communicative configurations, such as looking and vocalizing at the mother.

Infants with a Distressed-Inconsolable regulatory pattern in the FFSF, compared with infants with a Social-Positive Oriented pattern, also are more likely to exhibit incoherent cross-modal interactive behaviors during *en-face* interactions, but do so within a distinct communicative style. For example, these infants are more likely to close their eyes while verbally protesting and directing their arms and body in the mother's direction. They are also more likely to look away and turn their head away from the mother, while directing their arms in the mother's direction.

In sum, each pattern was associated with differences in the way infants communicate their states, needs, and interests to their caregivers. That is, the specific "affective behavioral configurations" that infants display during *en-face* infant-caregiver interactions vary in coherence (Weinberg & Tronick, 1994). Specifically, infants with a Social-Positive Oriented regulatory pattern display more frequent coherent cross-modal interactive behaviors than infants with other regulatory patterns. In contrast, infants with a Distressed-Inconsolable regulatory pattern exhibit more contradictory signals to their caregivers, such as reaching for their caregiver while turning their head away and crying, whereas infants with a Self-Comfort-Oriented pattern display more incoherent cross-modal behaviors characterized by gaze aversion, distancing, or exploratory behaviors during *en-face* interactions. We speculate that young infants develop unique ways of interacting with their caregivers that reflect their current regulatory strategies and help them cope with

Table 3
Summary of Multinominal Logistic Regression Results Predicting Infants' Regulatory Behavior Patterns in the FFSF at 3 Months.

Infant Regulatory Behavior Patterns		B	Std. Error	Wald	df	Sig.	Exp (B)	95% Confidence Interval for Exp (B)	
								Lower Bound	Upper Bound
Distressed-Inconsolable	Intercept	15.156	6.412	5.587	1	.018			
	Incoherent behavior	-.025	.012	4.033	1	.045	.975	.952	.999
	Apgar 1	-1.628	.697	5.453	1	.020	.196	.050	.770
Self Comfort-Oriented	Intercept	15.044	7.833	3.688	1	.055			
	Incoherent behavior	-.055	.019	8.073	1	.004	.946	.911	.983
	Apgar 1	-1.621	.851	3.633	1	.057	.198	.037	1.047

a. The reference category is: Social-Positive Oriented

social stressors in daily life, such as those experienced during the FFSF. These specific patterns of regulatory behavior may carry over to the specific ways infants organize their cross-modal interactive behaviors when communicating with caregivers. Infants who are more aroused, distressed, and less able to recover from stressful events may have greater difficulty organizing coherent communicative behaviors that may interfere with their ability to achieve their interactive and attachment goals. It may be that infants whose cross-modal interactive behaviors are coherent and easier for their caregivers to read, may receive more appropriate and effective regulatory support from their caregivers. Many of these associations had moderate or large effect sizes, which provides some support for this idea, although causal interpretations are not possible in the current design.

A similar pattern of associations was observed for maternal and infant interactive behavior during free play and infants' coherent and incoherent cross-modal interactive behaviors, although effect sizes are somewhat smaller. Specifically, maternal sensitivity during free-play is positively associated with a higher frequency of infants' coherent cross-modal interactive behaviors and negatively related to a higher frequency of infants' incoherent cross-modal interactive behaviors. Furthermore, similar associations were found for infants' cooperative behavior with the parent during free play. We also found that maternal controlling/intrusive behavior and infant compulsive/compliance behavior are positively correlated with a higher frequency of infants' incoherent cross-modal interactive behaviors and negatively correlated with a higher frequency of infants' coherent cross-modal interactive behaviors.

Moreover, consistent with findings reported in prior studies (Barbosa et al. 2019; Ribeiro et al. 2020), infants in the current study with a Social-Positive Oriented regulatory pattern are more cooperative with their mothers during free play, and their mothers are more sensitive to them, compared to infants with a Self-Comfort Oriented regulatory pattern. In turn, infants with a Distressed-Inconsolable regulatory pattern are rated as being more difficult during free play, and their mothers are rated as being more unresponsive. Lastly, infants with a Self-Comfort Oriented regulatory pattern in the FFSF exhibit more compulsive/compliance behavior during free play, and their mothers exhibit more controlling/intrusive behavior.

Our findings provide support for dyadic and transactional perspectives on the importance of early relationships for infants' early regulatory patterns (Beebe et al., 2012; Beeghly et al., 2011). The literature suggests that both infants' regulatory capacities and parent-infant relationships develop from a complex transactional process comprising a set of psycho-emotional and behavioral components that favor positive parent–infant bonding, such as shared gazing and facial affect, verbal exchanges, physical contact, and affectively positive play exchanges, timing, and reciprocity. Using the CARE-index, our study considered and observed all these dimensions during free play (Crittenden, 2003). The results indicate a meaningful correspondence between maternal and infant interactive behaviors, revealing that both partners adapt their behaviors according to the needs and behaviors of the other. For instance, sensitive mothers tend to have more cooperative infants during free play, and greater maternal controlling and intrusive behavior is associated with infant compulsive-compliance behavior. These associations also can be interpreted as individual-level adaptative behavior. Infants who are confronted with parental negative affect, intrusiveness, and controlling behavior may be more likely to comply and reduce their interactive bides during social interactions, thus avoiding negative responses. This finding suggests that infants organize their interactive and regulatory behavior according to their interactive contexts. These behavioral adaptations are likely flexible and open to change, but they also probably reflect infants' iterative interactive experiences and, if chronic or traumatic, can become internalized (Crittenden, 1992).

Mother-infant face-to-face communication involves many behavioral modalities, including shared gazing, facial expressions, vocalizations, touch, and the timing and affective valence of the interaction (Bögels et al., 2018). According to Beebe (2020), redundancy and coherence among different interactive behaviors may promote greater predictability and reciprocity of these interchanges, which in turn, may facilitate infants' perception of these dyadic patterns. Through infants' cross-modal behavioral configurations and appropriate parental reciprocal responses, both the infant and their parent can perceive the state of the other and sense whether the state is shared, which is thought to lead to a sense of relatedness. Infants' regulatory behavior strategies in the context of caregiver regulatory support and sensitivity are likely crucial factors in this process. Infants' ability to regulate their behavior and emotional states, together with caregivers' ability to read infants' signals and respond appropriately, may increase dyadic multimodal correspondence information that guides both partners' attention, promotes intersensory processing., and facilitates interpersonal relatedness (Beebe, 2020). All these aspects of the dyadic relationship can be promoted in preventive and family-based interventions to promote "secure based" relationships (Wright, & Edginton, 2016).

5.1. Study limitations, strengths, and future directions

When evaluating the results of the current study, it is important to consider its limitations and strengths. First, analyses were based on an understudied sample of mother-infant dyad from urban working to middle-class backgrounds in Portugal. These findings may not generalize to groups from other socioeconomic backgrounds or geographical areas. Furthermore, the sample included only full-term infants, which may limit generalizability to other groups of infants at higher biological risk. This study also did not evaluate infant-father interactions, which may differ substantially from those with the child's mother and may also contribute to infants' early regulatory patterns. Moreover, the statistical analyses were based on cross-sectional data in a correlational design, precluding causal interpretations of the findings.

This study also has several strengths. One is the use of direct observations in two interactive contexts (FFSF and free-play) to evaluate infant regulation and maternal and infant interactive behavior. Other strengths include using multiple methods (i.e., both microanalytic and more global approaches) to evaluate the coherence and incoherence of infants' cross-modal interactive behavior and infant regulatory behavior.

Despite its limitations, we believe the study's findings contribute to the growing knowledge about infants' early regulatory capacities and shed further light on how infant and maternal interactive behavior may contribute to them. We plan to continue to follow

this sample at older ages to evaluate links of infants' early regulatory patterns to parent-infant interaction quality and attachment security at later ages. Future studies should also utilize larger, more diverse samples of parent-infant dyads to evaluate these study questions.

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CRediT authorship contribution statement

Marina Fuertes: Writing – review & editing, Writing – original draft, Visualization, Supervision, Project administration, Funding acquisition, Formal analysis, Data curation. **Rita Almeida:** Writing – review & editing, Validation, Investigation, Data curation. **Inês Martelo:** Writing – review & editing, Validation, Methodology, Investigation, Data curation. **Miguel Barbosa:** Writing – review & editing, Validation, Methodology, Investigation. **Marjorie Beeghly:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Conceptualization.

Declaration of Generative AI and AI-assisted technologies in the writing process

The authors declare that they made no use of AI tools to analyze and draw insights from data as part of the research process. The authors used these technologies only to improve readability and language.

Declaration of Competing Interest

The authors declare no conflict of interest.

Data availability

Data will be made available on request.

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We are grateful to families for participating in the study and to health professionals who facilitated the data collection.

Data statement

Our data is available at https://osf.io/hcmpn or up request.

Informed consent statement

Written informed consent has been obtained from the participants or their parents (in the case of infants) to participate in this study and publish the results.

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