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Robust Stability and Physiological Correlates of Infants' Patterns of Regulatory Behavior in the Still-Face Paradigm at 3 and 9 Months

Miguel Barbosa
Universidade de Lisboa

Marjorie Beeghly
Wayne State University

João Moreira
Universidade de Lisboa

Edward Tronick
University of Massachusetts Boston

Marina Fuertes
Instituto Politécnico de Lisboa and University of Porto

This study examined the stability of three patterns of infant regulatory behavior identified in the face-to-face still-face (FFSF) paradigm at 3 and 9 months—social-positive oriented, distressed-inconsolable, and self-comfort oriented—and whether variations in infants' heart-rate were correlated with them. Although some studies have examined the stability of discrete infant behaviors, none have investigated the stability of early regulatory patterns across FFSF episodes over time. Healthy full-term infants and their mothers (N = 112) were videotaped in the FFSF when infants were 3 and 9 months old. Infants' regulatory patterns were scored with the Coding System for Regulatory Patterns in the FFSF. Infants' heart-rate level during each episode of the FFSF was also assessed. The social-positive-oriented pattern was the most prevalent at both ages. Cross-tabulation analysis showed a robust stability (Cohen's κ = .72) of the regulatory patterns from 3 to 9 months. The heart-rate level of infants with a social-positive-oriented pattern at 3 and 9 months showed recovery to baseline levels following the still-face. In contrast, the heart-rate level of infants with a distressed-inconsolable pattern at 9 months increased from the still-face to the reunion episode, whereas the heart-rate level of infants with a self-comfort-oriented pattern at 9 months did not change from the still-face to the reunion episodes. These results suggest that infants exhibit distinct organized regulatory patterns as early as 3 months that are stable over a 6-month interval and associated with variations in infants' physiological responses across FFSF episodes at both ages.

Keywords: patterns of infant self-regulation, heart-rate, still-face, stability

Researchers have extensively described infants' early self-regulatory behaviors in the context of challenging social interactions, such as those observed during the face-to-face still-face (FFSF) paradigm (Tronick, Als, Adamson, Wise, & Brazelton, 1978). However, it is still unclear whether these behaviors reflect infants' transitory responses to the specific stress of the still-face, or whether these behaviors contribute to an emerging organized and stable pattern of infant regulatory behavior.

The FFSF has been extensively used to investigate early regulatory processes between infants and caregivers (Tronick et al., 1978). The FFSF is made up of three successive 2-min episodes: a face-to-face play interaction (baseline) followed by a perturbation in social interaction during which the caregiver is instructed to continue looking at the infant while holding an expressionless face and to refrain from talking or touching the infant (still-face), followed by a resumption of playful interaction (reunion; see Adamson & Frick, 2003, for a review). Typically during the still-face episode, infant gazing and smiling at the caregiver's face decrease and negative affect increases, relative to that observed during the baseline interaction. In the third (reunion) episode, mothers are instructed to resume normal interaction with their infants, and typically during this episode, dyads try to repair the interactive disruption caused by the still-face. Although the still-face and reunion effects are well described, several studies also

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Miguel Barbosa, Faculdade de Psicologia and Faculdade de Medicina, Universidade de Lisboa; Marjorie Beeghly, Department of Psychology, Wayne State University; João Moreira, Faculdade de Psicologia, Universidade de Lisboa; Edward Tronick, Department of Psychology, University of Massachusetts Boston; Marina Fuertes, Escola Superior de Educação de Lisboa, Instituto Politécnico de Lisboa, and Centro de Psicologia, University of Porto.

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Correspondence concerning this article should be addressed to Marina Fuertes, Escola Superior de Educação de Lisboa, Instituto Politécnico de Lisboa, Campus de Benfica do IPL, 1549-003 Lisboa, Portugal. E-mail: marinaf@eselx.ipl.pt

report individual differences in infant responses during each episode of the FFSF, with some infants exhibiting more positive responses and others more negative or self-comforting behavior (see Mesman, van IJzendoorn, & Bakermans-Kranenburg, 2009, for a review).

Most investigators have focused on discrete regulatory behaviors displayed by infants during the FFSF (e.g., positive or negative affect) or the duration of time spent in each. Recently, however, a few researchers have begun to describe the organization of infant behaviors during the FFSF (e.g., Ham & Tronick, 2006; Montirosso et al., 2015). Contributing to this line of research, other investigators (Fuertes & Lopes dos Santos, 2009) documented individual differences in the patterns of infants' responses across FFSF episodes with respect to three dimensions: (a) engagement (the degree of dyadic reciprocity, shared pleasure and ability to prolong positive mutual interactions), (b) reengagement or return to the interaction (infants' ability to self-soothe and signal their desire to return to interaction with the caregiver), and (c) reparation (capacity to restore the disrupted interaction to baseline levels. building on prior descriptive work [narratives] of variations in infants' behavioral responses during the FFSF; Fuertes & Lopes dos Santos, 2009). These three patterns of infants' responses to the FFSF may also reflect variations in infants' emerging preverbal "expectations" about early parent–infant interactions: (a) that their own responses contribute to the repair of the disrupted interaction, (b) that their caregiver supports their self-regulation and contributes to the repair of the interaction, and (c) that reparation is possible.

Guided by this prior descriptive work and results from previous microanalytic research (Fuertes, Lopes dos Santos, Beeghly, & Tronick, 2006, 2009) a categorical approach was developed that describes three regulatory patterns in the FFSF. The first is the social-positive-oriented pattern, in which infants predominantly display positive behaviors during high/moderate reciprocal interactions in which interactive errors are easily repaired. Infants classified in this pattern also tend to react to the still-face with positive behaviors (e.g., smiling) that progressively decrease during the episode and that may be replaced by negative affect, followed by a clear recovery in the reunion episode. The second pattern is the distressed-inconsolable pattern, in which infants display conspicuous negative behaviors when reciprocity fails, and the repair of interactive mismatches becomes more challenging. Infants classified in this pattern immediately react to the still-face with negative affect that persists or increases during the reunion episode, protesting or resisting adult attempts to reengage them in social interaction. The third pattern is the self-comfort-oriented pattern, in which infants exhibit conspicuous avoidance of the adult in the first play and the reunion episodes (e.g., ignoring the adult's interactive initiatives, looking away, turning away) and display a predominance of self-comforting behaviors during all three episodes. In a later analysis, these researchers (Fuertes et al., 2014; Seixas, Barbosa, & Fuertes, 2017) demonstrated that these three regulatory patterns can be reliably identified in the FFSF by independent, trained judges, and are significantly associated with measures of mother–infant interactive behavior in other contexts, and with individual infant and maternal characteristics (e.g., maternal sensitivity in free play, maternal reports of infant temperament).

In contrast to other approaches (Ham & Tronick, 2006; Montirosso et al., 2015; Papousek, 2007), the current typology describes three broad-based infant self-regulatory patterns defined using the criteria described above (engagement, reengagement or return to the interaction, and reparation), as well as seven subgroups that reflect variations in the intensity and quality of the infants' behavioral responses (three subpatterns of social-positive oriented, two subpatterns of distressed-inconsolable, and one pattern of self-comfort oriented). In other words, this typology includes both the *behavioral function* of infants' responses during the FFSF, as well as the *intensity* and the *quality* of their behaviors.

The recent rise in scientific interest in describing the organization of infant self-regulatory behavior during the FFSF paradigm may reflect their theoretical significance. First, demonstrating that infants exhibit organized responses to the FFSF suggests that early self-regulatory behavior can be structured in complex patterns rather than being mere reactions to a social stressor. Second, each regulatory pattern may have a functionality inherent in it, which over time may become independent from the immediate social context. In other words, individual differences in infants' organized responses during the FFSF may be shaped by their repeated experiences in coregulation during social interaction with caregivers over time. The early preverbal "expectations" that infants may generate from these early iterative experiences may contribute to individual differences in attachment formation, internal working models of self and other, the emergence of behavior problems, or other emergent organizational processes (Bowlby, 1969; Tronick & Beeghly, 2011). Third, this theoretical proposal may contribute to the discussion of how early social and emotional behavior can be organized in regulatory patterns. According to evolutionary perspectives, these behavior patterns were selected from a range of behavioral possibilities that were less likely to contribute individual reproductive success and may be incorporated into the repertoires of individuals (Crittenden, 2000; Simpson & Belsky, 2016).

In the current study, we examined whether these three regulatory patterns described in prior work (Fuertes & Lopes dos Santos, 2009) were relatively stable from 3 to 9 months of age, or whether significant changes would be observed. Although this 6-month time interval is relatively short, infants undergo rapid neurodevelopmental and behavioral changes during this time period. For this reason, stability in infants' regulatory patterns to the FFSF over time may not be observed. On the other hand, individual differences in caregiver–infant mutual regulatory processes during social interaction also emerge and become increasingly consolidated during this time interval (Beebe et al., 2010; Fuertes et al., 2006, 2009), making it reasonable to expect stability.

Stability of infants' Responses During the FFSF Paradigm

Few studies have examined the stability of infants' responses in the FFSF paradigm over time (see Mesman et al., 2009, for a review). Among those that have, several investigators report that infants' responses during the still-face episode are relatively stable across a 2-week interval (e.g., Gianino, 1985; Montirosso et al., 2014; Montirosso, Tronick, Morandi, Ciceri, & Borgatti, 2013; Provenzi, Olson, Montirosso, & Tronick, 2016; Tronick & Gianino, 1986). However, other studies evaluating stability over longer time intervals report inconsistent findings (e.g., Cossette,

Pomerleau, Malcuit, & Kaczorowski, 1996; Mesman, Linting, Joosen, Bakermans-Kranenburg, & van IJzendoorn, 2013; Moore, Cohn, & Campbell, 2001; Shapiro, Fagen, Prigot, Carroll, & Shalan, 1998; Toda & Fogel, 1993).

Among longitudinal studies evaluating stability over at least a 2-month time interval, those that focus on specific behaviors (e.g., smile, fuss, cry, or looks at mother) molecularly, evidence for stability is low or nonexistent (Moore et al., 2001; Shapiro et al., 1998). For instance, Toda and Fogel (1993) measured infant facial expressions (i.e., smile, fuss, cry, or neutral) and gaze direction (i.e., looking at mother's face, mother's body, proximal away, distal away), in the three episodes of the FFSF at 3 and 6 months, and found no significant cross-time correlations. Similarly, Moore et al. (2001) reported no stability in the number of infants who smiled or cried in the still-face between 2 and 4 months, 4 and 6 months, or 2 and 6 months. However, gazing away from the mother was weakly correlated from 2 to 4 months ($r = .26$) and from 4 to 6 months ($r = .26$).

Contrasting findings are reported by other investigators evaluating the stability of other categories of infant behavior over time. For instance, there is evidence for moderate to high stability for infant emotional expressions such as interest/excitement ($r = .73$), enjoyment/joy ($r = .50$), observed during still-face episodes of the FFSF, but only from 3 to 6 months (Shapiro et al., 1998). However, no significant cross-time correlations were observed for other facial expressions that is, surprise/astonishment, anger/rage, and sadness/dejection (Shapiro et al., 1998).

Other researchers provide evidence for greater stability of higher order categories of infant behavior, such as positive and negative affect (Braungart-Rieker et al., 2014; Lowe et al., 2012; Mesman et al., 2013). However, the results of these studies are still somewhat inconsistent. For instance, Lowe et al. (2012) compared the association of infant affect and behavior in the FFSF from 4 to 9 months, and found that only positive affect exhibited by infants during the baseline episode was weakly correlated ($r = .24$) over time. Negative affect was modestly associated from 4 to 6 months ($r = .30$), but was not significantly correlated between 2 and 4 months. Similarly, Braungart-Rieker et al. (2014) assessed infants' positive and negative affect, gaze, and self-comforting behaviors in the three episodes of FFSF at 3, 5, and 7 months. Positive affect was significantly correlated in the play episode from 5 to 7 months ($r = .22$), and from 3 to 7 months ($r = .20$), as well as in reunion episodes across all time periods (rs range from .19 to .32), and in the still-face from 3 to 5 months ($r = .38$). Moreover, negative affect was significantly correlated only in the play episode from 3 to 7 months ($r = .22$), and gaze was associated only in the still-face episode from 5 to 7 months ($r = .26$). However, no significant cross-time associations were found for self-comforting behaviors in any episode across ages.

A different approach was employed by Mesman et al. (2013), who coded positive and negative affect in the three episodes of the FFSF using 4-point global rating scales. Only positive affect during the baseline ($r = .27$) and reunion ($r = .32$) episodes was significantly correlated between 3 and 6 months in this study.

In the current study, we evaluated whether greater cross-time stability could be observed when organized patterns of infant regulatory behavior were evaluated, rather than the discrete infant behaviors assessed molecularly in prior studies. We hypothesized that significant cross-stability would be observed for infant regulatory patterns, because these patterns are composite measures and may reflect individual differences in infants' organized responses during parent–infant social interactions; namely, the level of their engagement in interactions with their caregivers, their tendency to return to interaction, and their capacity to repair the interaction after disengagement. Thus, although several studies have evaluated the relative stability of discrete behaviors in the FFSF, no studies to our knowledge have examined the cross-time stability of early patterns of regulatory behavior across FFSF episodes, and over time.

Infants' Heart-Rate Activity in the FFSF Paradigm

We also evaluated whether different patterns of infant regulatory behavior observed during the FFSF at 3 and 9 months of age were associated with differences in infants' physiological responses during the FFSF using cardiac measures (heart-rate). Identifying such associations would suggest that infants exhibit biobehavioral coherence in the organization of their early regulatory patterns during social interaction with their caregivers. The few studies measuring infants' physiological responses during the FFSF report that heart-rate increases from baseline to still-face episode and decreases in the reunion (Fuertes, Beeghly, Lopes dos Santos, & Tronick, 2011; Haley, Handmaker, & Lowe, 2006; Haley & Stansbury, 2003; Ham & Tronick, 2006; Weinberg & Tronick, 1996). Moore and Calkins (2004) showed that infants who are able to significantly suppress their heart-rate during the still-face exhibit more synchronized matches with their mothers during the FSFF. In other work (Fuertes et al., 2011), the amount of positive coping behaviors infants exhibited during the FFSF was negatively correlated with the infants' heart-rate during the still-face episode, whereas the frequency of infants' self-directed behaviors was positively correlated with higher heart-rate during the still-face and the reunion episodes. We hypothesize that infants who exhibit a self-comfort-oriented pattern of regulatory behavior during the FFSF (Fuertes et al., 2006, 2009) will inhibit the expression of distress elicited by the still-face, as revealed by their physiological data. In support of this, prior work shows that the inhibition of distress during the still-face episode of the FFSF is associated with avoidant attachment at the end of the first year (e.g., Fuertes et al., 2009).

The Current Study

The primary goal of this study was to evaluate whether individual differences in patterns of infant regulatory behavior in the FFSF are (a) temporally stable from 3 to 9 months and (b) significantly associated with infants' physiological reactions to the FFSF. To address this goal, three specific aims were evaluated.

The first aim was to examine the relative stability of three patterns of infant regulatory behavior observed in the FFSF at 3 and 9 months of age: social-positive oriented, distressed-inconsolable, and self-comfort oriented. Although infants undergo rapid and critical developmental changes during this time period (e.g., Bruner & Haste, 2010; Piaget, 1936), such as gains in cognitive skills (e.g., joint attention) and the capacity for independent locomotion, which may change the nature of social relationships, we expected to find a moderate level of stability in the three patterns of regulatory behavior over time. Findings from prior

research (Fuertes et al., 2006, 2009, 2014) indicate that individual differences in infant regulatory patterns can be described as early as three months of age. A moderate level of temporal stability was also anticipated given the medically and demographically low-risk nature of the current sample, which may reflect a relative degree of stability in contextual and maternal factors in the caregiving environment.

In order to better understand the biobehavioral organization of each pattern and to find if each pattern corresponds to an independent organization of self-regulatory behaviors, other complementary measures such as physiological variables are necessary. Thus, the second aim was to investigate whether variations in infants' heart-rate activity in each episode of the FFSF paradigm were associated with the three infant regulatory patterns at 3 and 9 months. Based on prior research showing behavioral and physiological reactions to stress are related (Fuertes et al., 2011; Moore & Calkins, 2004; Stoller & Field, 1982), we expected to find a significant correspondence between infants' behavioral and cardiac responses to the FFSF at both ages.

Method

Participants

Analyses were based on data collected for 112 mother–infant dyads at the 3- and 9-month visits in a larger longitudinal study ($N = 162$). Mother–infant dyads were recruited from an urban Portuguese public hospital during their stay in the maternity ward after the infant's birth. All infants (54.5% male) were full term ($\geq$37 and $<$42 gestational weeks at delivery, with birth weight above 2,500 g), and all were healthy and typically developing at 3 and 9 months of age. Mothers' mean age at intake was 31.54 years ($SD = 4.08$; range = 20–39 years), their mean education was 14.80 years ($SD = 3.36$; range: 6–23 years), 93% were Portuguese, and 53% were primiparous.

Of the 162 recruited in the larger study, 23 dyads dropped out or could not be reached for follow-up at 9 months. Of the remaining 139, an additional 27 were excluded from analysis because the mothers did not follow FFSF procedure instructions (e.g., they were unable to sustain a still-face, by smiling or touching the baby during still-face episode; 14 cases), the infants were too distressed to participate in the FFSF (six cases), or there were video/audio problems (seven cases). Analyses were therefore based on a final sample of 112 mother–infant dyads with complete data at the 3- and 9-month visits.

Procedures

At 3 and 9 months postpartum, mothers were contacted to schedule a follow-up visit to the laboratory. Mother–infant dyads were videotaped during the FFSF paradigm (Tronick et al., 1978).

The FFSF paradigm (Tronick et al., 1978) includes three successive 2-min 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 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 normal play interaction with the infant. To mark the beginning and end of each episode more clearly for scoring purposes, each episode was separated by a 15-s interval, during which the mother was asked to turn away from their 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 that generated a time-synchronized split-screen image of each partner on a single video record. All procedures were approved by the Ethics Committee of the Centro Académico de Medicina de Lisboa (Consent received in June 2010), and all parents provided written informed consent.

Measures

The Coding System for Regulatory Patterns in the FFSF (Fuertes & Lopes dos Santos, 2009) was used to score the videotapes of infants' behavior in the three FFSF episodes. This coding system describes six subpatterns of infants' regulatory behavior that were derived from four dimensions of infants' behavior across the three episodes of the FFSF paradigm: (a) behavior organization (e.g., the infant exhibits predominantly social positive behavior or distressful behavior or self-comforting behavior, or mixed behavior), (b) intensity of exhibited behavior (e.g., the infant displays prolonged and intense crying), (c) quality of behaviors (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. The six subpatterns were then additionally grouped into the three a priori major categories of behavioral patterns described above: social-positive oriented, distressed-inconsolable, and self-comfort oriented (see Table 1).

The FFSF videotapes were scored for infant regulatory patterns by three trained, reliable coders. Coders 1 and 2 were blind to the study's hypotheses, the free play coding, and other variables of the study. Coder 3, an expert "gold standard," trained Coders 1 and 2. Intercoder agreement was calculated using Cohen's kappa coefficient. Cohen's kappa for intercoder agreement for 3 and 9 months data was very good (.78 and .75, respectively). After interrater reliability was calculated, the final scores of those cases with discrepant cases were discussed and resolved by conferencing with the expert coder.

Heart-Rate

Heart-rate reflects the infant's stress state, and changes in heart-rate have been used to investigate infants' changing affective reactions to different experimental procedures (e.g., Bertenthal & Campos, 1990; Haley et al., 2006; Haley & Stansbury, 2003; Ham & Tronick, 2006; Stoller & Field, 1982; Weinberg & Tronick, 1996). In the current study, changes in heart-rate across the three episodes of the FFSF paradigm at 3 and 9 months were used as an index of infant stress (i.e., significant acceleration between episodes indicating a distress state). Four pediatric electrodes were placed on infants' chests and connected to an evo Digital Holter recorder (Spacelabs, Washington, DC), which continuously registered the heart-rate during the entire FFSF paradigm. Recordings were transferred to a computer for artifact editing and then analyzed using an Impresario Holter analysis system. The heart-rate

Table 1
Coding System for Regulatory Patterns in the Face-to-Face Still-Face Paradigm

Patterns and subpatterns of regulatory behavior	Description
Social-positive oriented[a]	
Subpattern 1	Infants exhibit prolonged positive behaviors in the context of reciprocal interaction in the first episode. There is a clear and progressive decrease of positive affect during the still-face and a subsequent recovery during the third episode. Infants may take up to 30 s to recover in the last episode.
Subpattern 2	Infants exhibit a predominance of positive behaviors (but less frequent or less intense than in Subpattern 1) in the context of a reciprocal interaction. Nevertheless, a few periods of dyadic lack of synchrony can also be observed in the first episode. There is a progressive decrease of positive affect during the still-face and a subsequent recovery in the third episode. The recovery takes a maximum of 60 s.
Subpattern 3	Infants exhibit positive behaviors in a reciprocal interaction, but there are more and longer periods of lack of synchrony in the first episode compared to other social positive sub patterns, in which infants alternate with disturbance and self-comforting. Signs of disturbance and withdrawal may persist during the third episode, but infant gradually recover, and at least in the last minute of this episode, infants return to a reciprocal and positive interaction with their mothers.
Distressed-inconsolable[b]	
Subpattern 1	Infants exhibit positive behavior during the first episode, but there are periods of disengagement or moderate negative affect. Infants react to the still-face with an increasing and persistent negative affect. Signs of disturbance and withdrawal persist in the third episode without recovering, although infants may present few or brief manifestations of interest.
Subpattern 2	Infants' engagement in the first episode alternates among periods of interest/attention, withdrawal, and active resistance/protest. Infant react to the still-face with prompt evident negative affect that persists or increases in the third episode. Infant distress is so intense that the researchers must end shortly the third episode.
Self-comfort oriented[c]	
Subpattern 1	Infants predominantly avoid contact, including gaze aversion, muscular tension when touched, and general discomfort without exhibition of evident negative affect (e.g., masked and rigid facial expression, restrained vocalizations) during the first and third episodes. Active resistance and protest are only occasional or briefly presented. During the second episode infants present predominantly self-comfort and exploring behaviors. Some infants seem more relaxed during the second episode compared to other episodes. Infants consistently use self-comforting behaviors across all episodes.

[a] Predominance of positive social behaviors and recover after still-face. [b] Predominance of negative affect particularly in and after still-face, and failures in repairing interactive mismatches. [c] Conspicuous avoidance in first and third episode and predominance of self-comfort during all episodes.

activity was registered for each 5-s interval during the three episodes of the FFSF and the means were calculated for each episode. Cases that required artifact correction of more than 10% of the data or were incomplete due technical problems, such as infants who pulled off electrodes during the FFSF, were excluded from the analysis. This resulted in missing data of 29 (26%) cases at 3 months and 8 (7%) cases at 9 months. All infants accessed at 3 months were equally accessed at 9 months.

Analytic Plan

Three sets of statistical analyses were conducted. First, the distribution of the infants' patterns of regulatory behavior at 3 and 9 months was obtained using univariate frequency analysis. Second, to evaluate the stability of the regulatory patterns from 3 to 9 months, a three-way cross-tabulation was used to summarize the number of times each of the possible regulatory patterns combinations occurred. A chi-square test was used to determine whether regulatory patterns were independent or correlated. Additionally, Cohen's Kappa was used to measure the strength of association between regulatory patterns at 3 and 9 months and Goodman–Kruskal lambda (a proportional reduction in error coefficient) was used to assess the predictability of regulatory patterns at 9 months based on those at 3 months (Goodman & Kruskal, 1954).

Third, we carried out repeated measures analysis of variance to determine how infants' heart-rate varied across FFSF episodes in the three regulatory patterns. The dependent variable in this analysis was heart-rate and the independent variables were one within-subject factor, "episodes" (play, still-face, and reunion), and one between-subjects factor, "regulatory patterns" (social-positive oriented, distressed-inconsolable, and self-comfort oriented). Tukey's post hoc honest significant difference tests were used for testing the significance of differences among episodes and among regulatory patterns.

Results

Distribution and Stability of Patterns of Regulatory Behavior at 3 and 9 Months

The distribution of the three patterns of regulatory behavior at 3 and 9 months and the association between them at each age are summarized in Table 2. The distribution of the three infant regulatory patterns was very similar at both ages; details follow.

Of the 60 infants classified as social-positive oriented at 3 months, 88.3% received the same classification at 9 months, 11.7% were classified as distressed-inconsolable, and none as self-comfort oriented. Of the 38 infants classified as distressed-inconsolable at 3 months, 84.2% received the same classification at 9 months. The self-comfort-oriented pattern presented the lowest temporal stability (64.3%). Overall, the Pearson's chi-square value was highly significant ($p < .001$), indicating a nonrandom association between the three patterns of regulatory

Table 2
Frequencies and Percentages of Patterns of Regulatory Behavior at 3 and 9 Months

3 Months	9 Months			Total
	Social-positive oriented	Distressed-inconsolable	Self-comfort oriented	
Social-positive oriented	53 (88.3%)	7 (11.7%)	0 (0%)	60 (53.6%)
Distressed-inconsolable	4 (10.5%)	32 (84.2%)	2 (5.3%)	38 (33.9%)
Self-comfort oriented	0 (0%)	5 (35.7%)	9 (64.3%)	14 (12.5%)
Total	57 (50.9%)	44 (39.3%)	11 (9.8%)	112

Note. Percentage of classifications at 9 months by 3 months category. Pearson $\chi^2 = 116.02$, $df = 4$, $p < .001$; likelihood ratio $\chi^2 = 108.01$, $df = 4$, $p < .001$.

behavior at 3 and 9 months. A Cohen's kappa value of .72 also showed a substantial strength of concordance (Landis & Koch, 1977) as did a lambda of .67. Notably, in the latter test, the error in predicting regulatory patterns at 9 months is reduced by 67% when information from regulatory patterns at 3 months is used.

Infants' Heart-Rate Responses and Infant Regulatory Patterns During the FFSF at 3 and 9 Months Between and Within Groups

The analysis of variance results revealed no significant differences between the three infant regulatory patterns in the first and in the second episode of FFSF at 3 months (see Table 3). In the third episode, however, significant between-groups differences were revealed. Results of Tukey's honest significant difference post hoc tests indicated that infants classified as distressed-inconsolable had a mean heart-rate that was significantly higher than that of infants classified as self-comfort oriented. In contrast, at 9 months, several differences between the three groups in each episode were found (see Table 4).

After evaluating mean differences in heart-rate between the three groups by episode, we evaluated the heart-rate differences in each regulatory pattern across FFSF episodes at 3 and 9 months (see Tables 3 and 4, respectively). The purpose of these analyses was to ascertain whether heart-rate recovered to baseline levels in the reunion episodes for each regulatory pattern. Results of Tukey's post hoc tests revealed that the heart-rate of infants in the three patterns of regulatory behavior at 3 and 9 months was statistically higher during the still-face episode than during the baseline episode, showing the typical still-face effect with this physiological measure. However, only the heart-rate of infants with a social-positive-oriented pattern at 3 and 9 months showed recovery to baseline levels following the still-face; that is, there was no statistically significant difference in heart-rate for these infants between the baseline and reunion episodes, suggesting that in the reunion episode these infants recovered completely from the stress of the still-face.

In contrast, there was no significant difference in heart-rate between the still-face and reunion episodes for infants with a distressed-inconsolable pattern at 3 months or for infants with a self-comfort-oriented pattern at 9 months. These infants were unable to recover from the stressful still-face episode, during the subsequent reunion episode. This effect was even clearer among infants with a distressed-inconsolable pattern at 9 months, whose levels of heart-rate actually increased from the still-face to the reunion episode.

Discussion

The goal of the current study was to examine whether the three infant regulatory patterns (social-positive oriented, distressed-inconsolable, and self-comfort oriented) during the FFSF proposed in prior work (Fuertes et al., 2006, 2009, 2014) were stable from 3 to 9 months of age. A second goal was to evaluate whether infants' heart-rate activity during the FFSF at 3 and 9 months was associated with infant regulatory patterns at each age. Results indicate that there is a similar distribution of regulatory patterns at both ages, and that each pattern was relatively stable over time. Moreover, the most prevalent pattern is the social-positive-oriented pattern followed by the distressed-inconsolable pattern, and the self-comfort-oriented pattern.

Table 3
Infant Heart-Rate Responses During the Face-to-Face Still-Face Paradigm Episodes at 3 Months Within and Between Groups

Variables	Baseline (a)		Still-face (b)		Reunion (c)		Episodes effect, $F(2, 82)$	p	Tukey HSD
	M	*SD*	*M*	*SD*	*M*	*SD*			
Social-positive oriented (d)	143.05	1.80	145.59	1.77	142.56	1.93	6.15	.003	a, c < b
Distressed-inconsolable (e)	141.37	1.89	147.36	2.26	148.83	2.24	14.10	<.001	a < b, c
Self-comfort oriented (f)	136.96	2.48	142.05	2.30	139.52	2.41	6.98	.004	a < b, c
Pattern effect, $F(2, 82)$	1.16		1.06		3.72				
p	.206		.352		.028				
Tukey HSD					e > f				

Note. HSD = honest significant difference.

Table 4
Infant's Heart-Rate Responses During the Face-to-Face Still-Face Paradigm Episodes at 9 Months Within and Between Groups

Variables	Baseline (a)		Still-face (b)		Reunion (c)		$F(2, 101)$	p	Tukey HSD
	M	*SD*	*M*	*SD*	*M*	*SD*			
Social-positive oriented (d)	132.69	1.06	137.77	1.39	134.33	1.33	20.85	<.001	a < b
Distressed-inconsolable (e)	136.81	2.18	144.61	2.11	149.63	2.76	26.88	<.001	a < b, c
Self-comfort oriented (f)	127.34	2.19	133.31	2.43	132.57	3.00	8.51	.002	a < b, c
Pattern effect, $F(2, 101)$	6.25		4.00		17.83				
p	.021		.003		.005				
Tukey HSD	e > f		e > f, d		e > f, d				

Note. HSD = honest significant difference.

Temporal Stability of Patterns of Regulatory Behavior

As anticipated, the three patterns of infant regulatory behavior were significantly associated with each other over time. Specifically, early patterns of infant regulatory behavior observed at 3 months retained their predominant configuration at 9 months, despite the developmental changes occurring during this time period. Eighty-eight percent of infants with a social-positive-oriented pattern at 3 months, 84% of infants with a distressed-inconsolable pattern, and 64% of infants with a self-comfort-oriented pattern exhibited the same regulatory pattern at 9 months.

Our results contrast with those of prior studies that report no significant stability in infants' discrete responses in the FFSF (Cossette et al., 1996; Lowe et al., 2012; Toda & Fogel, 1993) or only modest temporal stability in negative affect (Moore et al., 2001) or positive affect (Braungart-Rieker et al., 2014; Mesman et al., 2013; Shapiro et al., 1998) at some interval of time between 2 and 7 months. To our knowledge, the current study is the first to report a robust temporal stability of patterns of infant regulatory behavior from 3 to 9 months of age. Indeed, not only did our study present evidence for strong stability of the social-positive oriented and distressed-inconsolable regulatory patterns and a moderate stability of the self-comfort-oriented pattern, it also demonstrates such stability across a longer time period than any previous study.

One possible explanation for these inconsistent findings is that many previous studies focus on the stability of frequencies of discrete infant behaviors (e.g., smiles, cry, gaze, hands action) either within the still-face episode (Moore et al., 2001; Shapiro et al., 1998), across different episodes of the FFSF, including between the baseline (first episode) and still-face episodes (Cossette et al., 1996), across all three episodes of the FFSF (Braungart-Rieker et al., 2014; Lowe et al., 2012; Toda & Fogel, 1993) or as patterns of change across episodes (Mesman et al., 2013).

In contrast, the current study used a more holistic approach to describe infants' regulatory behavior across the three FFSF episodes using the Coding System for Regulatory Patterns in the FFSF (Fuertes & Lopes dos Santos, 2009), which builds on results from prior narrative approaches as well as previous microanalytic work. The system is unique in that it considers specific patterns of infant behavior in the context of their changing function in each episode, such as: regaining adult attention, self-regulating, or expressing discomfort (see Fuertes et al., 2006, 2009). For instance, the first play episode of the FFSF (baseline) assesses infants' ability to engage in reciprocal transactions with the caregiver, whereas the still-face episode assesses infants' predominant ways of coping with the stress of the maternal still-face. In turn, the reunion episode evaluates infants' ability to recover from stress and reengage in reciprocal dyadic transactions with the mother. Our focus on the organizational patterns of infant behavior and its functionality in the different contexts of the FFSF, as opposed to molecular analyses of specific discrete behaviors, may help explain why we found evidence for significant cross-time stability in infant regulatory behavior from 3 to 9 months, whereas others have not.

This stability is especially notable given the major developmental (motor, cognitive and social-affective) shifts that occur between 3 to 9 months of age. It is very likely that infants' specific responses during the FFSF at each age reflect these developmental shifts. For instance, at 3 months, infants' positive behavioral responses may be reflected in less complex responses such as looks and smiles at the caregiver, whereas at 9 months, infants' positive responses may become more complex and also include gestures, bids for joint attention, longer vocalizations, and more mature self-regulatory behaviors, which are all integrated into infants' reciprocal response to the caregiver's bids.

Given these age-related changes in the nature and complexity of infants' behavior during the FFSF, it is not surprising that analytic approaches that focus on discrete behaviors provide little evidence for cross-time stability, particularly over longer time intervals. Studies using broader categories of infant behavior such as positive affect are somewhat more effective (e.g., Mesman et al., 2013), but findings for stability are still mixed. The present study provides a novel approach to evaluating the stability of infant regulatory behavior that appears to be more fruitful. This may stem from its focus on patterns of regulatory behavior that highlight each dyad's uniqueness, and also its evaluation of the function of the infants' behavior during each episode of the FFSF (e.g., ability to reengage in normal interaction during the reunion episode to a level that is similar to that observed at baseline).

Infants' Heart-Rate Responses During the FFSF According to Regulatory Patterns

Findings from the analyses of the heart-rate data in the current study confirm the still-face effect at a physiological level at both 3 and 9 months. Infants' physiological reactions to the FFSF were also significantly associated with the three patterns of regulatory behavior in each episode of the FFSF and at each age in distinct ways.

Specifically, the heart-rate responses of infants with a social-positive-oriented pattern increased from the baseline (levels observed in the first episode) to the still-face episode and decreased to the baseline levels in the reunion episode. These results indicate that social disruptions such as a maternal still-face affect both the behavioral and physiological systems of infants with a social-positive-oriented pattern. However, the decrease in heart-rate observed for these infants during the subsequent reunion episode suggests that reengagement with the mother in social interaction helps infants with a social-positive-oriented pattern to regulate physiological arousal and reorganize their behavior effectively. Also, we note that infants with a social-positive-oriented pattern have lower average heart-rate than infants in the other two groups in the first episode of FSFF. Indeed, infants with a social-positive-oriented pattern seem to be less aroused than other infants, even during normal face to face interactions. Our results are consistent with those of Montirosso et al. (2015), who reported that infants in the group they call socially engaged (i.e., infants who show high levels of social engagement and a low level of negative engagement at baseline) are more able to recover behaviorally during the reunion episode than infants in their disengaged and negatively engaged groups.

In contrast, the heart-rate responses of infants with a distressed-inconsolable pattern at 9 months in the current study clearly show that social disruptions strongly affect these infants' behavioral and physiological systems. In contrast to infants with a social-positive-oriented pattern, their heart-rate accelerated from the baseline to the still-face episodes at both ages, and this level remained high during the reunion episode at 3 months, and increased even higher during the reunion episode at 9 months, compared to the still-face episode at 9 months. Even after the reestablishment of social interaction in the reunion episode, the physiological arousal of infants with a distressed-inconsolable pattern did not attenuate and these infants were unable to decrease their negative state. This style of response indicates poor biobehavioral regulation. Notably, the regulatory behaviors of infants classified in both the social-positive oriented and distressed-inconsolable patterns and the associations of these patterns with changes in heart-rate are congruent with the still-face and reunion effects reported in prior studies of the FFSF (Mesman et al., 2009).

Infants classified in the self-comfort-oriented pattern also exhibit an acceleration in heart-rate from the baseline to the still-face episodes but display less negative affect during the still-face episode than infants in the distressed-inconsolable pattern. These infants also use more self-comfort behaviors during the still-face, compared to infants in the other patterns, which presumably reflects infants' attempt to cope with their distress. Based on the behavioral data alone, it is difficult to be confident that these infants are experiencing distress, given their lower level of negative affect. The physiological data clarifies interpretation: the acceleration of their heart-rate from the baseline to the still-face provides further evidence that these infants are indeed experiencing distress during the still-face episode. This pattern of findings suggests that these infants may be inhibiting behavioral signals of the distress they are experiencing, even though changes in arousal are evident at the physiological level. However, they do not appear to be as distressed as infants in the distressed-inconsolable pattern during the still-face episode of the FFSF at 9 months or during the reunion episode at 3 and 9 months.

Variations in infants' biobehavioral responses to the FFSF may also reflect the quality of the dyadic interaction. For infants in the distressed-inconsolable pattern or self-comfort-oriented pattern, this quality may not have been sufficient to help the infant regulate distress following the still-face and repair the dyadic mismatches in an effective manner, as is sometimes observed during mother–infant interaction (Beeghly, Perry, & Tronick, 2016). This finding is consistent with the behavioral signs of discomfort shown by the infants in the self-comfort-oriented pattern during the reunion episode. Given that there were few cases of the self-comfort-oriented pattern in our study, future research should continue to examine this regulatory pattern in the FFSF and its correlates.

Several investigators suggest that preverbal infants form procedural representations of early relationships, such as state-transforming, facial mirroring, disruption and repair, mutual approach or approach/avoid spatial orientation, and degrees of self and interactive contingency (Beebe et al., 2010, 2016). These social expectations may help explain why infants with a self-comfort-oriented pattern at 3 and 9 months behaviorally inhibit the expression of distress elicited by the still-face, which is revealed by their physiological data, or why infants with a social-positive-oriented pattern openly share their distress with their mothers. Although future research is needed, we speculate that the three patterns of regulatory behavior identified in this study may reflect distinctive action sequences based on different expectations of mother–infant social interactive behaviors, including her effectiveness as a regulatory source during stressful interactive situations. Therefore, infants with a social-positive-oriented pattern may openly signal their distress because they expect to be comforted by their mothers. Consistent with this hypothesis, Moore and Calkins (2004) suggested that infants who congruently display expressions of negative affect to their mother in the still-face when physiologically aroused have learned and expect that their mothers will be responsive to their signals. The implicit relational knowing is stored and accumulated by infants from engaging in repeated routine social interactions with caregivers, which allows them to develop ongoing procedural expectancies of interactive sequences of actions and events (Bruschweiler-Stern et al., 2002; Nahum & Boston Change Process Study Group, 2008; Tronick, 2007). These possibilities will be explored in future analyses in our lab.

Additionally, we posit that the failures of reparatory processes in the reunion episode observed for infants with a self-comfort-oriented or a distressed-inconsolable pattern may create prolonged periods of dyadic mismatch, which generate stress, high activity of the heart-rate, and inhibition/avoidance or resistance/protest behavioral strategies to deal with the negative affect. This dynamics could increase the probability of chronically unrepaired interactive mismatches and the risk of compromising the future development of self-regulation (Beeghly, Fuertes, Liu, & Delonis, 2010). If these possibilities are supported in future studies, they may have important clinical implications. The identification of vulnerable infants with these patterns of regulatory behavior as early as 3 months offers the opportunity to implement early intervention programs.

Without further studies, however, these possibilities are only speculations. Whether the three patterns predict infants' later infant developmental and behavioral outcomes, such as attachment or executive functioning is currently unknown. Nevertheless, we contend that studies designed to increase understanding

about the implicit biobehavioral organization of infants' responses to the FFSF and their relative stability over time is an important endeavor in its own right, because it has the potential to shed new light on the nature of infants' self-regulatory development during the first year of life and its links to later developmental outcomes. It seems reasonable to expect that early patterns of regulatory behavior would help support and constrain infants' efforts to achieve internal and external regulation in playful and stressful social contexts, such as the infants' attempts to regain the caregiver's attention during the still-face and to restore the interaction with her. But whether the three patterns of infant regulatory behavior observed in this study are associated with infants' internal working models of relationships and/or their later social and attachment relationships awaits future research. At first glance, the current findings of organized patterns of regulatory behavior by 3 months of age seem inconsistent with Bowlby's (1969) internal working models proposal, which posits that the emergence of early representations of attachment relationships are gradually shaped by the infants' repeated social experiences with caregivers during daily routines. However, it may be that the early emergence of organized patterns of regulatory behavior presage individual differences in earlier-emerging stage-salient tasks, such as emotional expressivity and regulation in challenging circumstances (e.g., internalizing vs. externalizing tendencies), or variations in how infants learn to coregulate during social interactions with others.

Another goal for future research is to evaluate other correlates of the three patterns of regulatory behavior identified in the current study, including quality of the mother–infant relationship in other contexts, as well as infant and maternal characteristics, such as temperament, psychosocial adaptation, and demographics. This research could shed light on how variations in infants' early behavioral responses to the FFSF become stable, self-coherent, and organized patterns of regulatory behavior in the first year of life.

Strengths and Limitations

Our study has both strengths and limitations that are important to consider when evaluating the current findings. Strengths include the study's longitudinal design, its use of multiple methods (i.e., observational and physiological measures) and the opportunity to test and validate further the use of the Coding System for Regulatory Patterns in the FFSF (Fuertes & Lopes dos Santos, 2009). This is a new measure that highlights infant behavioral adaptation patterns across each episode of the FFSF, with a physiological measure (heart-rate) included for convergent validity. The evaluation of additional behavioral measures for infants and mothers in future research may deepen our understanding of the complex interplay among infant, maternal, and interactive variables in the emergence of infant regulatory patterns. It would also be important in future research to evaluate the temporal organization of each regulatory pattern.

Another strength of our study is that it provides strong evidence for the stability of infant regulatory patterns over time. For instance, the number of infants who changed their regulatory pattern from 3 to 9 months was very low (n = 18, 16% of the full sample). This robust stability might also be seen as a limitation, however, because it hinders our ability to examine variables that may contribute to positive and negative changes in infant regulatory patterns over time. Although this study had a relatively large sample size given its longitudinal design, which afforded sufficient power to address the main study aims, the number of infants with a self-comfort-oriented pattern was relatively small. This may have limited our statistical power to identify potential correlates of this pattern over time. Replicating the current study in a larger, more diverse sample might help address these limitations and make findings more generalizable.

Another limitation is that we utilized a single physiological measure (heart-rate). Although heart-rate changes are generally considered to be a good indicator of physiological arousal and regulation during the FFSF, the use of additional physiological measures (e.g., respiratory sinus arrhythmia and galvanic skin conductance) or neuroendocrine measures (e.g., salivary cortisol) could improve our understanding of the biopsychosocial nature of these regulatory patterns in future studies.

In sum, three patterns of infant regulatory behavior were observed during the FFSF in the current longitudinal sample (social-positive oriented, distressed-inconsolable, and self-comfort oriented), which were relatively stable from 3 to 9 months. Moreover, each pattern was associated with different cardiac responses during each FFSF episode, suggesting that infants' early regulatory skills are biobehavioral in nature. It is our hope that the results of this study provide a small step forward in our understanding of the emergence of individual differences in infants' self-regulatory patterns during the first year of life. Considering the robust stability of these emergent regulatory patterns over time, future research should investigate the impact that each pattern may have on infant's later developmental outcomes, including attachment and other developmental outcomes (e.g., executive functions).

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