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The Bidirectional View of Mother-Infant Interaction by Gaze and Facial Affect

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SUMMARY

Objective: The aim of this research was to assess gaze behaviors and facial affect expressions in mother-infant interaction within the frame of self-contingency and interactive contingency, reflecting self-regulation and interactive regulation, respectively. In Model 1, second-by-second changing gaze behaviors (on partner's face/off partner's face) and in Model 2, facial affect expressions (from positive to negative) were examined. Self-contingency reflects the variability or stability in gaze directions and facial affect expressions in each partner. Interactive contingency reflects the degree of mother-infant gaze and facial affect attunement or interactive regulation relative to each other.

Method: Sample was composed of 56 healthy mother-infant dyads. All infants were 4 months old, and mean maternal age was 29.61 (SD=3.71). Mother-infant interactions were filmed at the lab. Interactions were coded second-by-second for mother-infant gaze behaviors and facial affect expressions with video microanalysis method. The analysis method was multilevel-multivariate time series analysis.

Results: According to Model 1-2, mother-infant gaze behaviors and facial affect expressions were neither too stable nor too variable, rather, the change in gaze behaviors and facial affect expressions in each partner showed predictable patterns. Mothers regulated their gaze behaviors and facial affect expressions in relation to that of their infants. Infants regulated their facial affect expressions in relation to their mothers' facial affect expressions, but infant gaze interactive contingency to mother gaze was marginally significant.

Conclusion: In interactions, infants and mothers regulate the rhythms of their own behavior and at the same time contingently coordinate with that of the partner. This bi-directionally regulating environment is the foundation of infants' relationship expectations and bio-social-behavioral regulation capacity, which may be related to psychopathology in future.

Keywords: Mother-infant interaction, face-to-face communication, video microanalysis, multilevel-multivariate time series analysis

INTRODUCTION

Gaze and Facial Affect in Mother-Infant Interaction: Clinical Significance

In the first year of life, socio-emotional and brain development of the infant is facilitated by maternal caregiving and mother-infant interaction (Feldman 2015). The early mother-infant interaction consists of all the patterns in which the mother and the infant match to each other in non-verbal communication modalities such as gaze and affect, and the repair of moments of mismatches in these communication modalities (Stern 1985, Tronick 1989). Infants are highly sensitive to the direction of mother's gaze and the quality of facial expressions from the first months and have the capacity to sense the degree of contingency to their own behavior in these modalities (Meltzoff and Moore 1977, Stern 1985, Trevarthen and Aitken 2001). In addition, four-month-old infants have the capacity to initiate (by looking at the mother) and to end (by ending looking at the mother) interaction by regulating their own gaze behavior, and they can express affect through facial expressions (Beebe et al. 2010, Feldman 2007, Repacholi et al. 2014).

Gaze is among the basic communication modalities that frame face-to-face interaction (Beebe et al. 2010). During a stressful interaction, the infant's heart rate variability (bio-indicator of emotion regulation) decreased more in mother-infant dyads who shared more mutual gaze proportionally (Feldman 2007). To clarify, mutual gaze shapes the biological foundations of infants' evolving emotion regulation capacity. In mutual gaze, the infants' social brain circuits activate and physiological arousal increase (Johnson et al. 2005, Field 1981). Following the arousing moments of mutual gaze, infants naturally stop looking at the mother. Infant looking away as the arousal increases reflect infants' evolving self-regulation capacity (Kopp 1989). This process decreases physiological arousal,

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and so prepare the infant for mutual gaze again, in his/her pace (Beebe et al. 2016). The mother following the direction of infant gaze and responding to infant gaze-on by looking at and to infant gaze-off by waiting enough facilitates infant self-regulation capacity (MacLean et al. 2014).

Another core communication modality in face-to-face interaction is facial expressions that communicate affect (Beebe et al. 2010). The moments of mother-infant affect matching function as biological regulation such as the synchrony of heat rate (Feldman et al. 2011). Thus, this biological regulation in mother-infant interactions shapes the life-long stress responsiveness by changing the brain structures that regulate the infant's stress response (Champagne 2008). The infant can express emotion through facial expressions such as stressful, happy or neutral, and the mother can match to the infant with expressions such as empathic, happy or neutral-interested (Bigelow and Power 2014). The infant can also respond to the mother's affect with his/her own affective expressions, and ongoing affect sharing occurs in the interaction. Given the mother can mirror to the affect expressed by the infant, the infant begins to develop interpersonal expectations that the emotions are recognized and contained (Beebe et al. 2016). The maternal mirroring in this communication modality facilitates to transform the infant bodily experienced affect to representations and self-regulation (Fonagy et al. 2003). Hence, the mother facilitates the infant's self-regulation capacity with the exchanges in the affect modality.

The bidirectional dance in gaze and facial affect constituting a biobehavioral regulatory environment in interactions provides a protective baseline for psychopathology risk in childhood and adulthood. According to the studies in the literature, the level of mutual gaze in the fifth month and the affect synchrony in the third and ninth months in interactions supported the development of self-regulation in childhood (Feldman and Greenbaum 1997, Feldman et al. 2006). Another comprehensive study indicated that gaze and affect synchrony on a second-by-second basis (micro-level) in mother-infant interactions were the foundations of the development of symbol use, empathy, and the ability to read intentions in childhood and adolescence (Feldman 2007). These implications shape the individual's capacity to establish close relationships in the future.

On the other hand, optimally contingent interactions in the gaze and affect modality at 4 months contributed to the development of infant secure attachment at 12 months (Beebe et al. 2010, Beebe et al. 2016). The mother's difficulty in maintaining mutual gaze and non-optimal matching in affect (frozen or non-empathic facial responses of the mother to the infant stress) predicted disorganized attachment, which might increase the risk in terms of psychopathology (Beebe et al. 2012). According to the meta-analysis findings, disorganized attachment developing on the basis of early interactions is particularly associated with externalization and partially with internalization symptoms during childhood and adolescence (Madigan et al. 2013). When the disorganized orientation in the attachment organization persisted into adulthood, this orientation continued to be associated with externalization (aggression, anger and hostility) and internalization symptom levels (anxiety and depression) (Paetzold et al. 2015). Therefore, the current research focuses on early mother-infant face-to-face interaction due to its implications on self-regulation, variables that may affect close relationships, and attachment orientation that may be associated with psychopathology.

The Bidirectional View of Mother-Infant Interaction: Dyadic Systems Approach

International and national studies examine mother-infant/child interaction commonly in terms of maternal sensitivity (Selcuk et al. 2010, Verhage et al. 2016). Maternal sensitivity literature theoretically assumes the infant's contribution to interactions; however, this literature remains limited in analyzing this contribution empirically in accordance with a bidirectional approach (Hane et al. 2003). In addition, studies that examine the nature of early interactions with maternal sensitivity evaluate sensitivity by looking at the general nature of interactions, that is, at macro-level. Recently, attachment theorists emphasize the contribution of examining the mother-infant relationship in terms of specific communication modalities in face-to-face interaction such as gaze and facial affect at micro-level (on a second-by-second basis) to explain the attachment quality of the infant (Bornstein and Manian 2013, van Ijzendoorn and Bakermans-Kraunenburg 2019).

From this point of view, the dyadic systems approach provides a theoretical and empirical model that allows to examine mother-infant interactions from a bidirectional perspective (Beebe et al. 2010, Beebe, Cohen et al. 2016, Beebe et al. 2020). According to this approach, mother and infant affect each other simultaneously moment-by-moment in interactions (Beebe et al. 2016). Therefore, in the interaction, the questions of "how does the infant affect the mother" and "how does the mother affect the infant" can be answered simultaneously in accordance with the bidirectional perspective. Mutual interactional regulation, in which the "infant affects the mother" and "the mother affects the infant", is accompanied by the self-regulation process of the mother and the infant (Gianino and Tronick 1988). The self-regulation process of mother and infant affects interactional regulation and at the same time self-regulation is affected by interactional regulation. As a result, mother-infant interactions are the co-created product of both mother's and infant's self-regulation and interactional regulation processes.

Infants perceive the relationship between two consecutive events through temporal matching or contingency (Cohn and Tronick 1988, Beebe et al. 2016, Bigelow 1998, Bigelow and

Power 2014, Trevarthen and Aitken 2001). Therefore, in the early period, infants' expectations for relationships develop -at the micro-level- through the second-based temporal match (Beebe, Cohen et al. 2016). Therefore, the dyadic systems approach uses the video micro-analysis method to examine self-regulation and interactional regulation (Beebe 1982). In this context, gaze behavior and facial expressions, which can vary on a second basis, are examined with the contingency index, which reflects temporal matching (Beebe et al. 2016, Messinger et al. 2012). For example, the question of how many seconds after the infant's facial affect follows a similar facial affect expression in mother is answered with the contingency index. In this study, since dyadic relationship is examined in time-dependent events, self-regulation was operationally defined as self-contingency and interactive regulation as interactive contingency (Beebe et al. 2016).

Self-Contingency and Interactive Contingency: Clinical Significance

Self-contingency refers to how the mother and the infant's gaze behavior ("looking at the partner's face" or "not looking at the partner's face") and facial affect (transition from positive to negative affect) vary from moment-to-moment (Beebe et al. 2016). Increased variability (decreased self-contingency) or stabilization (increased self-contingency) in the behaviors of mother and infant in both communication modalities indicates stress in the interaction of the dyad (Beebe et al. 2010, Beebe et al. 2011, Jaffe et al. 2001). For example, in the postpartum period, the increase in the mother's level of depressive symptoms was associated with a decrease in self-contingency in the infant's gaze and in the mother's facial affect at the fourth month (Beebe et al. 2008). Therefore, the depression level of the mother in the postpartum period resulted in unpredictability in the gaze behavior (transition between the conditions of looking at the mother's face or not) of the infant, a self-regulation repertoire for the infant, and the mother's own emotion (the transition in facial expressions expressing emotion) at four months. This finding suggests that this unpredictable variability in the self-contingency of the mother and infant may also disturb the interactive contingency in these communication modalities.

Interactive contingency refers to the level of mother-infant contingent coordination, moment-by-moment, in gaze and affect (Beebe et al. 2016). Infants have the capacity to show interactive contingency by the fourth month. However, it is worth noting that mothers' capacity to show interactive contingency is more developed and asymmetrical compared to that of infants (Bigelow and Power 2014). As with self-contingency, insufficient or excessive interactive contingency reflects the stress in dyadic interactions (Beebe et al. 2010, Beebe et al. 2011, Jaffe et al. 2001). According to the literature, the mother's level of psychopathology affects her interactive contingency in the gaze and affect modalities. For example, mothers with high level of postpartum depressive symptoms showed lowered interactive contingency to the infant's gaze and facial affect in the fourth month (Beebe et al. 2008). To clarify, as the level of depressive symptoms in the postpartum period increased, mothers were less able to regulate their own gaze and affect according to that of their infants in the fourth month. In the same study, infants of mothers with high levels of depressive symptoms in the postpartum period also showed low interactive contingency in regulating their gaze behavior according to the mother's gaze behavior. According to another study, the increase in the level of anxiety symptoms of the mother heightened infant facial affect interactive contingency coordinating with mother facial affect (Beebe et al. 2011).

Based on the literature summarized, we think that self-contingency and interactive contingency studies can shed light on how psychopathology is transferred from mother to infant as well as the effects of maternal psychopathology on the infant bio-social-emotional development. Studies imply that the mother's level of depressive symptoms may affect the evolving interpersonal expectations of the infant by altering the interactions toward withdrawal and anxious symptoms toward vigilance (Beebe et al. 2008, Beebe et al. 2011, Granat et al. 2017).

From this point of view, the current research aims to contribute to clinical practice in several aspects by examining mother-infant interactions, specifically self-contingency and interactive contingency in mother-infant gaze and facial affect within the framework of a bidirectional perspective. It provides a theoretical and empirical model for researchers and practitioners working in the field of child and adult mental health to examine early interactions that may be associated with the infant bio-socio-emotional development indicators and lifetime risk of psychopathology. In addition, it is a preliminary work for the empirical knowledge to be transferred from research to practice to apply into the contents of prevention and intervention for new mothers by providing insights on how the risk of psychopathology from mother to infant can be transferred at micro-level. Therefore, in prevention and therapeutic interventions that can be carried out with the perspective of the current research, it can be aimed that mothers can read and match to the micro-level communication behaviors of the infant, and that the infant is an active participant in the interaction.

The Purpose and the Approach of Current Research

The aim of this research was to examine the mother-infant face-to-face interaction in the fourth month from a dyadic systems approach. Accordingly, mother-infant gaze and facial affect self-contingency and interactive contingency were examined. National mother-infant interaction studies are quite limited, and studies available are mostly limited to maternal sensitivity (e.g., Selcuk et al. 2010). As far as is known, there is no national study examining mother-infant interactions from a bidirectional perspective (simultaneous examination of the empirical contribution of mother and infant to interaction) and within the framework of contingency reflecting the regulation of specific communication modalities such as gaze and affect. Therefore, this research is the first study at national level. In terms of self-contingency (predictability or behavioral variability in gaze and affect) and interactive contingency (mother-infant matching, or coordination in gaze and affcet) in mother-infant interactions, international studies have shown that mother-infant dyads in different cultures are more similar than different (e.g. Keller and Otto 2009). Therefore, the present research aims to indicate this cross-culturally shared phenomenon in mother-infant dyads in different cultures can be examined in our national context.

For the purpose of this research, gaze and affect behaviors of mothers and infants were coded first via video microanalysis method (Beebe 1982, Stern 1974). The 2.5 minute mother-infant interactions were coded on a second-by-second basis, respectively, for mother gaze (for 150 seconds), for infant gaze (for 150 seconds), for mother facial affect (for 150 seconds), and for infant facial affect (for 150 seconds). Then, behaviors in gaze and affect modalities are paired for the mother and the infant to examine contingency processes.

Model 1: Infant Gaze-Mother Gaze Modality Pairing (see Figure 1)

Model 2: Infant Facial Affect-Mother Facial Affect Modality Pairing (see Figure 1)

First according to Model 1, we expected to find that infant gaze self-contingency would be significant. That is, prior infant gaze behavior (t_{-3} second) would significantly predict current infant gaze behavior (t_0) (Arrow 1). Secondly, we expected to find that infant gaze interactive contingency would be significant. That is, prior mother gaze behavior (t_{-3} second) would significantly predict current infant gaze behavior (t_0) (Arrow 2). Third, we expected to find that mother gaze self-contingency would be significant. That is, prior mother gaze behavior (t_{-3} second) would significantly predict current mother gaze behavior (t_0) (Arrow 3). Finally, we expected to find that mother gaze interactive contingency would be significant. To clarify, prior infant gaze behavior (t_{-3} second) would significantly predict current mother gaze behavior (t_0) (Arrow 4).

Similarly, in Model 2, we expected to significantly predict infant facial affect self- and interactive contingency and mother facial affect self- and interactive contingency.

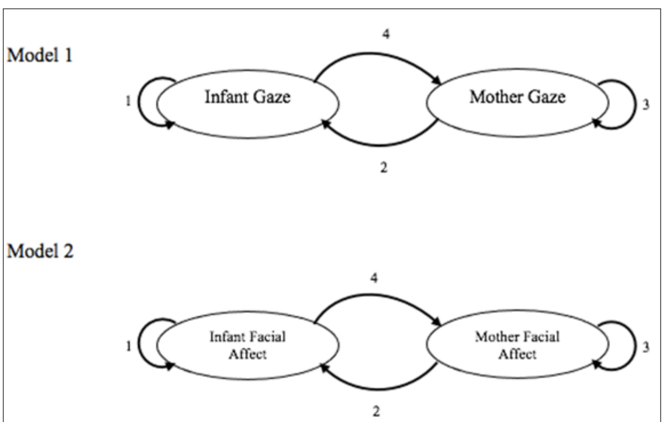

Figure 1. Schematic Illustration of Infant Gaze-Mother Gaze and Infant Facial Affect-Mother Facial Affect Modality Pairings

METHOD

Participants

The current research includes the 4th month assessment of a larger study in which mother-infant dyads began to be monitored in the postpartum period. In the fourth month, 57 mother-infant dyads participated in the video recording of the interactions. A mother from video-recorded mother-infant dyads unpredictably used the ring on her finger as an object that altered the infant gaze behavior. Therefore, this mother-infant dyad was excluded from the sample. As a result, video microanalysis could be conducted on records of 56 mother-infant dyads. The average age of the mothers (*N*=56) in the sample is 29.61 (*SD*=3.71). Mothers were all married and 57.1% of them were university graduates. Majority of the mothers, 65.5%, stated that they were working full time in a paid job. The monthly income average of the mothers in the sample is 6.832 Turkish Liras (*SD*=2.93). While 2 of the mothers (3.6%) reported that they have a current psychiatric diagnosis (anxiety disorder and major depression), 5 (7.1%) reported that they had psychiatric problems in the past. However, when questioned thoroughly, it was understood that the aforementioned mothers were not under treatment (medication or psychotherapy) due to their diagnoses, and symptoms related to their diagnosis improved. Therefore, these mothers were not excluded from the sample.

When the mother-infant face-to-face play interactions were recorded, all infants were 4 month-old and 67.9% of them were male. Delivery method of infants born on time and at normal weight is cesarean for 64.3% of infants and average birth weight is 3.387 kilograms (*SD*=0.28). Complications during delivery were stated by 21.4% of the mothers. When these complications were questioned, the emerging contents were slowing of breathing, decreased oxygen level, slowing of heart rate, fetal distress, sudden changes in the planned delivery method, epidural delivery and problems related to anesthesia. However, according to the mother's report, all babies were developmentally and physically healthy at the time of the research.

Instruments

Socio-Demographic Information Form

Socio-demographic information form, prepared by the researchers, assessed the mother's age, education level, employment status, and whether she had any psychiatric diagnosis, or not. Descriptive characteristics of the infant such as the age, gender, and birth weight were also questioned with this form.

Mother-Infant Face-to-Face Interaction Coding System

In the present research mother gaze, infant gaze, mother facial affect, and infant facial affect were included among the communication modalities coded by video microanalysis. Facial affect behaviors in face-to-face play interaction were coded using ordinal scales as required by the multi-level-multivariate time series analysis conducted within the scope of this research (Beebe et al. 2010). The video microanalysis coding system was used for the first time in a study conducted in our country with this research. Therefore, the corresponding author was trained by Dr. Beatrice Beebe for a year to become a reliable coder in video microanalysis. Gaze was coded on a categorical scale, 1 = on the partner's face and 0 = not on the partner's face on a second-by-second basis. Facial affect were coded on an ordinal scales ranked as high to low. Mother facial affect was coded on a 16-point ordinal type scale on a second-by-second basis: 90 = mock surprise, 88 = mini mock surprise, 85 = smile 3, 80 = smile 2, 70 = smile 1, 67 = "oh" face, 64 = positive interest 4, 62 = positive interest 3, 61 = positive interest 2, 60 = positive interest 1, 50 = neutral, 45 = empathic (woe) face, 40 = negative face, 30 = scrunch face, 20 = dissociated face and 10 = threat face. Infant facial affect was coded on a 7-point ordinal type scale: 85 = medium-high positive, 70 = low-medium positive, 57 = smile 2, 56 = smile 1, 55 = interest/neutral, 40 = mild negative and 20 = negative. In the original study, Cohen Kappa inter-rater reliability values for each behavioral coding were as follows: infant gaze 0.80, infant facial affect 0.78, mother gaze 0.83, and mother facial affect 0.68 (Beebe et al. 2010). In the current study, Cohen Kappa inter-rater reliability values for each behavioral coding were as follows: infant gaze 0.86, infant facial affect 0.80, mother gaze 0.86, and mother facial affect 0.80. The current sample mean percentage values of mother-infant gaze and facial affect behaviors were presented in Table 1.

Procedure

Ethical permissions were obtained from Hacettepe University Ethics Committee (Number: 35853172 / 431-3728) and Ankara Public Health Directorate (Number: 67350377 / 604.02) to carry out the present research. The findings reported here belong to the second time assessment of a more comprehensive two-time research, which was conducted in the infant's 4th month. Inclusion criteria for the first time

Table 1. Average Percentages of Gaze and Facial Affect Codes

	Mother Facial Affect														
	Mock Surprise	**Mini Mock Surprise**	**Smile3**	**Smile2**	**Smile 1**	**Oh Faze**	**Positive Interest 4**	**Positive Interest 3**	**Positive Interest 2**	**Positive Interest 1**	**Neutral**	**Empathic**	**Negative**	**Scrunch**	**Threat**
Average Percentage (Total seconds)	0.2% (14s)	0.2% (15s)	0.4% (33s)	2.1% (179s)	29.3% (2464s)	0.2% (15s)	1.1% (90s)	3.8% (317s)	32.2% (2705s)	23.5% (1973s)	0.0% (4s)	0.4% (36s)	2.4% (198s)	0.4% (33s)	2.5% (212s)

	Infant Facial Affect							**Mother Gaze**		**Infant Gaze**	
	Medium /High Positive	Medium /Low Positive	Smile 2	Smile 1	Interest/ Neutral	Mild Negative	Negative	On Infant's Face	Off Infant's Face	On Mother's Face	Off Mother's Face
Average Percentage (Total seconds)	2% (168s)	5.5% (461s)	10.3% (864s)	23.1% (1940s)	40.9% (3437s)	10.8% (904s)	1.4% (115s)	84.1% (7066s)	15.7% (1319s)	60.9% (5113s)	38.2% (3211s)

s = seconds
Average percentage calculations were based on the total of coded seconds: 8400 s (N = 56 x 150).
Dissociated Face in mother facial affect coding system is not presented in Table 1 since mothers in this sample did not express dissociated face.

assessment in the postpartum period were as follows: mother's having her first baby, being married, being in the postpartum period (baby being between 25-45 days of age), the baby being born at normal weight (over 2.5 kilograms) and on time (37 weeks and after) and baby's not having a physical or developmental disorder. The exclusion criteria were that the mother was younger than 18 years of age, had more than one child, had a biological disability or a psychotic disorder, and the infant had a biological or developmental disorder (detected later after recruitment), even though she was born at normal weight and on time. The gender of the infant was not an inclusion or exclusion criteria. Mother-infant dyads who met the inclusion criteria were reached through Family Health Centers (FHC). In this context, the corresponding author first went to FHCs and identified the mother-infant dyads that fit the inclusion criteria together with the nurses. Afterwards, the mothers were called through the nurses, the content of the study was conveyed on the phone, and appointments were made for the first time assessment to be held at the participant's home during the postpartum period with the mothers who volunteered to participate in both time assessments. Since the first communication with mothers was carried out through nurses, approximately 90% of the mothers who were contacted volunteered for the research. The main concern of the mothers who did not volunteer to participate in the study was the video recording that would take place in the laboratory in the second time assessment.

After the first time assessment in the postpartum period, the birth dates of the infants were followed and the mother-infant dyads were invited to Hacettepe University Clinical Psychology Laboratory to complete the video recording of mother-infant face-to-face play interaction within the 4th month. Mother-infant interaction video recording appointments were planned considering the infant's eating and sleeping patterns. Accordingly, the video recorded started immediately after the mother-infant dyads came to the laboratory without wasting too much time. First of all, the mother-infant dyad was invited to the room prepared for video recording. The infant was safely seated in a baby seat placed on a table. The mother was directed to sit in front of her baby and at face level.

Before starting the video filming of mother-infant interaction, the instruction given to the mothers was as follow: *"Play with your baby for a period of 10 minutes just as you would do in your home"*. No toys or materials were given to the infant and/or mother. Following the instruction, the researcher left the room where the mother-infant dyad was and ensured that the interactions were recorded without any problems in the video recording room. Two separate cameras, covering the head and upper torso of the infant and the mother, were started simultaneously and recorded the interaction for 10 minutes without interruption. With the necessary technical equipment a split-screen view (half for the mother and half for the baby) of the interaction from two synchronized cameras was generated and used for video microanalysis coding to test the main hypotheses of the research. On the basis of the literature (Beebe et al. 2016, Beebe et al. 2018), the 2.5-minute (150-second) of the interaction was coded with video microanalysis separately for both mother and infant in gaze and affect modalities. After the video recording, mothers were given a short feedback about the quality of their interactions; the questions, if any, were answered and a certificate of participation named "Science Baby" was given to the infants.

Data Analysis

The hypotheses of the research were tested with multilevel-multivariate time-series analyses. Time-series analysis is run to determine the organization of a single time-series, i.e. how a person's series of behaviors emerge (self-contingency) or the relationship of two time-series to each other, i.e. whether the behavior series of both partners influences each other as time progresses (interactive contingency) (Beebe et al. 2016). While the predictability of current behavior from one's own prior behavior on a second-by-second basis defines self-contingency (autocorrelation), the coordination of current behavior to one's partner behavior on a second-by-second basis defines interactive contingency (the lagged cross-correlation). The multi-level nature of analysis stems from the data structure in which multiple measurements in time-series are nested within individuals. The multi-variate nature arises from the simultaneous modeling of measurements of mother and infant.

Multilevel-multivariate time series analysis was carried out using the Mplus 8.1 package program (Muthén and Muthén 1998-2017). The Structural Equation Modeling (SEM) approach is used in the analyses conducted with Mplus. With this approach, stated as Dynamic Structural Equation Modeling (DYEM) by Asparouhov, Hamaker, and Muthén (2018), multilevel-multivariate time series analyses can be carried out more efficiently than random coefficient models of the traditional approach. The model is also known as the combination of time-series analysis and SEM analysis. Bayesian estimation method is used in DYEM analyses in Mplus. Although Bayesian methods in multilevel-multivariate time series analyses have many advantages over the maximum likelihood methods of traditional approach, the most important of these is that robust results can be obtained even in smaller samples.

The diagram of the model analyzed by DYEM, drawn according to the SEM approach, was presented in Figure 2. The square variables in the left part of the diagram for mothers and infants indicated the coded measurements in each t second. The green circles indicated the average of

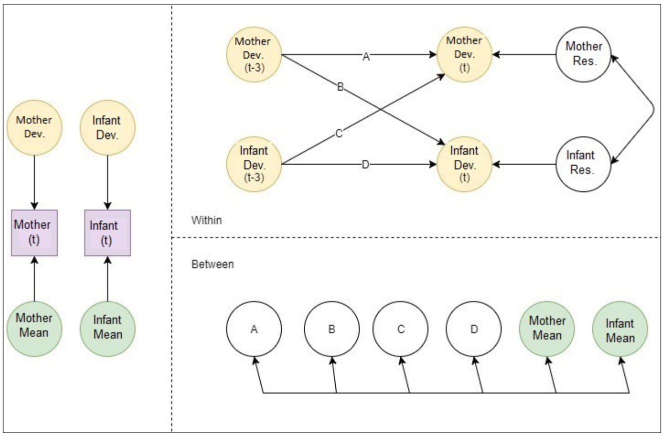

Figure 2. Dynamic Structural Equation Modeling in Multilevel-Multivariate Time-Series Analysis
Dev.: Deviation, Res.: Residual

measurements for a total of 150 seconds for mothers and infants, while the yellow circles indicated the deviation of the measurements at each t second from these averages. In the upper right part of the diagram, the arrows indicated by A, B, C, and D show the self- and interactive contingency estimates for mothers and infants, and these effects, which cannot be directly observed, were modeled at the within-dyad level. In the lower right part of the diagram, it is seen that previously modeled variables were modeled in relation to each other at the between dyad level. The DYEM time-series analysis is based on the confidence interval in accordance with the Bayesian approach in hypothesis testing. In addition, one-tailed p-value (p-value expressing probability calculated later for the distribution of the confidence interval) was obtained from the analysis results.

Before conducting the multilevel-multivariate time series analyses, it was decided how many seconds of lag should be taken for estimates of mother-infant self-contingency and interactive contingency. In the literature, it is suggested that a 3 second delay (3 lagged) can be taken (Beebe et al. 2008). In addition to this suggestion, by performing preliminary analyses on the data, the length of the lag was gradually increased to values higher than 1 and the effect of the average value of the interactive contingency on the varying delays for all mother-infant dyads was investigated. As a result of the preliminary analyses carried out, it was observed that the mean value of the effect (infant interactive contingency estimation), especially from the mother to the infant, was positive for the whole sample only after a delay of 3 seconds. Therefore, it was decided to use a 3 second delay (t-3) for the contingency estimates.

In summary, whether mother self- and interactive contingency and infant self- and interactive contingency that were depicted with A, B, C, and D arrows, respectively, in Figure 2 were significant or not were tested for Model 1 and Model 2 modality pairings.

RESULTS

Model 1: Infant Gaze-Mother Gaze Modality Pairing

In Model 1, to what extent the degree of infant gaze self- and interactive contingency and mother gaze self- and interactive contingency are predictable in mother-infant face-to-face interaction were tested. The findings showed that infant gaze self-contingency (β=0.33, *p*=0.000; 95% CI [0.28, 0.37]) and mother gaze self-contingency (β = 0.08, *p*=0.004; 95% CI [0.02, 0.13]) were significant. Both the infant's and the mother's own gaze behavior t-3 seconds prior predicted the current gaze behavior at t_0. Therefore, infant's and mother's own gaze behavioral alternation rhythm showed a predictable pattern. Mother gaze interactive contingency was also significant (β=0.09, *p*=0.000; 95% CI [0.04, 0.14]). Accordingly, the infant's gaze behavior t-3 seconds prior predicted the mother's current gaze behavior at t_0. Mothers were able to monitor the baby's gaze behavior and regulate their gaze behavior according to the infant's gaze behavior. On the other hand, Model 1 findings showed that infant gaze interactive contingency indicated a marginal trend (β=0.04, *p* = 0.079; 95% CI [-0.01, 0.08]). According to the marginal trend, infants tended to follow the mother's gaze behavior and regulate their gaze behavior according to the mother, but this trend did not reach significance. Findings were presented in Figure 3 and Table 2.

Model 2: Infant Facial Affect-Mother Facial Affect Modality Pairing

In Model 2, to what extent the degree of infant facial affect self- and interactive contingency and mother facial affect self- and interactive contingency are predictable in mother-infant face-to-face interaction were tested. Model 2 findings showed that infant facial affect self-contingency (β=0.22, *p*=0.000; 95% CI [0.19, 0.25]) and infant facial affect interactive contingency (β=0.07, *p*=0.000; 95% CI [0.04 0.09]) were significant. According to these findings, infant's own facial affect t-3 seconds prior predicted the current facial affect at t_0. In other words, infant's own facial affect behavioral stream showed a predictable pattern. Simultaneously, the mother facial affect t-3 seconds prior predicted the infant's current facial affect at t_0. That is, infants regulated both their own facial affect and at the same time were regulated by mother facial affect. In addition, mother facial affect self-contingency (β=0.09, *p*=0.000; 95% CI [0.07, 0.12]) and mother facial affect interactive contingency (β=0.04, *p*=0.002; 95% CI [0.01, 0.07]) were also significant. Accordingly, mother facial affect t-3 seconds prior predicted the current facial affect at t_0. In other words, mother's own facial affect behavioral stream indicated a predictable pattern. Simultaneously, the infant facial affect t-3 seconds prior predicted the current mother facial affect at t_0. Thus, mothers regulated both their

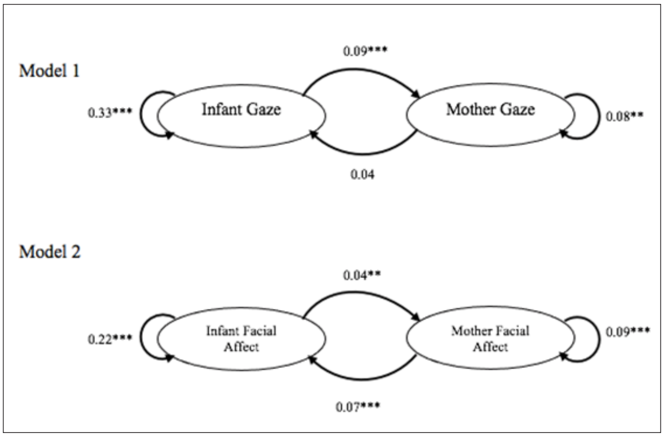

Figure 3. Infant Gaze-Mother Gaze and Infant Facial Affect-Mother Facial Affect Self- and Interactive Contingency Findings
**p<0.01, ***p<0.001, one-tailed

Table 2. Standardized Coefficients in Mother-Infant Interaction Models

Model 1. Infant Gaze-Mother Gaze Modality Pairing			
	Standardized Coefficients β	**p**	**95% Confidence Interval**
I Gaze S-C	0.328***	0.000	0.282-0.370
I Gaze IC	0.036†	0.079	-0.014-0.084
M Gaze S-C	0.075**	0.004	0.021-0.131
M Gaze IC	0.087***	0.000	0.038-0.135
Model 2. Infant Facial Affect-Mother Facial Affect Modality Pairing			
	β	**p**	**95% Confidence Interval**
I Facial Affect S-C	0.223***	0.000	0.19-0.25
I Facial Affect IC	0.065***	0.000	0.04-0.09
M Facial Affect S-C	0.094***	0.000	0.07-0.12
M Facial Affect IC	0.043**	0.002	0.01-0.07

Model 1. I Gaze S-C: Infant Gaze Self-contingency (the variability in infant's gaze behavior); I Gaze IC: Infant Gaze Interactive Contingency (the degree of coordination of infant's gaze behavior to mother's gaze); M Gaze S-C: Mother Gaze Self-contingency (the variability in mother's gaze behavior); M Gaze IC: Mother Gaze Interactive Contingency (the degree of coordination of mother's gaze behavior to infant's gaze)
Model 2. I Facial Affect S-C: Infant Facial Affect Self-contingency (the variability in infant's facial affect); I Facial Affect IC: Infant Facial Affect Interactive Contingency (the degree of coordination of infant's facial affect to mother's facial affect); M Facial Affect S-C: Mother Facial Affect Self-contingency (the variability in mother's facial affect); M Facial Affect IC: Mother Facial Affect Interactive Contingency (the degree of coordination of mother's facial affect to infant's facial affect)
Model 1 and Model 2 were examined with multilevel-multivariateseries-analysis. In models, while examining each contingency index, the effects of other contingencies were controlled and therefore, mother's and infant's self-effects (the variability within the infant and the variability within the mother) and bidirectional effects (the effect from the infant to mother and the effect from the mother to the infant) could be assessed. Model 1 data set was generated by coding each second of 150 second-segment for mother gaze (on infant's face/off infant's face) and infant gaze (on mother's face/off mother's face), separately, with video micro-analysis. Model 2 data set was generated by coding each second of 150 second-segment for mother facial affect (from positive to negative) and infant facial affect (from positive to negative), separately, with video micro-analysis.
†p<0.10, *p<0.025, **p<0.01, *** p<0.001, one-tailed.

own facial affect and at the same time were regulated by infant facial affect. Findings in facial affect modality pairing documented that infant and mother had a predictable pattern in their own facial affect flow, and, simultaneously regulated their facial affect according to that of the partner. Findings were presented in Figure 3 and Table 2.

DISCUSSION

According to the findings of infant gaze-mother gaze modality pairing examined in Model 1, infant gaze self-contingency, mother gaze self-contingency and mother gaze interactive contingency were predictable in mother-infant interactions in the fourth month. In this regard, mothers indicated a predictable pattern in the behavior of looking at the baby's face or not, and at the same time regulated their own gaze behavior according to the gaze behavior of the infants. That is, when the infant looked at the mother's face, the mother responds by looking at the infant. Or, when the infant stopped looking at the mother's face, the mother stopped looking at the infant. Therefore, mothers follow the infant's gaze direction and adapt to change in infant gaze. On the other hand, infant gaze interactive contingency was not significant and indicated a marginal effect. To clarify, infant's behavior of looking at or not looking at the mother's face presented a predictable pattern in itself, but infants did not regulate their gaze behavior according to the mothers' gaze behavior. The present findings in the gaze modality are generally consistent with the literature, except for infant gaze interactive contingency (Beebe et al. 2016, Harel et al. 2010, Lavelli and Fogel 2013).

The finding that infant gaze interactive contingency, which means the infant's regulation of his/her gaze behavior according to the mother's gaze behavior, indicated a marginal trend can be attributed to several factors. Mothers have an asymmetrical role in terms of interactive contingency. Mothers tend to show more interactive contingency than the infant's interactive contingency capacity (Beebe 2006, Beebe et al. 2016). Therefore, finding regarding infant gaze interactive contingency might not reach to significance. On the other hand, in the present study, as stated in the method section, a three-second lag was determined as the criterion for estimates of all interactive contingency analyses. For example, when the mother's gaze is directed towards the baby's face, the answer to the question whether the baby's gaze is directed at the mother's face after three seconds was sought. Although a three-second lag for the estimation of interactive contingency is determined within the framework of the literature and preliminary analyses, it may be necessary to extend the lag time for the infant gaze interactive contingency to reach significance (Margolis et al. 2019). Some studies showed that the degree to which the infant and the mother respond to each other can be up to a five-second delay (van Egeren et al. 2001). Therefore, we can argue that the infant gaze interactive contingency might reach significance if a lag of five seconds, that is, a longer delay, was determined.

As a result, the hypotheses of infant-mother gaze modality pairing were largely confirmed. Self-contingency in gaze makes the infant for the mother and the mother for the infant predictable in attention regulation. With an infant who does not have a predictable self-regulation in interaction, it may be difficult for the mother to show interactive contingency in attention. The mother's sense of the infant's pattern of looking or looking away at a certain level supports her ability to show interactive contingency in gaze. The same is binding for the infant. The synchronization of gaze determines the framework of the relational experience between mother and infant (Beebe et al. 2018, Feldman et al. 2011, Lotzin et al. 2015). It is also associated with the capacity to build empathy and intimacy capacity as the development proceeds (Feldman 2007). According to current research, it is understood that healthy mother-infant dyads have self-regulation in gaze, and simultaneously, the mothers can regulate their gaze behavior according to the that of infants.

According to the findings of infant facial affect-mother facial affect modality pairing examined in Model 2, infant facial affect self- and interactive contingency and mother facial affect self- and interactive contingency were significantly predictable. Accordingly, infants and mothers presented predictable patterns in facial affect expressions within their own behavioral flows. Mothers and infants, who regulate facial affect expressions within themselves, were simultaneously regulated by the facial affect expressions of their partner. That is, infants monitored their mothers' affect and mothers monitored their infants' affect and they regulated their facial affect according to each other. Current findings are consistent with the dyadic systems approach and empirical studies in the literature (Beebe et al. 2016, Feldman et al. 2011, van Egeren et al. 2001). Facial affect is very critical to examine the "mirroring" process that is organized jointly by the mother and the infant (Beebe et al. 2016, Slade 2005). The mother, who adapts to the infant's emotions with facial expressions, facilitates the infant's bodily experienced emotions turn into self-regulation and sense of self (Fonagy et al. 2003). While mirroring, the mother's interactive regulation by matching the infant's affect but on the other hand by making it also marked creates an expanding and fulfilling relational experience (Gergely and Watson 1999). The intersubjective infant, on the other hand, has the capacity to share affect through facial expressions (Bigelow and Walden 2009, Trevarthen 2011). Optimal sharing in facial affect is the basis for the infant's secure attachment organization and self-development (Beebe et al. 2010).

There are some implications that can be translated into clinical practice in the light of the findings. First, the importance of the interaction being organized by the specific behaviors of the infants should be emphasized to mothers in interventions to be carried out with both healthy and at-risk mother-infant dyads. According to the findings, there is an ongoing self-regulation and interactive regulation in the interactions of mother-infant dyads in gaze and affect. For this reason, the importance of being able to read the signals from the infant in each communication modality should be emphasized in practice with mothers. For example, in order to support the mother to wait long enough when the infant looks away (such as not trying to turn the infant's head towards herself, not being intrusive by getting too close to the infant), mothers can be informed that looking away is not due to the rejection of the interaction with the mother, rather, in all healthy mother-infant dyads, infants may look away for a short period of time. The infant will then return to the mother when regulated enough. Furthermore, it is supported by the present research findings that when the mothers read the signals sent by the infant optimally in the facial affect and respond appropriately, infants can adapt to mothers with affect expressions. Therefore, the empirical finding that can be translated into mothers in clinical practice, is that infants are quite sensitive to maternal facial affect expressions and the level of maternal match to their own facial expressions. As a result, the ability to read the mother-infant interaction modalities in a holistic manner may be among the goals of interventions with mothers. As supported by the current research, emphasizing how an active participant the infant is in the interaction within the framework of his own self-regulation and interactive capability, especially by the fourth month, may contribute to improving the quality of mother-infant interactions.

According to the literature, self-contingency and interactive contingency processes examined by video microanalysis in mother-infant interactions at 4 months predicted the attachment quality of 12-month-old infants (Beebe et al. 2010). Therefore, current research findings provide an innovative methodological perspective for future national attachment research and provide empirical knowledge of the bidirectional nature of mother-infant interactions. According to studies conducted in different cultures, mothers' preferences to interact face-to-face with their infants (such as how often they prefer face-to-face interaction, how they arouse, regulate, and express emotions) differ across cultures, but the contingency in face-to-face interactions show cross-cultural similarity (Beebe et al. 2016, Bornstein et al. 2012). Thus, current research shows that the contingency in mother-infant interaction, which is shown to be a common phenomenon in different cultures, are also valid for mother-infant interactions in Turkish culture.

The research has some limitations that may inform future studies. In this study, the predictive power of micro-level patterns observed at the 4th month on the attachment organization of the infant at 12th month was not examined. Hence, it will contribute to examine the relationship between the video microanalysis findings and the attachment organization of the infant in future national studies. Multilevel-multivariate time series analysis is carried out due to the coding on a second-by-second basis and a robust data set is obtained in this way. Therefore, it is an analysis method robust to small sample size. However, the number of mother-infant dyads included in the sample still constitutes a limitation for the current research. In addition, current sample of mother-infant dyads belong to the middle-upper socio-economic level and mothers had their first healthy baby. These characteristics limit the generalizability of the findings. Finally, it was aimed to conduct the research with healthy mothers. However, evaluations regarding the mental health of the mothers were limited to the answers given by the mothers to the current and past psychiatric diagnosis questions directed by the corresponding author on the demographic form. This situation creates a limitation in terms of mental health assessments of mothers. The literature indicated that mother-infant self-contingency and interactive contingency were affected by the mother's depression and anxiety symptom level (Beebe et al. 2008, Beebe et al. 2011, Granat et al. 2017). Conducting future studies with mother-infant dyads from clinical samples with a similar approach of the current study will contribute.

CONCLUSION

This study demonstrated that four-month mother-infant face-to-face interactions are organized by mother-infant self-contingency and interactive contingency in different communication modality pairings. Consistent with the emphasis on infant self-contingency processes in the dyadic systems approach (Beebe and Lachman 2002, Beebe et al. 2016), infant's behavioral rhythm in gaze and facial affect documented a predictable pattern in itself. Self-contingency in this context is a form of self-regulation. A certain degree of infant self-contingency makes the infant predictable for the mother in all communication modalities. Infant self-contingency (Beebe et al. 2016), as a neglected component in interaction research, is an important part of face-to-face interactions, independent of other processes in dyadic interaction, as supported by the findings of the current research. Therefore, the infant is also an active participant in interactions. The effect sizes of mother-infant interactive contingency suggest that self-contingency may be more determinant in organizing the relational experience of the dyad compared to interactive contingency. Thus, while mother-infant interactions are mostly shaped by self-contingency, there is also an interactive regulation in gaze and affect.

In this study, non-verbal behaviors that would not be noticed by watching the interaction with the naked eye and globally were coded separately for mother and infant via video microanalysis method in two communication modalities and a comprehensive bi-directional approach was presented. Mother-infant interactions were filmed in laboratory with technical equipment required for video microanalysis, which necessitates coding of interaction behaviors on a second-by-second basis. The analyses of the research were carried out with multilevel-multivariate time series analysis. Hence, the current research is considered to be methodologically strong. The coding system that allows to micro-analyze interactions was used for the first time in this study in Turkey. The mentioned characteristics constitute the strengths of the research. The limitations of the research is to suggest specific implications for clinical research and practice. To clarify, the most important limitation of the research is the lack of comprehensive evaluations of maternal mental health and longitudinal follow-ups that would explain how early interactions are associated with developmental and clinical infant variables.

In conclusion, the current research reveals that mother-infant interaction is organized with micro-level behaviors in the non-verbal period (for example, mother-infant monitoring and regulating each other's facial affect). When this organization is optimal, it facilitates "to know" and "to be known" for the developing relational self of the infant, and also functions as a physiological and biological regulation (Lyons-Ruth 2008, Pratt et al. 2015). In this vein, internal working models of the infant develop ("My looking is responded by looking"; "When I want to regulate myself, I can look away"; "When there is a change in my internal state, this change is seen") and thus, the baby's self-regulation capacity and secure attachment is facilitated. The micro-level interactions examined in this research have a rewarding function for the mother. The regulation observed at behavioral level in dyads occurs at the biobehavioral level (Feldman et al. 2011). The current research presents an example of how mother-infant interactions are regulated at the behavioral level.

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