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Spontaneous emotional coordination of first-born dizygotic twins and singletons with their mothers in early infancy

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ABSTRACT

We compare matching of facial expressions of emotion, completion of the positive valence of emotional expression, attunement of emotional intensity, and non-matching of emotion, in engagements with their mothers of firstborn dizygotic twins and of singletons. Nine twins and nine singletons were video-recorded at home in spontaneous face-to-face interactions from the second to the sixth month after birth. Microanalysis of infant and maternal facial expressions of emotion revealed *qualitative and quantitative differences* that indicate that engagements with twins had more frequent and more accurate emotional matching and attunements compared to those with singletons. Singletons displayed more emotional completion and non-matching reactions. Expressions of matching for pleasure and interest followed different developmental patterns in the two kinds of dyads. These results are discussed in relation to the theory of innate affective intersubjectivity. Differences may shed light on the relationship between sharing early life with a twin, and development of self-other awareness.

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KEYWORDS Emotional coordination; emotional non-matching; twin infants–mother interaction; innate intersubjectivity; prenatal affective engagement; developing companionship

Introduction

By comparing emotional engagement in natural communication between mothers and first-born twins or singleton infants, we examine the ways in which varieties of emotional expression are exchanged between the two kinds of dyad in early months. Differences may shed light on the relationship between sharing early life with a twin and development of self-other organization with possible consequences for the ability of the child and parent to regulate and negotiate interpersonal challenges in the future.

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The theoretical frame of this study

Our investigation was conceived in accord with the theory of *innate intersubjectivity* which holds that infants possess complex motives and emotions for sustaining companionships, which are adapted to perceive, respond to, attract and influence how other persons feel and what they, in response, will perceive and do (Trevvarthen, 1993, 1998; Trevvarthen & Aitken, 2001). This readiness for coordination of feelings with others in the first six months, before any articulate 'theory of mind', is reflected in the state of emotional equilibrium or intra-subjective coherence within the self of the child – how secure and creative they feel in their activities and communication. We emphasize the innateness of these adaptations with evidence from a new more descriptive and less prescriptive and experimental science of infancy, which finds evidence of intuitive cooperation in intentions and feelings from birth. It researches the biology of this shared affective consciousness (Panksepp, 2007), and how it develops from conception. The steps by which infants master artefacts of cooperative cultural life in informal games give further information on the natural growth of embodied inter-subjectivity and how it motivates learning from within the child (Trevvarthen, 2011).

Sensitivity for regulation of both subjective and intersubjective impulses and feelings undergoes age-related changes attributable to developments in prospective control of body movements and in the motivating processes adapted for cultural learning (Trevvarthen & Aitken, 2003). In the period of 'Primary Intersubjectivity', from 6 to 12 weeks after birth, the infant Self shows direct sensitivity to the timing and values of expressions of feeling in intimate *proto-conversation* with a receptive and sympathetic Other (Bateson, 1979; Trevvarthen, 1979). Reciprocal imitation of expressive movements constitutes the process by which mental activity of a conscious Self in movement is transferred between minds (Trevvarthen, 1986, 1993). In subsequent weeks the 'Period of Games I', from 3 to 6 months, expresses a transformation of the infant's powers of action, which results in both an increasing exploration of the environment and effective manipulation of objects. The mother now communicates not only with the infant's emotions and expressive motives responsive to and directed towards her, but with a constantly changing attentiveness of her baby to surroundings and an increase of motives to explore and to perform acts on nearby objects (Trevvarthen, 1986). In these months, play with infants reveals constructive changes in three essential dimensions of expressive movement that motivate human learning: 'kinematics' (timing), 'physiognomics' (form) and 'energetics' (intensity) (Trevvarthen, 1986). These are foundations for the *rhythm*, *quality* and *narrative* of human 'communicative musicality' (Malloch & Trevvarthen, 2010).

Previous research on emotional transactions of twins and non-twins in early infancy

Longitudinal studies of mothers' communication with triplets in infancy showed that while there were *similarities* in infant–parent synchrony and in maternal and

infant affect, there were *differences* favoring singleton infants – in infant gaze at mother, and in the mother's sense of competence and sensitivity (Feldman & Eidelman, 2004, 2005; Feldman, Eidelman, & Rotenberg, 2004). These were interpreted as consequences of the extra burden to the attachment feelings of the mother when she had three individuals to care for at the same age. In studies that give more attention to the emotional initiatives of the infant, evidence on the quality of emotional transactions between twins and non-twins comes from comparative studies on imitation and spontaneous interactions of DZ twins observed separately with the mother (Kugiumutzakis, Kaklamani, Sarafidou, Markodimitraki, & Pateraki, 2009; Markodimitraki & Kokkinaki, 2014; Pateraki, 2011), and from studies on interactions of mothers with singletons (Kokkinaki & Vasdekis, 2015; Kokkinaki, Vasdekis, Koufaki, & Trevarthen, 2016). These studies have provided the following findings:

- Emotional engagement and imitation was structured in more frequent and shorter subunits of time in 6 twin infant–mother dyads compared to those of 9 singletons. This difference was greater with infants 3, 5 and 6 months of age;
- For singletons, the probability of emotional *non-matching* was higher than the probability of emotional matching and completion. For twins, *matching* predominated over interpersonal engagement categories that included *completion* and *non-matching*, or *intermittent non-matching*;
- There is evidence of *emotional consistency* for singletons, twins and their mothers through units of 'dialogue'; and
- In both singletons and twins there is a *non-significant infant age effect* on the non-linear developmental trajectory of emotional matching in communication with the mother. Emotional matching of both *pleasure* and *interest* in interactions with twins shows a fluctuating trend with peaks at 2, 4 and 6 months. Matching of *pleasure* in singleton infant–mother interaction shows an increasing trend, while *interest* matching follows a fluctuating trend with a peak at 5 months.

Aim, hypotheses and importance of this project

Based on the relevant literature and the above studies made in Crete, we addressed the following hypotheses concerning differences between mothers' engagements with twins and singletons:

- There will be differences in *timing* of infant-mother 'dialogues' between the two dyads (*Hypothesis 1*);
- There will be a quantitative difference in *emotional coordination* (*Hypothesis 2a*) and qualitative differences in *interpersonal engagement* (*Hypothesis 2b*);
- There will be similarities in the *emotional consistency* of each partner (*Hypothesis 3*); and

- There will be similarities in the non-significant infant age effect on the developmental non-linear trajectory of *emotional matching* (Hypothesis 4).

In previous studies of mothers' engagements with twins and singletons, measures of emotional regulation focused on expressive capacities of individuals. Observations at successive age levels were videotaped in different settings, and recordings of naturalistic spontaneous infant–parent interactions were made at one age point. Analysis of parent–infant synchrony concerned only gaze, touch synchrony and co-vocalization and did not include affect matching. Finally, micro-analysis was not continuous since the coder selected one behaviour for measurement in each 10-s epoch.

The present study is directed to obtaining more detailed information on emotional dynamics between the mother and her infant. Interpretation of the findings of this study depends on *continuous* micro-analysis, to an accuracy of 1/25th of a second, of spontaneous facial expressions of emotion of a sample of 9 twin infant–mother and 9 singleton infant–mother pairs, each of which was video-recorded for 7 min from the 2nd to the 6th month of infant's life at 30-day intervals at infants' home. Inevitably, micro-analysis in such detail of non-verbal expressive behaviours is a difficult and time-consuming enterprise which must be carried out in ways that facilitate statistical procedures (Beebe, 1982). It is also difficult to obtain a large sample of families of twin infants (Losoya, Callor, Rowe, & Goldsmith, 1997), and to make comparison with many families with healthy infants for an extensive observational period (Keller & Zach, 2002).

We chose to compare emotional coordination of facial expressions of twins and singletons with their mothers in early months to extend our understanding of the first experiences of self–other organization and its emotional foundations. The special situation of being in close company with a twin from the start of intentional and sentient life offers the unique experience of being a mirror image of a separate person like oneself on whose actions there are uniquely abundant opportunities to respond and reflect (Cassidy, Fineberg, Brown, & Perkins, 2005; Zahn-Waxler, Robinson, & Emde, 1992).

New evidence of prenatal affective life and proof of fetal awareness of the sensitive company of a twin reveals a precocious sense of self, with awareness of being in contact with a separate Other similar one's Self yet likely to be different in temperament (Castiello et al., 2010; Piontelli, 1992; Reissland & Kisilevsky, 2015). Twinship may, in consequence, favour earlier development of social-emotional awareness. On the other hand, the 'twin bond' has been described as a tight link between individuals which hinders their social adaptation, contributes to delaying differentiation between oneself and one's twin, and leads to a genuine 'confusion' of personality and roles in life (Ainslie, 1979; Zazzo, 1960, cited by Robin & Casati, 1994).

In twinship there is an additional implication for development of maternal attachment. Exclusive parenting is disrupted since more than one infant is the

target of the attachment process at the same time (Feldman & Eidelman, 2004). Parents of multiple birth infants, twins or triplets, tend to become attached either to the multiple birth set, or to preferentially bond with one infant at the expense of the other or others. Both alternatives may lead to restricted parenting (Holditch-Davis, Roberts, & Sandelowski, 1999). The experience of emotional coordination with a parent generates affective states and causes effects in development of infants and children, which may last (Feldman & Eidelman, 2004).

Our purpose is to discover effects of twinship that may help clarify the human nature of early affective development in intimate relations (Trevvarthen & Panksepp, 2016), building on the insights of Daniel Stern who pioneered a micro-analysis of a mother interacting with her three-and-a-half year old twins, which revealed the mutual influence of 'affective attunement' of her engagements with the two boys (Stern, 1971).

Method

Participants

Nine DZ twin infant-mother and nine singleton infant-mother pairs from Greece, Crete took part in this study.^{1,2} We excluded infants who were at medical risk, with birth weight less than 1700 gr, or with gestational age less than 34 weeks (Table 1).

Taking account of complicating factors as discussed above, and with information from related studies (Holditch-Davis et al., 1999; Tomasello, Mannle, & Kruger, 1986) the two groups were matched retrospectively on maternal age, socioeconomic status and family composition, as well as fathers' age and level of education. Infants were approximately matched on gestational age and birth weight, accepting that normally twin infants have slightly lower values in both of these measures. For birth weight, 42.7% of twin infants weigh at birth less than 2500 gr (Sutcliffe & Derom, 2006).

¹The video-recordings of singletons communicating with their mothers used in this study were made for the Ph.D. research of the first author at the Department of Psychology, University of Edinburgh, under the supervision of Prof. Colwyn Trevarthen. Ethical approval for their use was granted by the Royal Infirmary of Edinburgh, NHS Trust (8/95). The video-recordings of twins and their mothers came from a longitudinal naturalistic study which aimed to compare basic aspects of spontaneous imitation in dialogues of mothers with twins and singletons. We acknowledge the assistance of Professor Colwyn Trevarthen for the final preparation of this paper. We are deeply indebted to the infants and their families for offering their time, cooperation and patience to participate in the study.

²The sample of twins for this study included only DZ infants, after parents of MZ twins refused to participate (see Pateraki, Markodimitraki, Kaklamani, & Kugiumutzakis, 2008). We studied only first-born twin infants for two reasons: (a) to avoid recording observations when one adult interacts with more than one child of the same family (Feldman & Eidelman, 2004), and (b) to exclude effects of differences in the brain structure and brain size which are recorded between second-born twins and their first-born co-twins (Hulshoff Pol et al., 2002).

Table 1. Demographic information for the sample ($N = 36$).

	Singleton infant–mother dyads ($N = 18$ subjects, 9 singletons and 9 mothers)		Twin infant–mother dyads ($N = 18$ subjects, 9 first-born twin infants and 9 mothers)	
	Mean	SD	Mean	SD
Mother age (years)	30.44	4.74	30.44	3.71
Mother education (years)	14.88	2.02	13.77	2.33
Father age (years)	34.55	5.81	35.11	4.56
Father education (years)	15.11	2.42	13.33	2.00
Gestational age (weeks)	38.00	.86	36.00	1.32
Birth Weight (kg)	3522.22	498.81	2474.44	224.28
Birth height (cm)	52.16	2.29	49.55	1.33
Breastfeeding (days)	75.66	81.29	51.00	31.10
Infant age	2–6 months old (recorded at 30-day intervals)		2–6 months old (recorded at 30-day intervals)	
Way of delivery	7 SVD ^a /2 CS		All CS	
Male/female	5 boys (55%)/4 girls (45%)		7 boys (77%)/2 girls (33%)	
Sex of twin pairs			6 mixed gender/2 boy-pairs/1 girl-pair	
Birth order in the family	5 first-born infants/4 second-born infants		6 first-born infants/3 second-born infants	
Family composition	Two-parent families		Two-parent families	
Socio-economic status	Middle-class families		Middle-class families	

^aSVD = Spontaneous Vaginal Delivery, CS = Caesarian Section.

Twin zygosity determination

Opposite-sex twin infant pairs were accepted as dizygotic (Wilson, 1983), and zygosity of same-sex twins was established according to the Zygosity Questionnaire for Young Twins (Goldsmith, 1991).

Procedure

Video-recordings were made at 30-day intervals, 15 days after the beginning of proto-conversations in the *Primary Intersubjectivity Period* at six weeks until the end of *Period of Games I* at 6 months; that is, at 2, 3, 4, 5 and 6 months (Trevarthen, 1993). The instruction given to the mothers was: ‘Play as you normally do with your baby’. Each video-recording lasted 7 min. In all, five video-recordings were made for each of the 9 twin-infant–mother pairs and 9 singleton infant–mother pairs, giving a total of 90 video-recordings for the entire sample. However, due to short-term health problems two visits of twin pairs were missed, and we retained 616 min of recordings.³

³Contact with the families of twin and singleton infants was established with obstetricians and paediatricians who opened access to birth records. After birth, medical staff gave a letter to each family informing them about the aim and the ethics of the research. After 15 days, researchers telephoned each family in order to reassure consent for participation in the study. Before the end of the first month, researchers visited each family at their home for a discussion. In the course of this visit it was explained to parents of singletons that this was a study of parent–infant play that aimed to reveal possible differences in playful activities of parents in the two cultures studied. Parents of twins were informed that this was a study comparing the way of communication between twin infant–mother and singleton infant–mother pairs [The recruitment procedure and recording arrangements for the sample of singletons and twins are detailed in Kokkinaki (1998) and in Pateraki et al. (2008), respectively].

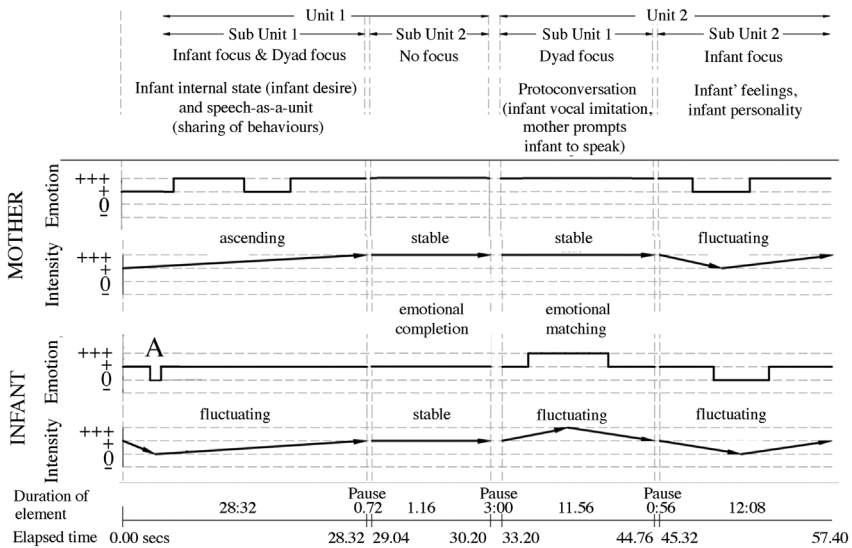


Diagram 1. An example of micro-analysis of facial expressions of emotions in a spontaneous interaction of a 2-month-old singleton infant with his mother.

Notes: At A, in Unit 1, the infant shows a brief drop in level of emotion, which had been at the same level as the emotion of the mother. This shows a change from emotional matching to emotional non-matching. Subunit 2 of Unit 1 is a brief, 1.16 s, interruption of communication in which both mother and infant attend to each other with positive expressions at moderate to high intensity. This is followed by an animated two-part engagement in Unit 2, ending with mother's comments on the infant's changing feelings.

Coding

A micro-analysis of facial expressions of emotion, by mothers and by twin and singleton infants in spontaneous 'dialogues' with their mothers, was made with defined measures.⁴ Before this analysis, the record of the mother's infant-directed speech in each sample was divided into units and subunits of narrative, separated by pauses (see Kokkinaki et al., 2016 for full description of the plan for microanalysis and coding). An example of this preliminary description of segments of behaviour of mother and infant in dialogue is presented in Diagram 1.

⁴In order to make a reliable micro-analysis of facial expressions of emotions by mothers and infants in the course of spontaneous 'dialogues' between them, the flow of interaction had to be described with defined measures. With this aim, micro-analysis and coding proceeded as follows: (1) maternal infant-directed speech and infant vocalizations/non-speech sounds were transcribed from the video-recording by both researchers, and then they were checked for accuracy by an assistant; (2) written verbatim accounts of maternal infant-directed speech were classified into 'focus categories' and 'thematic sequences'; (4) each focus category was segmented into units and subunits of analysis, according to the duration of the pause preceding and following each thematic sequence. The chosen segmentation procedure for microanalysis of facial expressions, using the speech of the mother to distinguish units and sub-units of communication, was applied in the same form for all subjects; and (5) within each sub-unit of analysis, infant and maternal facial expressions of emotion were micro-analyzed and then they were grouped into categories of interpersonal engagement (see Kokkinaki et al., 2016 for full description of the plan for microanalysis and coding). Micro-analysis of facial expressions of emotion by singletons and their mothers was carried out by the first author, and those of mothers of twins and their infants by the second author.

Table 2. Definitions of the types of facial expressions of emotions, the qualities of emotional valence and the categories of direction of emotional intensity change.

Emotional category	Movements
<i>Facial expressions of emotion</i>	
Pleasure addressed to the partner	Eyes open, lips closed or slightly open, corners of mouth and cheeks drawn back and upwards causing wrinkles on each side of the mouth
Interest addressed to the partner	Eye contact, gaze oriented to the partner's face or body, combined with raised or knitted eyebrows, cooing (infant) or other vocalizations (infant or mother) and pre-speech mouth movements (infant)
Interest or pleasure directed to the external world	Signs of interest and/or pleasure directed away from mother, to surroundings
Neutral expression	Unsmiling face, with no signs of body movements, vocalization or intent to vocalize (such as pre-speech mouth movements); signs of self-absorption (looking passively own torso or limbs), or sleepiness (yawning, rubbing eyes)
Sad or withdrawn expression by infant	Furrowed brow, wrinkles around the eyes and nose, tight and protruded lips, open or closed mouth, corners of the mouth downwards; infant is gazing at or away from the parent
Negative expression by mother	Signs of annoyance (expressed verbally or by facial expression)
<i>Emotional valence</i>	
Positive	(+++) ⁵ pleasure to the partner, (++) pleasure to inanimate world, (+) interest directed to the partner
Neutral	(0) neutral facial expression and interest directed to external world
Negative	(−) negative facial expression
<i>Direction of change in emotional intensity</i>	
Ascending	The valence of the last emotional state of one partner (at the end of the subunit) is <i>higher</i> than the valence of the first emotional expression of the same partner (in the beginning of the subunit) (Figure 3(A) and (B))
Descending	The valence of the last emotional expression of one partner is <i>lower</i> in the scale than the valence of the first emotional expression of the same partner (Figure 3(A) and (B), mother descending emotional intensity; Figure 3(D) and (F), infant descending emotional intensity)
Fluctuating	The valence of the first and the last emotional expressions of one partner is the <i>same</i> in position in the scale while the intermediate valence(s) differ (Diagram 1, Unit 2 and Subunit 2, mother and infant exhibit fluctuating emotional intensity)
Stable	The valence of the emotional state of either partner is <i>unchanged</i> in the whole course of the subunit (Diagram 1: Unit 1, Subunit 2, maternal and infant show stable emotional intensity)

Facial expressions of emotion

Within each chosen subunit of dialogue framed by the mother's attempts to engage with her infant, micro-analysis of how twin or singleton infant and the mother made facial expressions of emotions was carried out to identify four types of facial expressions: (1) *happiness*, which includes: (a) pleasure directed to the partner, or (b) pleasure directed to the external world; (2) *interest* directed: (a) to the partner, or (b) to the external world; (3) *neutral expressions*, and (4) *sadness* [see Table 2 for definitions and Figures 1 and 2; see Kokkinaki (1998)⁵].

⁵Full descriptions of facial expressions of emotion and the theoretical background for their identification may be requested from the first author.



(1a) smile



(1b) bright smile



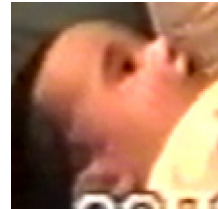
(1c) intense smile



(2a) intense look at the mother-immobile arms



(2b) wide open eyes-raised eye brows



(2c) "pre-speech" mouth movements



(2d) reversed U-shape mouth



(3a) interest to external world



(3b) self-absorbed

Figure 1. Facial expressions of a 5-month-old infant illustrating different emotions in spontaneous interactions with his mother. (1) – Expressions of *pleasure* shared with the mother; (2) – expressions of *interest* in the infant; (3) – *neutral* or *non-social* emotional expression.

Qualities of emotional valence

Micro-analysis of infant and maternal facial expressions of emotion was continuous. The onset time in the expression of an emotion of one partner was also the offset time of the previous emotion of that person. In the course of one subunit in the flow of maternal speech, it was most likely for each partner to express more than one emotional state. In order to obtain a description of the change of intensity of interpersonal engagement over time, the valence or appeal of facial expression within each category of emotion was represented by a symbol. The sequence of these symbols of each partner in the course of each subunit of analysis determined four categories for the direction of emotional intensity change: *ascending*, *descending*, *stable* and *fluctuating* (Table 2).



Figure 2. Facial expressions of a mother illustrating different emotions in spontaneous interactions with her infant. (1) – Expressions of *pleasure* shared with the infant; (2) – expressions of *interest* in the infant; (3) – *neutral* or *non-social* emotional expression.

Interpersonal engagement categories

Interpersonal engagement categories were coded according to: (a) the type; and (b) the emotional valence of facial expression. Interpersonal engagement categories according to the *type* of facial expression of emotion were coded as: (a) *matching*; and (b) *non-matching* [see Table 3; Figure 3(A)–(D) for an example of an emotional narrative that culminates to emotional matching; Diagram 1 for an example of emotional *matching* (Unit 1, Subunit 1, when both the mother and the infant express interest; Unit 2, Subunit 1, when both the mother and the infant express pleasure) and *non-matching* (Unit 1, Subunit 1, when the mother is interested in the infant and the infant is in neutral emotion)].

Interpersonal engagement categories according to the *valence* of facial expression of emotion were coded as: (a) *attunement*; and (b) *completion* [Table 3; Diagram 1 for an example of *fluctuating attunement* (Unit 2, Subunit 2); *stable attunement* (Unit 1, Subunit 2) and *completion* (Unit 1, Subunit 2, when the mother is pleased while the infant is interested in the mother); Figure 3(A)–(B) for examples of *infant ascending emotional intensity* and *maternal descending emotional intensity*, respectively].

Table 3. Definitions with examples of interpersonal engagement categories according to the type and the valence of facial expression of emotion.

Category	Description	Examples
<i>Interpersonal engagement according to type of facial expression</i>		
Emotional matching	One partner displays the same facial expression of emotion as the other partner, independently of the intensity	The mother smiled to the infant while the infant grinned
Emotional non-matching	One partner, or both, show no interest in interacting with the partner	One expressed pleasure to the partner, while the other showed negative in emotion. When both were not in communication, one partner was neutral in emotion while the other was negative
<i>Interpersonal engagement according to valence of facial expression</i>		
Emotional completion	One partner completes the positive valence of facial expression of emotion (pleasure or interest) of the other partner	While the mother shows pleasure, the infant expresses interest
Attunement	One partner expresses shifts in the direction of emotional intensity to match shifts of the other partner	In <i>descending attunement</i> , the intensity of both partners' emotional state at the end of the subunit was lower than at the beginning of the subunit; e.g., both partners changed from pleasure directed to the partner (+++) to interest (++) directed to the partner

Inter-observer reliability

Inter-observer reliability assessment was made for *the type, the valence and the intensity of emotions* within the defined subunits of analysis⁶ (see Note 6 for

⁶To measure inter-observer reliability, a second observer, who had been trained in the use of the coding scheme but was not aware of the hypothesis under investigation, scored a random sample of 30% of the video-files (3 singleton infant- and 3 twin infant–mother pairs). We did not carry out agreement on the identification of units of analysis because the segmentation procedure, which provided the framework for the microanalysis of facial expressions, was not directly related to the research questions of this project. For each variable assessed for reliability, Cohen's kappa was initially calculated for each partner and then, the mean value of κ was calculated for each mother–infant pair.

Regarding reliability assessment of *the type of facial expressions of emotions*, the mean value of Cohen's Kappa was calculated separately for each and every type of facial expression of emotion because coding of each partner's facial expressions of emotions within each subunit of analysis was not mutually exclusive (see *Qualities of Emotional Valence*). Within each subunit of analysis, the observer was asked to code the type(s) of facial expressions of emotions for each partner. An agreement occurred when both observers recorded the occurrence of the same type of facial expression of emotion for each partner. A disagreement occurred when one observer recorded a certain type of facial expression of emotion and the other did not, or when one recorded a certain type of facial expression for a certain partner and the other recorded a different type of facial expression for the same partner. Inter-observer reliability assessment for *the valence of emotional expressions* was carried out in a similar way.

Regarding inter-observer assessment of *the intensity of emotions*, the coding of each partner's emotional intensity change was mutually exclusive. Agreement occurred when both observers recorded the occurrence of the same category of emotional intensity change for a certain partner. Disagreement occurred when one observer recorded a certain category of emotional intensity change for a certain partner and the other recorded a different emotional intensity change for the same partner within the same subunit.

After the end of inter-observer reliability assessments, the two scorers discussed and corrected each assessment on which there was disagreement. The statistical analysis was carried out after all the corrections were made on the data-set.

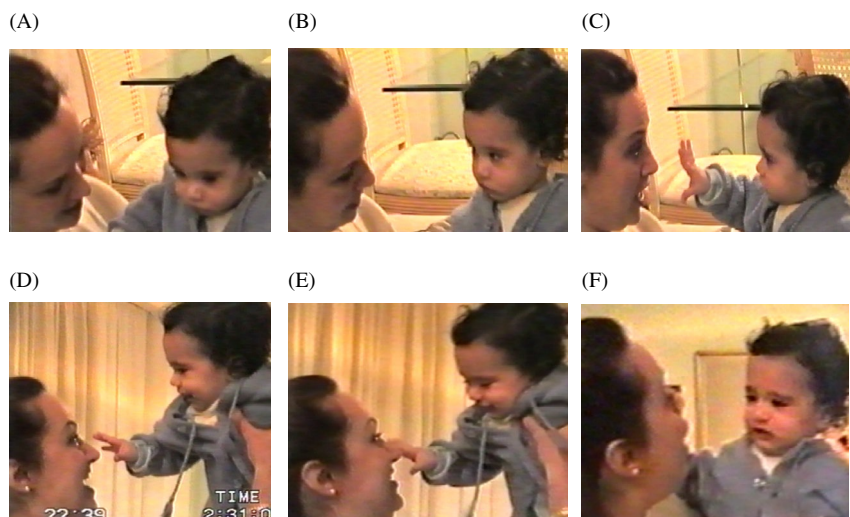


Figure 3. An example of an episode of pleasure matching between a 6-month-old singleton infant and his mother (1 Unit of analysis consisting of 1 Sub-Unit of 36.36 s). The numbers for each picture represent the time in hours, minutes, seconds and twenty fifths of a second for that event. (A) and (B) Illustrate: (a) *infant ascending emotional intensity*; the expression of the infant changes from external interest (0) to interest addressed to the mother (++); and (b) *maternal descending emotional intensity* since the mother's expression changes from a relaxed pleasure directed to the infant (+++) to interest in him (++). (D)–(F) Provide an example of *infant descending emotional intensity* since the infant's emotions change from a happy expression directed to the mother (+++) to negative expressions (–).

Notes: [02.30.54.10 (Figure 3(A))]: The mother expresses relaxed pleasure to her baby while suggesting: "Let's leave ..." (*beginning of the sub-unit of analysis*). At the same time, the baby is interested in the external world. [02.30.55.04, (Figure 3(B))]: After about 1 s, the mother is getting serious to her baby while she repeats: "Let's leave, come on ...". The infant has already turned to the mother and expresses interest to her. [02.30.56.14, (Figure 3(C))]: After less than a second, in the course of mutual eye contact, the mother repeats her suggestion with raised eye brows while the infant frowns, showing a clear expression of interest to the mother and he stretches his hand to her. [02.31.02.24, (Figure 3(D))]: After about 6 s, the interaction becomes more intense, the mother stood up while she keeps on repeating her suggestion and enriches her "story" by shaking rhythmically the baby to the left and to the right. The infant enjoys the mother's verbal repetitions combined to the kinetic game and *matching of pleasure* takes place. [02.31.03.21, (Figure 3(E))]: For about 1 s, both the mother and the infant keep on enjoying and sharing pleasure expressions while the mother repeats her suggestion. [02.31.30.19, (Figure 3(F))]: After about 27 s the mother terminates her verbal and kinetic game (*end of the thematic sequence and of the sub-unit of analysis*) because the infant starts whimpering while the mother consoles him immediately. The mother's "story" of repeated suggestions to the infant for them to both leave this place is framed by the emotional narrative described above, which lasted 36.36 s.

details on reliability assessments). Inter-observer reliability for the type, the valence and the intensity of emotions ranged from .76 to .84, .78 to .84, and from .77 to .84, respectively. Inter-observer reliability for all categories ranged from .76 to .84, the mean value of κ (Cohen's kappa) being .80. Fleiss (1981) characterizes kappas over .75 as excellent.

Statistical analysis

The Loglinear General Model was used to determine relationships between variables. The optimal Model was obtained using the LRT test (Likelihood Ratio Test) and the final Model retained a non-significant distance (in LRT terms) with the Saturated Model. The level of significance was set at 5%. In all cases the Optimal Model consisted of only one two-way interaction between infant and maternal emotional expressions, emotional intensity and infant/maternal emotional expressions in the beginning and at the end of each subunit. Friedman test (with sliding windows) was used to explore possible age-related changes of emotional expressions across the five data points. Through Friedman analysis, we took into consideration the fact that we had different number of subunits for each subject and at each age point. The significance level for Friedman test set at 5%.

Results

Units and sub-units of analysis in twin infant- and singleton infant-mother interactions (Hypothesis 1)

The frequency of units of analysis was higher in twin infant-mother interaction (746) than in singleton-mother interaction (406) ($p < .001$, two-tailed Binomial test). Subunits of analysis in twin infant-mother interaction (3,578) outnumbered significantly subunits in singleton-mother interaction (1,858) ($p < .001$, two-tailed Binomial test) (compare Figures 3 and 4 on the temporal patterns of the two interactions).

Birth status effect on infant and maternal types of facial expressions of emotion (Hypothesis 2a and 2b)

A complex interaction between birth status vs. maternal emotional expressions vs. infant emotional expressions (LRT-value = 94.498, $df = 16$, $p < .001$) evidenced that: (a) the subunits in which both twin infants and their mothers express *pleasure* (35%) (*emotional matching*) predominated over subunits in which both singletons and mothers expressed pleasure (4.1%); (b) twin infants are more likely to express *interest* to the mother when the mother is interested in the infant (35.2%) (*matching*) while singletons infants are more likely to be interested in the mother when she is pleased (17.9%) (*emotional completion*); (c) It is more likely that twin infants, but not singletons, are neutral in emotion when mothers are also neutral (50.6%) (*matching*) than when she is pleased (24.8%), interested in the infant (27%), or in the external world (13.3%), or negative in emotion (10.3%); (d) twin infants are more likely to express *external interest* when mothers express external interest (57.3%) (*matching*), while singletons are more likely to express external interest when mothers express pleasure (42.7%) (*emotional non-matching*); (e) twin infants are more likely to be negative in emotion when



Figure 4. An example of *successive matchings of pleasure* between a 6-month-old twin infant and his mother (1 unit of analysis consisting of three sub-units of analysis in 10.92 s). Notes: As for Figure 3, the numbers for each picture represent the time in hours, minutes, seconds and twenty fifths of a second. [02.56.48.12, (Figure 4(A))]: At the beginning of the first Sub-Unit of analysis, the mother, with a mood of pleasure, starts a four-round non-speech sound and kinetic game, making an effort to draw her baby's attention. The baby expresses external interest, looking at the camera. [02.56.49.00, (Figure 4(B))]: After less than a second, the mother terminates the first round of the game while she expresses pleasure to her baby. The baby starts grinning while still looking away from her. [02.56.49.03, (Figure 4(C))]: After three 25ths of a second, between the first and the second round, the intensity of the game increases and while infant and mother's expressions of pleasure intensify matching of pleasure expressions starts. [02.56.52.02, (Figure 4(D))]: After about three seconds, the third round of the game has been completed while mother and infant enjoy sharing expressions of pleasure. [02.56.54.06, (Figure 4(E))]: After less than 2 s, the mother has completed the fourth round of the game, ending the first Sub-Unit of analysis, while pleasure matching in the course of mutual eye contact still takes place. [02.56.55.02, (Figure 4(F))]: Shortly, after less than a second, the mother starts a vocal game making repeated sounds to begin the second Sub-Unit of analysis, while both partners still share pleasure expressions with mutual eye contact. [02.56.57.00, (Figure 4(G))]: For about 2 s, the mother continues the vocal game in the second Sub-Unit, while both partners become more and more excited. [02.56.58.06, (Figure 4(H))]: After about a second, the vocal game has been completed to end the second Sub-Unit of analysis. Now the mother starts paying emphasis in her speaking to describe the infant's presence, beginning of the third Sub-Unit, addressing the baby with the question: "What's this little child?". Both partners still show pleasure with mutual eye contact. [02.56.59.10, (Figure 4(I))]: After about a second, in the course of pleasure matching, the mother completes the infant-focus verbal expression at the end of the third Sub-Unit of analysis. In this example of a playful engagement with a 6-month-old, in the course of 10.92 s, the mother changes very quickly through three different thematic sequences, which were framed by the emotional narratives described above. Very shortly, after 8 25ths of a second [02.56.59.18] the mother will start a new vocal game.

their mothers are negative (62.1%) (*matching*) while singletons are negative in emotion when their mothers are interested in them (30.3%) (*non-matching*).

Birth status effect on infant and maternal emotional intensity (Hypothesis 2a)

A complex interaction between birth status vs. maternal emotional intensity vs. infant emotional intensity (LRT-value = 119.451, $df = 9$, $p < .001$) is indicated by the evidence that: (a) the subunits in which both twin infants and their mothers (25.4%) *ascend* in their emotional intensity (*emotional attunement*) are less than the subunits in which both singleton infants and their mothers (29.1%) *ascend* in their emotions; (b) twin mother-infant pairs *fluctuate* in their emotional intensity (41.6%), or maintain it *stable* (92.1%) more often than singleton infant-mother pairs (31.5 and 52.9%, respectively); and (c) twin infants' emotional intensity is more likely to be *descending* when twin mothers' emotions are in *descending* emotional intensity (29.8%), while singletons' emotional intensity is more likely to be *descending* when mothers *fluctuate* in their emotions (22.6%).

Birth status effect on infant and maternal emotional expressions in the beginning and at the end of subunits (Hypothesis 3)

The interaction between birth status vs. infant emotional expressions in the beginning of subunit vs. infant emotional expressions at the end of the subunit (LRT-value = 740.352, $df = 16$, $p < .001$) is shown to be complex by the evidence that this relationship occurs more often and is stronger for *pleasure* (88.5%), *interest* (85.9%), *external interest* (89.5%), *neutral* (91.5%) and *negative emotion* (88.0%) in twin infant-mother pairs compared to singleton infant-mother pairs (45.6, 49.2, 68.1, 53.2, 61.2%, respectively).

Finally, comparison of birth status vs. maternal emotional expressions in the beginning of sub-unit as compared to the maternal emotional expressions at the end of the sub-unit (LRT-value = 196.863, $df = 20$, $p < .001$) indicates that this relationship occurs more often and is stronger for *pleasure* (92.9%), *interest* (87.3%), *external interest* (67.2%) and *neutral emotion* (91.7%) in twin infant-mother pairs compared to singleton infant-mother pairs (87, 64.1, 9.4 and 0%, respectively).⁷

Infant age effect on emotional matching (Hypothesis 4)

For the non-linear developmental curves of *matching for pleasure and interest* in interactions of singleton and twin infants with their mother (Figures 5 and 6), Friedman test analyses provided evidence of non-significant infant age effect

⁷Due to their low frequencies, negative emotions of the mother were excluded from the analysis of the relationship between maternal emotions in the beginning and at the end of subunits.

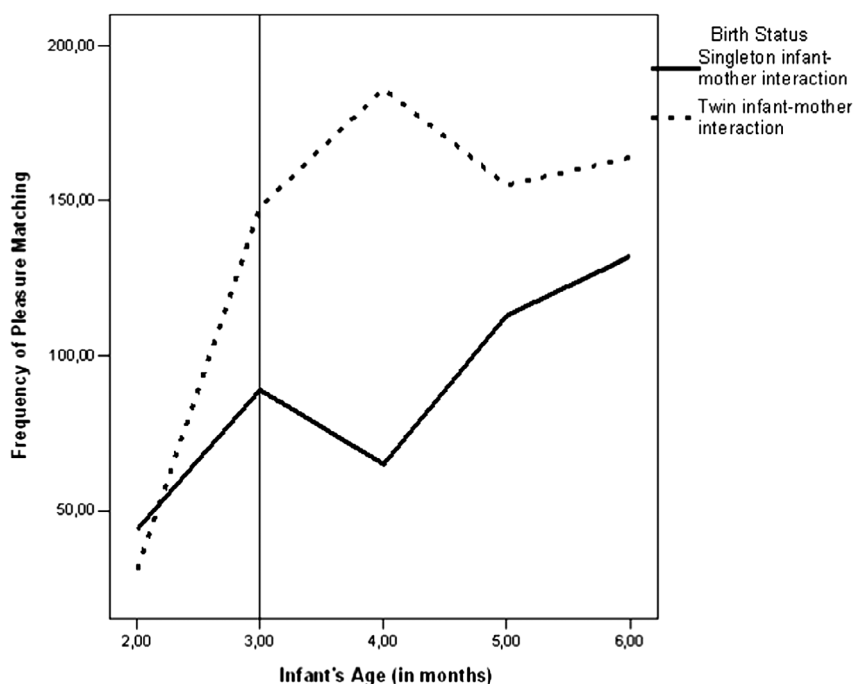


Figure 5. Developmental curves of *pleasure matching* in twin infant- and singleton infant-mother interactions across the age range of this study.

on the frequency of *matching for pleasure and interest* across the 5 age points of this study.

Discussion

Qualitative and quantitative differences in measures of emotional engagement between first born twin infants and singleton infants in communication with their mothers show more frequent and accurate emotional matching and attunements for the twins. Singleton infants with their mothers display more emotional completion and non-matching of emotions. This evidence confirmed the results of previous studies of communication with twins in Crete (Kugiumutzakis et al., 2009).

Differences in emotional matching, attunement, completion and non-matching between the two dyads may affect *timing, form* and *energy adjustment* of movements in the different dyads.

Adjustment of timing between adult and infant is indicated by two measures of the interpersonal sharing of feelings. First, *emotional matching* indicates a close synchronising of emotions between infants and mothers in intimate communication, which permits transfer and imitation of the internal motives

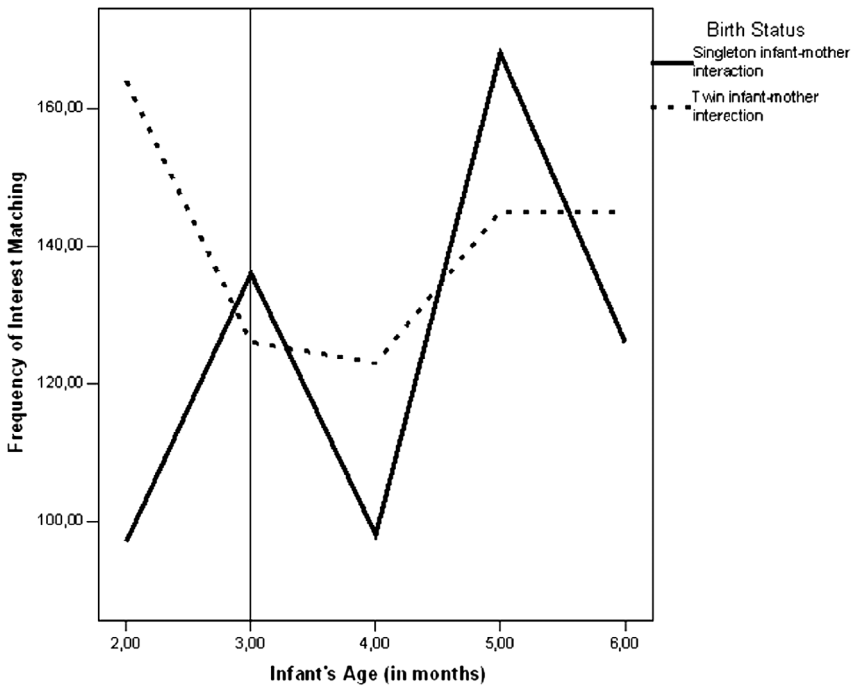


Figure 6. Developmental curves of *interest matching* in twin infant- and singleton infant-mother interactions across the age range of this study.

by which each subject is regulating the dynamics of their own consciousness and purposes (Trevarthen, 1993). Second, *emotional attunement* presupposes a specific readiness to grasp the feelings of the other's behaviour, one that can discriminate and respond differentially to the different emotions behind the expressions, and in sequence with the changing values of expressions in time (Trevarthen, 1997).

Emotional matching by sight of facial expressions depends upon changes in the spatial patterns of movements of parts of the face that change with feelings, and perception of these as signs of another's feelings of vitality (Darwin, 1872; Porges, 2011). The human facial communicative system has a complex anatomy comprising '... a bisymmetric set of muscle units that are differentially excitable ...' (Trevarthen, 1985, p. 22), and '... nearly the full complement of facial action components is present at birth and that many coordinated combinations of facial actions, close to those by which adults demonstrate ... distinct states of mind, may be distinguished' (Trevarthen, 1986, p. 229, describing the findings of Harriet Oster, 1978).

Mutual adjustment of prospective control of movement to regulate effort or energy is signalled in different ways, by emotional *matching*, defined as direct correspondence in the emotional valence of the facial expressions of the

two partners (Table 1), by emotional *attunement*, which requires sympathetic adjustment of shifts in emotional intensity, and by emotional *completion*, when one partner completes and thus confirms the positive valence of emotional expression of the other. These regulating patterns of mutual activity provide evidence in our data that both singletons and twin infants, when they are in communication with their mothers, experience feelings of both self-awareness and other-awareness, as well as awareness of purposeful coordination of emotional states through shared time. We obtained evidence of consistency of emotional states in the behaviours of twin and singleton infants and their mothers.

Both twin/singleton mothers and twin/singleton infants adjust their timing, form and energy of their expressions to obtain inter-synchrony, created with love in companionship, sharing a 'narration' or communicative 'project' that is guided by specifically human social affections (Trevarthen, 1993, 2013).

However, contrary to our initial hypothesis, we found differences in emotional consistency between the two kinds of dyad, which indicate variations in emotions regulating coherence in awareness, consciousness and purpose, unified intentionality of the self, and balance of internal states.

Developmental trajectories of matching for *pleasure* show an increasing trend for both twins and singletons from 2 to 3 months (Figure 5), reflecting an increasing fascination for face-to-face interaction in protoconversations, which characterise Primary Intersubjectivity. There is an increase of *interest* matching in the interactions of singletons with their mothers (Figure 6). In the same period, *interest* matching shows a decreasing trend in twin infant–mother interactions, possibly as a consequence of the very strong increase of *pleasure* matching they are showing in the same period. Their confirmation of engagement in play is more intense.

After the third month, in the Period of Games, there are fluctuating trends in matching of pleasure and interest in both dyads, reflecting developments in the body and brain of the infant at this stage (Trevarthen, 1986, 1993), with clearly marked advances in the infant's attentiveness and playfulness and changes in communication, self-awareness and engagements with objects. Our evidence indicates that twin infant–mother and singleton infant–mother dyads show different developmental patterns of response to these changes in the infant's self-awareness, curiosity about objects, and 'vitality dynamics' (Stern, 2010) (Figures 5 and 6).

The differences in emotional engagement between the two kinds of dyad are associated with differences between the behaviours of parents. Parents of twins facing two infants at the same time, may respond to both simultaneously, or to one at a time alternately. For the twin-mother dyads the one-on-one observation episode required for our study will be a novel, and possibly awkward or challenging experience. Mothers and fathers of twins, will feel a lack of personal involvement with their infants focused on enjoyment, since they must spend

much time looking for ways just to keep both twin infants quiet and under control (Holditch-Davis et al., 1999).

A constitutional factor affecting communication of an infant twin with a parent may be differences in brain structure acquired before birth. White matter volume in frontal cerebral cortex has been found to be greater in neonate DZ twins compared to singletons (Knickmeyer et al., 2011), and frontal white matter contributes significantly to the function of emotional coordination (Pacheco et al., 2009).

We acknowledge that our study possesses several limitations, which invite further work.

Repeated observations were obtained on a small number of individuals. The families of twins chosen for this study are not representative of the whole twin population, being families who volunteered and who met certain inclusion criteria. Early interactive experiences to which first- and second-born singletons are exposed to vary, our mixed population of first- and second-born singletons constitutes an interfering variable limiting the interpretation of results.

As mentioned, the typical experience for parents of twins is likely to involve interacting with both infants simultaneously. The comparison of emotional engagements needs to be completed by attention to second-born twin infant–mother dyads, and by inclusion of observations with fathers. Investigations to compare the emotional expressions in triads with both first- and second-born twin infants, as well as with triads of mothers and siblings with small age differences would clarify the processes of relating.

Finally, the focus on facial expressions as an index of emotions requires further investigation of role of other expressive systems, including patterning and quality of vocalisations, and postural and gestural movements of head and hands that convey rich affective information in interpersonal relationships (Weinberg & Tronick, 1994).

Disclosure statement

No potential conflict of interest was reported by the authors.

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