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Co-development of Child–Mother Gestures Over the Second and the Third Years

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This study looks at whether there is a relationship between mother and infant gesture production. Specifically, it addresses the extent of articulation in the maternal gesture repertoire and how closely it supports the infant production of gestures. Eight Spanish mothers and their 1- and 2-year-old babies were studied during 1 year of observations. Maternal and child verbal production, gestures and actions were recorded at their homes on five occasions while performing daily routines. Results indicated that mother and child deictic gestures (pointing and instrumental) and representational gestures (symbolic and social) were very similar at each age group and did not decline across groups. Overall, deictic gestures were more frequent than representational gestures. Maternal adaptation to developmental changes is specific for gesturing but not for acting. Maternal and child speech were related positively to mother and child pointing and representational gestures, and negatively to mother and child instrumental gestures. Mother and child instrumental gestures were positively related to action production, after maternal and child speech was partialled out. Thus, language plays an important role for dyadic communicative activities (gesture–gesture relations) but not for dyadic motor activities (gesture–action relations). Finally, a comparison of the growth curves across sessions showed a closer correspondence for mother–child deictic gestures than for representational gestures. Overall, the results point to the existence of an articulated maternal gesture input that closely supports the child gesture production. Copyright © 2006 John Wiley & Sons, Ltd.

Key words: co-development of child–mother gestures; deictic gestures; representational gestures; dyadic speech and gesture relations

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Babies use gestures as a way to communicate with adults (e.g. mothers). Mothers talk to babies and use gestures as well. But when gesturing to each other, do mothers and babies produce a similar reportoire of gestures? What is the role played by maternal and child speech in gesture production? Is there a close correspondence between the mother and child pattern of changes in gesture production over the second and the third years? These were the main questions addressed in this study. Mothers and their 1- and 2-year-old children were followed during 1 year of observations. Measures of a variety of mother and child gestures observed at home during free play, bath and dinner were taken every 3 months. The gestures selected were those which have received research attention: *pointing* at a person or an object (e.g. Bates *et al*., 1979; Blake *et al*., 1992; Franco and Butterworth, 1996; Hannan, 1992; Pettito, 1993; Zinober and Martlew, 1985); *instrumental gestures* that usually include *request, give, show* (Bates *et al*., 1979, 1989; Blake *et al*., 1992; Pettito, 1993); *social gestures* as, for instance, waving 'hello' or 'bye-bye' (e.g. Pettito, 1993); and *symbolic or enactive gestures* as, for instance, 'opening his mouth wide' like hippos do, or 'pretending to drink out of an empty cup' (e.g. Acredolo and Goodwyn, 1985; Bates *et al*., 1989; Caselli and Volterra, 1990; Goldin-Meadow and Morford, 1990; Pettito, 1993; Zinober and Martlew, 1985). The mother's repertoire of gestures was selected after the child's repertoire to analyse the adaptation of mothers' gestures to child gestures. The decision was made taking into account Bekken's (1989) results concerning the mothers' overall use of infant-type gestures when addressing their child. We also included motor actions to see whether mother adaptation is evident in gestures but not in actions. According to Zinober and Martlew's (1985) criteria, gestures involve an intention to convey meaning to another person, whereas actions are directed to objects or events and lack that communicative function.

The first issue is to compare the mother and child repertoire of gestures and actions over the second and third years. The expected changes in the child gestures according to previous studies pointed to a clear change from a greater use of instrumental gestures at the beginning of the second year, to a greater use of pointing, later in the second year (Bates *et al*., 1975; Masur, 1983; Blake *et al*., 1992). Social and symbolic gestures are present from the beginning of the second year (Acredolo and Goodwyn, 1985, 1988). Overall, there is not a general decline in the use of gestures from the second to the third years of age (Blake *et al*., 1992). Thus, most symbolic gestures continue to be used in the transition to language (Zinober and Martlew, 1985), and the rate of pointing even increases at the end of the third year (Hannan, 1992; Capirci *et al*., 1996).

To what extent does the maternal repertoire of gestures change with these developmental changes? Iverson *et al*. (1999) reported a stability in the production of maternal gestures across 16 and 20 months, being the majority of gestures produced instrumental, pointing and conventional (social), whereas symbolic and emphatic (non-semantic content) gestures were much less common. More information is needed with respect to those changes that may occur at earlier and later ages. It is important to know whether maternal gesturing changes as much as infant gesturing does over the second and the third years.

The second issue is to assess whether maternal and child speech are related to maternal and child gesture production. According to McNeill (1992), speech and gesture work together, therefore a close relation should be expected. We related the mean rate-per-minute of closed-class words and open-class words produced by the mother and child at each age-point with their corresponding mean

rate-per-minute of gestures. Closed-class vocabulary corresponds to the limited vocabulary of grammatical markers (prepositions, pronouns, auxiliary verbs and conjunctions), whereas open-class words correspond to the changing vocabulary of content words (nouns, verbs and adjectives). Although we do not provide a measure of gesture–speech combination, the same temporal unit was selected to relate speech and gesture production. In addition, we assessed whether speech–gesture relations differ according to the type of gesture.

A relation between mother and child language has been reported in many studies (e.g. Hampson and Nelson, 1993; Tamis-Lemona *et al*., 2001). A relation between maternal language and child pointing has also been found in many studies (Butterworth and Morissette, 1996; Goldfield, 1990; Harris *et al*., 1995; Pettito, 1993). In addition, the child's use of pointing has been found to be related to the production of the first words (Butterworth and Morissette, 1996; Camaioni *et al*., 1991; Harris *et al*., 1995; Pettito, 1993). However, less is known concerning the influence of mother–child speech on maternal gesture. Iverson *et al*. (1999) have found preliminary evidence for positive relations between children's use of gesture and speech at two age-points (16 and 20 months of age) and maternal gesture production. Maternal verbal production was also related to child gesture and verbal production. Mothers' total gesture production at 16 months was significantly correlated with children's total gesture production. At 20 months maternal and child gestures production continued to be positively (although not significantly) related, and maternal pointing was significantly related to children's gesture production. The present study allows for a full set of language and gesture comparisons across 10 age-points.

The third issue is to examine the co-development of the mother and child pattern of changes across sessions in each age group. Iverson *et al*. (1999) performed a global comparison of the mother and child gestural repertoire at two age-points, which did not allow for a search of specific adaptations as a function of the type of gestures. In the present research, a fine-grained comparison of the growth curves of each mother and child gesture over five points in time was accomplished using regression analysis specially suited for modelling the shape of changes with longitudinal data (generalized estimating equations, McCullagh and Nelder, 1989).

We classify the gestures into two broad categories, following Capirci *et al*. (1996): *Deictic* and *representational* gestures. *Deictic* gestures (pointing and instrumental) simply 'signal' or 'point' to a given referent located in the physical context and require a triadic communicative intention. The triadic process occurs when one of the partners attempts to direct another's attention to some outside entity that becomes a focus for shared experience (e.g. Bates *et al*., 1975; Franco and Butterworth, 1996; Tomasello and Camaioni, 1997). *Representational* gestures (symbolic and social gestures) 'stand for' or 'represent' some referent, class of referents or relation and requires a bi-directional communicative intention that does not depend on perceptually orienting the recipient (Tomasello and Camaioni, 1997). The imitation process occurs when an individual understands the communicative intention of a gesturer and then reproduces the same gesture when she or he has the same intention (e.g. Acredolo and Goodwyn, 1985, 1997). The mother's role in such an imitative process is to consistently provide a direct model of the gesture during a daily routine and to monitor the child's imitation of the gesture at that moment or afterwards. Given the different interactive nature of the two types of gestures, it is likely that the mother's gesture production might support the infant production of gestures in different ways, depending on the type of gesture involved.

To test this hypothesis we compared the mother and child growth curves for deictic and representational gestures, looking at the degree of correspondence between the mother and child pattern of changes. If mothers are adjusting their deictic gestures to the child developmental level they would primarily use instrumental gestures (a more primitive means for contact targets) and then those means would be progressively replaced by pointing (a more sophisticated device for indicating distal targets). Therefore, we expect a close correspondence between the mother and child pattern of changes of deictic gestures.

A weaker correspondence is expected concerning the comparison of the mother and child growth curves for representational gestures. The production of a symbolic or a social gesture usually takes place within the same particular context (e.g. a well-rehearsed routine). However, children are able to abstract the gesture from the specific context and generalize it to other referents (typically in the case of symbolic gestures). In addition, the child imitation is frequently deferred, as has been reported in babies as young as 14 months of age (e.g. Meltzoff, 1988) and can be extended to new situations. Therefore, mothers would produce symbolic and social gestures at a given point in time without any immediate response on the part of the child and vice versa and yet the learning process would be successful in the long run.

In sum, three major aims were addressed in this study: First, to compare the mother and the child gestures (pointing, instrumental, symbolic and social gestures) and motor actions in each age group. It is predicted that the distribution of mother and child gestures would be very similar at each age group and would not decline across groups. Second, to analyse whether there is a relation between maternal and child speech and gesture production. We expected close speech–gesture relations, but did not know whether speech–gesture relations would differ according to the type of gesture. Finally, we examine the co-development of mother and child gestures and actions across sessions in each age group. Maternal gesturing would presumably closely follow the shape of changes of infant gesturing for deictic gestures but not for representational gestures.

METHOD

Participants

Four one-year-old babies and their mothers (the younger group) and four two-year-old babies and their mothers (the older group) were followed for 12 months. Mean age of children in Group 1 was 12.4 months (S.D. = 0.2) and mean age of children in Group 2 was 24.3 months (S.D. = 0.1) at the time of first testing. All infants were first-born, and all had mothers (mean age was 29, range 26–34 years, for both groups) with a university education and SES ranged from medium to high level. Four children had mothers who worked outside the home, and four children had mothers working at home (half for each age group). Table 1 gives for each infant their sex, the age period studied, the number of home sessions, the total number of videotaped minutes and the number of communicative gestures and actions produced by the child, the mother and both.

Procedure

All infants and their mothers were videotaped at home during a sequence of everyday routines starting with free play, bath and dinner. Observations were

Table 1. Comparative data on the children and mothers

					Child		Mother		Both	
Child	Age period	Sex	No. of session	Total time	No. of gesture	No. of action	No. of gesture	No. of action	No. of gesture	No. of action
PA	12–24	F	5	220′	339	24	139	3	17	1
LA	12–24	F	5	186′	191	21	141	9	10	1
JP	12–24	M	5	185′	111	42	104	7	10	2
CA	12–24	M	5	271′	79	14	204	33	5	11
CR	24–36	F	5	141′	124	18	84	4	1	0
PC	24–36	M	5	271′	154	9	192	15	9	0
PB	24–36	M	5	196′	138	6	164	2	0	1
CE	24–36	M	5	244′	208	24	202	7	6	0

made every 3 months within a week interval (five sessions per dyad). The same experimenter videotaped all the sessions for all dyads after three warm-up visits at the beginning of the study. The total observation time was 14.3 h for Group 1 and 14.2 h for Group 2.

Coding

Six types of manual activity, similar to those used by Pettito (1993), were observed either in the child or the mother, or both (simultaneous performance). Four were communicative gestures and two were motor actions. Gestures were considered to be communicative if they were accompanied by eye contact with an interactive partner, vocalization or other clear evidence of an effort to direct the attention of another person present in the room (see Capirci *et al*., 1996).

1. *Pointing gesture*: (outstretched arm with index finger extended to objects, persons while alternatively looking at the adult and the referent). Infant pointing was spontaneous (initiated by the child) or induced (triggered by a mother's locative question). Maternal pointing was spontaneous. In any case it involves distance from the reference).
2. *Instrumental gestures*: request (opening and closing hands to ask for something to the mother/baby, raising arms to be picked up by the mother); give (hands an object to the mother/baby checking his/her attention to establish the joint reference) and show (holds up an object in the mother's/baby's line of sight).
3. *Social gestures*: (e.g. waving 'hello', 'bye-bye', 'clapping hands') involved culturally established gestures more or less standardized during the realization of social routines by the mother or the child.
4. *Symbolic gestures*: (e.g. 'pretending to drink out of an empty cup', 'combing hair without a comb', 'moving head' as a horse). Maternal symbolic gestures were also enactive or relative to objects, animal or person. In any case, for a gesture to qualify as a symbolic one it has to have a representational component (without physically manipulating the object or using a substitute object).
5. *Motoric hand activity without objects*: (e.g. banging, scratching) isolated or chained movements performed on surfaces with empty hands.
6. *Actions with objects in hand*: (e.g. brushing with a brush, eating with spoon) clearly distinguished from symbolic gestures in that the child or

the mother may have actually produced the manual form by physically manipulating the object.

Two independent coders rated all of the home sessions for each dyad. Reliability was calculated by the Kappa coefficient: 0.88 for the younger group and 0.87 for the older group. The coefficient remained above 0.86 across gestures and motor actions.

Mother and Child Speech

All the verbal interactions for each dyad at each age-point observed during play, bath and dinner routines were transcribed from the videotapes. Two measures of child and mother speech were employed. The first measure is the number of closed-class words, that is, determinants, temporal and modal adverbs, prepositions, pronouns, conjunctions and auxiliary verbs produced per minute. The second measure was the number of open-class words including nouns, derivate adverbs, adjectives and verbs produced by minute. Word repetitions were not counted as separate instances (e.g. aquí, aquí, aquí). Words used or pronounced in a manner different from Spanish adult usage were also included for analysis ('ete' instead of 'este', 'aba' instead of 'agua'). Other vocalizations were not counted. The total number of words per minute for the mother and child was obtained by summing the total number of closed-class and open-class words per minute.

Data Analysis

To compare the mother and the child gestures, motor actions and speech production across age groups (first issue) a series of *t*-test were performed on gestures, motor actions and speech rates. We used rate-per-minute instead of absolute or relative frequencies to control for time variability across subjects and sessions. Only significant effects are reported. The alpha level was set at 0.05. Rank-order correlations across ten age-points were used to examine the relationships among maternal and child speech and gesture measures (second issue).

To model the shape of changes of mother and child gestures and actions across sessions in both age groups (third issue), regression analyses were carried out using generalized estimating equations or GEE (Diggle *et al*., 1994; McCullagh and Nelder, 1989; Lyang *et al*., 1992; Stokes *et al*., 1995; Zeger and Liang, 1986). Our data are counts observed at different sessions, and a more convenient non-normal error distribution is Poisson (Diggle *et al*., 1994), using session duration as offset (McCullagh and Nelder, 1989). Some properties of GEE analysis are recommended to model the developmental pattern of changes in the current study. GEE parameters have a classical regression interpretation. The difference is that in classical regression standard errors are obtained assuming no correlation between measures, whereas in GEE they are obtained assuming a particular correlation structure. The best results in terms of goodness of fit statistics was obtained with a first order auto-regressive correlation structure AR(1) which assumed a decreased correlation as the time lag between two longitudinal observations increased (e.g. correlation between measures of sessions 1 and 2 was expected to be higher than that between measures of sessions 1 and 5). The procedure SAS GENMOD (Version 8.0, SAS Institute, Inc., 1999) was used.

RESULTS

Results are organized according to the three research aims.

Comparison of Infant and Mother Gestures and Actions Across Groups

The means and standard deviations of production rates for the four gesture categories and the two motor actions are given in Table 2 by age group and gesturer (mother, child or both). Data from free play, dinner and bath episodes were collapsed given that there were no differences in gesture and action production. Mean rate of production for each gesture or action type was calculated by subject and session and then averaged across subjects and sessions. The standard deviations are large in the child data of Group 1 because one infant (CA) contributed a disproportionately small number of gestures to the mean.

The accumulative rate of gestures per minute (by adding up the rate of production of all gestures for each group and gesturer in Table 2) was 1.08 (range from 0.30 to 1.54) for children and 0.76 (range from 0.56 to 0.82) for mothers in Group 1. The accumulative rate in Group 2 was 0.80 (range from 0.57 to 0.89) for children and 0.88 (range from 0.60 to 0.90) for mothers. Similar calculation was made for actions: accumulative rate in Group 1 was 0.17 (range from 0.05 to 0.27) for children and 0.10 (from 0.01 to 0.13) for mothers; for Group 2 was 0.08 (from 0.02 to 0.13) for children and 0.04 (from 0.01 to 0.10) for mothers.

Concerning the first issue, results indicated that the mother and child gestural repertoires look very much alike in both groups. Pointing and instrumental gestures were by far the most frequently produced gesture for both mothers and children. The rates of maternal pointing and instrumental production were higher than the rate of social gestures (t (3) = 5.57, $p < 0.05$; t (3) = 5.6, $p < 0.05$, respectively), and of symbolic gestures (t (3) = 7.2, $p < 0.01$; t (3) = 6.5, $p < 0.01$, respectively) in Group 1. The difference between social and symbolic gestures was marginally significant (t (3)=2.3, $p>0.05$). Similarly, the rate of children's pointing and instrumental production were higher than the rate of social gestures (t (3) = 4.67, $p < 0.05$; t (3) = 4.1, $p < 0.05$, respectively) and of symbolic gestures (t (3) = 5.4, $p < 0.05$; t (3) = 4.6, $p < 0.05$, respectively). The difference between social and symbolic gestures was marginally significant (t (3) = 2.7, $p > 0.05$). Finally, the rate of initiated pointing was higher than the rate of induced pointing (t (3) = 3.2, $p < 0.05$).

In Group 2, the rate of maternal pointing was higher than the rate of social gestures (t (3) = 5.3, $p < 0.05$). The rates of maternal pointing and instrumental gestures were higher than the rate of symbolic gestures (t (3) = 6.5, $p < 0.01$; t (3) = 5.3, $p < 0.05$, respectively). The rate of pointing was higher than the rate of instrumental gestures (t (3) = 5.16, $p < 0.05$). The difference between social and symbolic gestures was marginally significant (t (3) = 2.3, $p > 0.05$). Similarly, the rates of children's pointing and instrumental production were higher than the rate of social gestures (t (3) = 4.9, $p < 0.05$; t (3) = 5, $p < 0.05$) and of symbolic gestures (t (3) = 5, $p < 0.05$; t (3) = 5.2, $p < 0.05$). The rate of initiated pointing was higher than the rate of induced pointing (t (3) = 3.9, $p < 0.05$). The difference between pointing and instrumental gestures was marginally significant (t (3) = 2.6, $p > 0.05$). Therefore, pointing became a very important deictic means for the mother and child in Group 2.

There were only marginally significant age changes in the mothers' data: the rate of maternal pointing tended to increase with age (t (7) = 2.12, $p > 0.05$) and the rate of instrumental gestures tended to decrease with age (t (7) = 3, $p > 0.05$).

Table 2. Mean and standard deviation of rate of production per minute and absolute frequencies of number of total words and number of open-class words, gestures, and action categories

	Total words	Open-class words	Initiated pointing	Induced pointing	Instrumental	Social	Symbolic	Motoric activity	Action object
Child									
Group 1									
M (S.D.)	2.14 (2.8)	1.1 (1.5)	0.30 (0.16)	0.12 (0.18)	0.39 (0.35)	0.04 (0.03)	0.07 (0.07)	0.10 (0.02)	0.03 (0.02)
Ab. Fr.	1918	1023	259	96	320	32	8	74	27
Group 2									
M (S.D.)	15.8 (7)	6.9 (2.5)	0.38 (0.12)	0.10 (0.07)	0.19 (0.08)	0.05 (0.03)	0.02 (0.02)	0.05 (0.02)	0.02 (0.02)
Ab. Fr.	14198	6121	324	90	146	25	24	37	18
Mother									
Group 1									
M (S.D.)	40.5 (11.8)	20.3 (5.8)	0.31 (0.11)		0.27 (0.08)	0.05 (0.04)	0.01 (0.01)	0.04 (0.03)	0.02 (0.01)
Ab. Fr.	35399	17709	288		227	44	12	29	23
Group 2									
M (S.D.)	58.1 (18.8)	27.3 (8.3)	0.50 (0.14)		0.15 (0.03)	0.07 (0.01)	0.01 (0.01)	0.02 (0.01)	0.01(0.009)
Ab. Fr.	51895	24191	430		118	70	14	10	18

Marginally significant changes were also observed in the child data, the rate of instrumental gestures also decreased with age (t (7) = 2.2, $p > 0.05$).

Concerning actions, the rate of production of motoric actions was higher for the children in Group 1 than in Group 2 (t (7) = 3.2, $p < 0.05$). Finally, the co-occurrence of child and mother gesturing or acting was very low: 36 cases of gestures and 15 of actions in Group 1 and 14 cases of gestures and 1 of actions in Group 2.

Comparison of Infant and Mother Speech, Gestures and Actions

The second research aim was to analyse whether there is a relation between maternal and child speech and gesture. The means and standard deviations of speech production per minute are given in Table 2 by age group and mother or child. Mean rates of total and closed-class word production were calculated and averaged across subjects and sessions to perform a global comparison between age groups. As expected, results indicated that the rate of child total speech production was higher in Group 2 than in Group 1 (t (7) = 8.1, $p < 0.01$). The rate of child open-class words was higher in Group 2 than in Group 1 (t (7) = 8.8, $p < 0.01$). The rate of maternal total speech production was higher in Group 2 than in Group 1 (t (7) = 3.5, $p < 0.05$), as well as the rate of closed-class production (t (7) = 3.8, $p < 0.05$). The overall pattern of results was observed in each of the subjects of the sample.

To explore the relations among speech, gestures and actions produced by the child and the mother, a set of rank-order correlations was computed across 10 observation points (data from the four dyads at each observation point were averaged). Children's spontaneous and induced pointing were grouped into a single category of pointing. Mother and child symbolic and social gestures were also grouped, respectively, into a single category of representational gestures. Results are presented in Table 3.

First, mother and child speech was strongly correlated across observations. Second, maternal and child language were significantly related to gestures. Maternal speech was significantly correlated with children's pointing and negatively correlated with children's instrumental production. Similarly, children's speech was significantly correlated with mothers' pointing and negatively with mothers' instrumental production. Thus, language production increased

Table 3. Spearman rank-order correlations between maternal and child speech, gesture and action measures

Mother	Child					
	Total words	Pointing	Instrumental	Representational	Motoric activity	Action object
Total words	0.95**	0.75*	−0.88**	0.41	−0.47	−0.14
Pointing	0.82**	0.63*	−0.73*	0.29	−0.21	0.03
Instrumental	−0.79**	−0.50	0.72*	−0.06	**0.83****	−0.25
Representational	0.58	0.06	−0.63*	−0.02	−0.07	−0.42
Motoric activity	−0.60	−0.39	**0.73***	0.17	0.56	−0.23
Action object	−0.07	**0.57** (**0.72****; **0.78****)	−0.11	0.57	−0.33	0.49

*$p < 0.05$; **$p < 0.01$. In bold face those correlations that remained significant or became reliable (in brackets) after mother and child speech were partialled out.

with age as pointing did unlike the instrumental gesture. Maternal and child open-class production showed a similar pattern of relations with gesture and action measures. Third, maternal and child pointing and instrumental production were significantly related, indicating that deictic production follows a similar trend for the mother and child. Maternal representational production was negatively related to child instrumental production. Finally, maternal and child instrumental gestures were positively related to child and maternal motoric activity.

To examine the impact of maternal and child language on dyadic gesture–gesture and gesture–action relations, Kendall partial-rank correlations were performed for each of the correlations reported in Table 3. Only the correlations involving maternal and child gestures with maternal and child motoric actions or action object remained after maternal speech was partialled out. The correlation between child pointing and maternal object action was statistically significant (0.72**). Similarly, the correlations involving maternal and child gestures with maternal and child motoric actions or action object remained after child speech was partialled out. The correlation between child pointing and maternal object action became statistically significant (0.78**). This means that maternal and child language have an impact on communicative gesture–gesture exchanges, but not on gesture–motoric/action exchanges.

Modelling the Pattern of Changes in Maternal and Child Gesture and Action Production Across Sessions

To model the pattern of changes in infant–mother gestures and actions across sessions in both age groups (third research question) GEE analysis was used. Three growth curves were tested for modelling the observed pattern of changes: linear, quadratic and cubic. The slope of the linear component is a measure of a *sustained* logistic variation in age of gesture production, either positive or negative. The quadratic component, particularly an early *slow* rise or decrease in developmental frequency, may reflect the tendency for some children or mothers, but not all, to increase or decrease across sessions the production of the gesture. The cubic component, particularly the leveling out at the upper or lower end, would be expected to reflect a *rapid* increase or decrease in gesture production for all children or mothers. Table 4 presents a summary of GEE estimation results for the set of slopes of regression analysis for pointing and instrumental gestures produced either by the child or the mother by age groups and by groups x sessions.

Mother and child rate of pointing showed a similar trend of increases across sessions in Group 1. In the child data, the rate of self-initiated pointing slowly increased across sessions in Group 1. A sustained and rapid increase was observed for the rate of induced pointing in Group 1. In the mother data, a sustained increase was observed in Group 1. The group alone did not produce any significant result in the child and mother data. Figure 1 illustrates the pattern of change on the weighted count of pointing gestures (number of pointing divided by the logarithm of the time session and averaged across subjects) for the child and the mother across age intervals.

Mother and child rates of instrumental gestures showed a similar trend of decreases across sessions in both groups. In the child data, the rate of instrumental gestures showed a sustained decrease in both groups (stronger in the older group) across sessions. As for the mothers, the rate of instrumental gestures showed a sustained and rapid decline in Group 1 and a sustained

Table 4. Robust Z values for a GEE Poisson regression analysis with children's and mothers' pointing and instrumental gestures

Child	Pointing (self-initiated)		Pointing (induced)		Instrumental Gestures	
	12–24 months	24–36 months	12–24 months	24–36 months	12–24 months	24–36 months
Group	−0.94		−0.19		1.79	
Linear	1.35	0.84	43.75***	−0.63	−2.49**	−3.40***
Quadratic	1.93*	0.08	−0.79	−0.16	0.64	−0.68
Cubic	−1.59	−0.66	5.88***	−0.89	0.47	−1.68
Mother	Pointing				Instrumental	
Group	−1.88				3.41***	
Linear	3.28**	1.15			−5.24***	−2.85**
Quadratic	−0.30	−0.56			−1.46	−0.88
Cubic	−0.10	0.43			−2.03*	−0.11

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

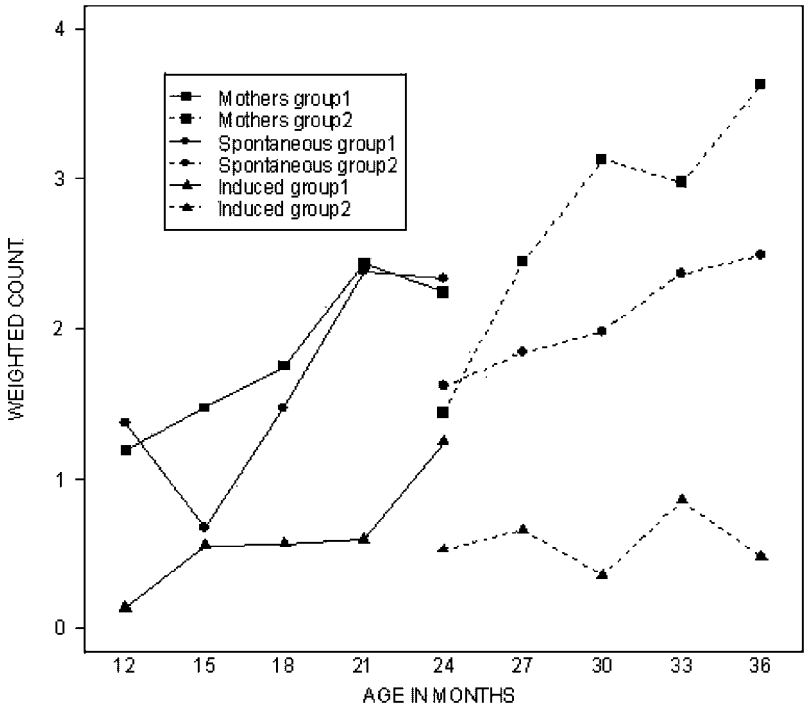

Figure 1. Pattern of changes on the weighted count of mothers' and babies' spontaneous pointing and induced pointing (only babies) in Groups 1 and 2 across the age intervals.

decrease in Group 2 across sessions. A significant slope appeared for group differences in the mothers' data. That means that the logarithm of the total frequency of Group 2 (weighted by the total time) was significantly lower than that of Group 1. Figure 2 illustrates the pattern of change of instrumental gestures.

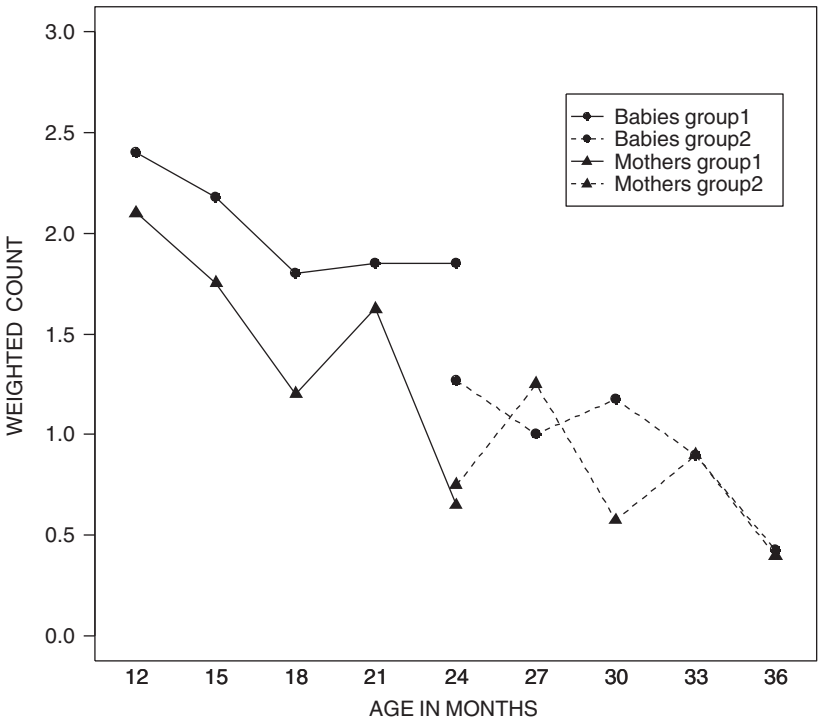

Figure 2. Pattern of changes on the weighted count of mothers' and babies' instrumental gestures in Groups 1 and 2 across the age intervals.

Table 5. Robust *Z* values for a GEE Poisson regression analysis with children's and mothers' social and symbolic gestures and action

Child	Social gesture		Symbolic gesture		Action	
	12–24 months	24–36 months	12–24 months	24–36 months	12–24 months	24–36 months
Group	0.58		—		1.14	
Linear	−0.10	−0.78	—	—	−0.65	−0.58
Quadratic	0.83	1.13	—	—	−1.27	−1.10
Cubic	−2.96**	−1.20	—	—	−7.71***	−0.44
Mother	**Social**		**Symbolic**		**Action**	
Group	−1.62		−0.72		1.37	
Linear	−1.39	3.13***	18.40***	1.77	−0.19	−1.49
Quadratic	−1.31	−2.38**	−17.78***	−1.55	0.51	−0.56
Cubic	−0.78	2.42**	63.90***	−0.88	0.34	0.49

**$p < 0.01$; ***$p < 0.001$.

Table 5 presents a summary of GEE estimation results for the set of slopes of regression analysis for social, symbolic and motor actions (with and without objects) produced either by the child or the mother by age groups and by groups *x* sessions. The mother and child rates of social, symbolic and motor actions did

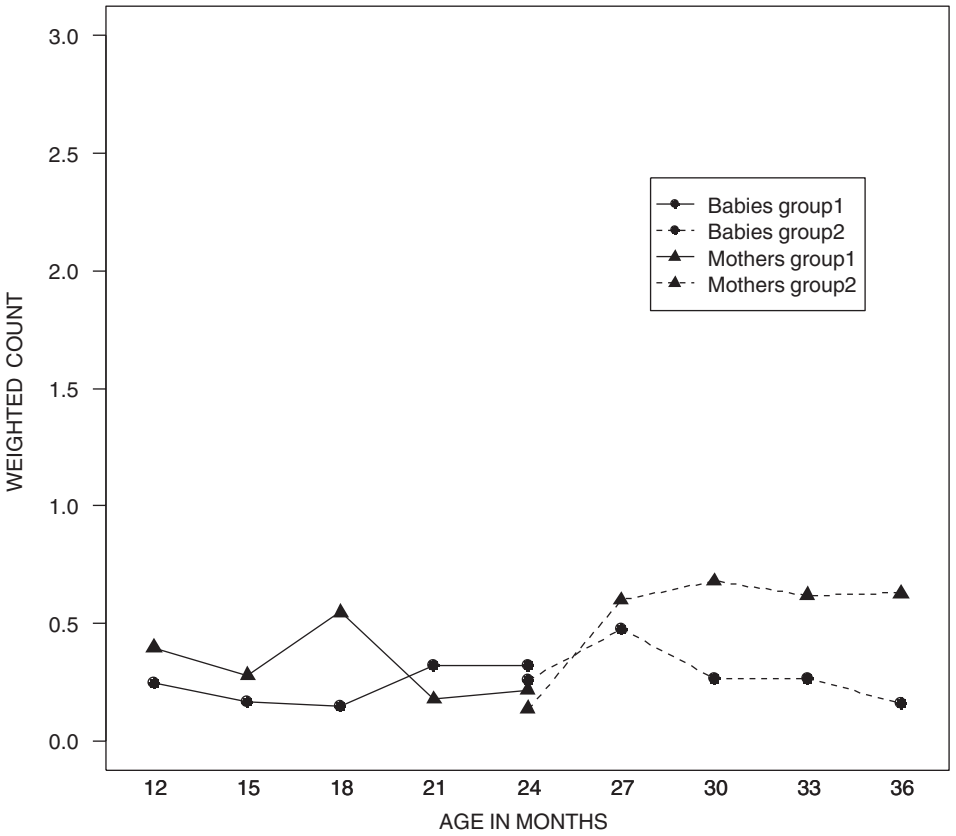

Figure 3. Pattern of changes on the weighted count of mothers' and babies' symbolic plus social gestures in Groups 1 and 2 across the age intervals.

not show similar trends at all. For the social gestures, the mother and child growth curves did not coincide in shape or in the age group. In the infant data, the rate of social gestures showed a rapid decrease in Group 1 across sessions. As for the mothers, a complex pattern consisting of a sustained and fast increment and a slow rate of decrease was observed in Group 2. The group alone did not produce any significant results in the child and mother data.

For the symbolic gesture, GEE algorithm did not converge in the infant data indicating the lack of a regular pattern. For the mother data, a complex pattern of change was observed consisting in a fast, sustained increase and a slow rate of decrease in Group 1. The group alone did not produce any significant results in the data. Figure 3 illustrates the pattern of change of social plus symbolic gestures.

Finally, the rate of infants' actions performed with and without objects showed a strong and fast decrement in Group 1 across sessions. Data from the mothers did not show any significant developmental trends.

DISCUSSION

The present study was designed to examine the co-development of gestures exhibited by mothers of 1- and 2-year-old children followed during 1 year of

observations. Infants and mothers showed a sustained activity level across groups during long periods of observation (an average of 3.5 h/child). Nevertheless, the accumulative rate of gesture production was slightly lower than that obtained in previous studies (Bekken, 1989; Morford and Goldin-Meadow, 1992), probably due to the daily routine nature of the activities involved in the current study.

The first issue was to compare the repertoire of mother and the child gestures in the two age groups. The results confirmed our predictions, in that the distribution of mother and child gestures looked very much alike and showed few marginal changes across groups, in line with other results in the literature (Bates *et al*., 1975; Masur, 1983; Blake *et al*., 1992; Zinober and Martlew, 1985). In contrast, only the rate of child motoric activity changed with age. Pointing was by far the most frequently produced gesture for both mothers and children. In other studies, deictic gestures were also frequently produced and did not decline with the transition to language (Capirci *et al*., 1996; Hannan, 1992). The rate of pointing was higher than that of instrumental gestures in the mothers of the older group and slightly higher in their children, indicating a prominence of pointing as a deictic device around the third year (Blake *et al*., 1992). In contrast, symbolic gestures were the least frequent type of gestures to occur in our sample and remained steady over time (Iverson *et al*., 1999; Pettito, 1993). The rate of social gestures was slightly higher than that of symbolic gestures, probably because social gestures are practiced in social routines like the ones included in our study (Iverson *et al*., 1999). The co-occurrence of mother–child gesturing and acting was very low, especially in Group 2.

The second issue was to analyse whether maternal and child speech were related to maternal and child gesture production. Across observations, mother and child language production increased and was strongly correlated, confirming other studies (Hampson and Nelson, 1993; Tamis-Lemona *et al*., 2001). Mothers' production of gestures also supports the infant gesture production over the second and the third years, extending the findings of Iverson *et al*. (1999). However, there is a close relation between mother and child deictic gestures but not between mother and child representational gestures, probably due to the low number of occurrences. Maternal and child pointing and instrumental gestures were positively related across observations. Maternal representational production was negatively related to child instrumental production.

Interestingly, language production plays a different role depending on the type of gesture. Maternal and child speech were significantly correlated with child and mother pointing production. A relation between maternal language and child pointing has been found in many other studies (Butterworth and Morissette, 1996; Goldfield, 1990; Harris *et al*., 1995; Pettito, 1993). Maternal and child speech were also positively related to mother and child representational gestures, though the relation was not statistically reliable, probably due to the low frequency of symbolic data (e.g. Acredolo and Goodwyn, 1985). These results suggest a possible link between language and communicative activities mediated by gesture (distal referencing and symbolic activity). In contrast, maternal and child speech were negatively related to mother and child instrumental and motoric activity. Moreover, instrumental gestures such as give, show and request, that require very close or contact targets as reference objects, were clearly linked with motor programmes, and such relations remained after partialling out the mother and child language effects. Likewise, the relation between the child pointing and the mother manipulating an object grew stronger after partialling out the maternal and child language. That means that the

child's pointing is not only related to maternal speech but also to maternal action with objects.

The third research aim was to analyse how close are the patterns of change of mother and child gestures and actions across sessions in both age groups. Data from the mothers showed a significant developmental trend in the rate of mothers' gestures but not in the actions. Thus, maternal adaptation to developmental changes was not due to a generic adjustment to motor activity but was specific for gesturing. Gestures are generally intended to be communicative (De Ruiter, 2000). Therefore, it makes sense that mothers may adapt their gestures in trying to successfully communicate with their children.

The developmental synchrony of mother–child gesture differs according to the type of gesture. There is a closer correspondence between the mother and child growth curves across sessions for deictic than for representational gestures. The rate of production of deictic gestures increased similarly for maternal and child pointing from 12 to 24 months, and remained stable from 24 to 36 months. The rate of production decreased similarly for maternal and child instrumental gestures from 12 to 36 months, as Figures 1 and 2 illustrated. It is clear that mothers used the same deictic means as babies although they had the full repertoire of possibilities at hand. Showing is a more primitive way of referencing than pointing in that only the latter can refer to distal targets (Bates *et al*., 1975). Despite that, mothers used these primitive means when it was necessary to optimize the communication with their babies. Progressively, mothers abandoned these primitive means in favour of pointing just like their children did.

For representational gestures, the adjustment between the mother and child patterns of change was less clear (see also the correlational data). Although the mothers' rate showed developmental changes, the maternal trends did not fit with those exhibited by the children. Child rate of social gestures decreased from 12 to 24 months, whereas the maternal rate of social gestures increased and decreased from 24 to 36 months. No regular pattern of changes was obtained for the infant rate of symbolic gestures, whereas the maternal rate increased and decreased from 12 to 24 months, as Figure 3 illustrates. Consequently, there was a lack of synchrony between the mother and child patterns of social and symbolic gestures. We have hypothesized that the lack of synchrony might be a result of the interactive requirements (e.g. deferred imitation), but we cannot discount the possibility of other confounding factors (e.g. lack of statistical power given the low rate of production of representational gestures). More research is needed before a definite conclusion can be reached on this point.

In conclusion, the mothers' gesture production comprises an articulated input mainly composed by deictic and representational gestures that are typically found in the child's repertoire of gestures during the second and the third years of age. Maternal adaptation to developmental change is specific for gesturing but not for acting. Maternal and child speech play an important role in gesture production. However, this role is clear for dyadic gesture–gesture relations but not for dyadic gesture–action relations. Thus, depending on the type of maternal gesture, a child may consistently engage either in language-based activities (with pointing and representational gestures) or in motor-based activities (with instrumental gestures). Changes in the mothers' deictic production closely follow the developmental changes of children's deictic gestures, showing the importance of time adjustment, at least for deictic gestures. These results obtained by means of within-dyad longitudinal comparisons are compatible with the existence of an articulated 'gestural motherese' (Bekken, 1989; McNeill, 1992;

Iverson *et al*., 1999). However, more research is needed to fully substantiate this proposal.

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REFERENCES

Acredolo L, Goodwyn S. 1985. Symbolic gesturing in language development: a case study. *Human Development* **28**: 40–49.
Acredolo L, Goodwyn S. 1988. Symbolic gesturing in normal infants. *Child Development* **59**: 450–466.
Acredolo L, Goodwyn S. 1997. Furthering our understanding of what humans understand. *Human Development* **40**: 25–31.
Bates E, Camaioni L, Volterra V. 1975. The acquisition of preformatives prior to speech. *Merrill-Palmer Quarterly* **21**: 205–226.
Bates E, Benigni L, Bretherton I, Camaioni L, Volterra V. 1979. *The Emergence of Symbols: Cognition and Communication in Infancy.* Academic Press: New York.
Bates E, Thal D, Fenson L, Whitesell K, Oakes L. 1989. Integrating language and gesture in infancy. *Developmental Psychology* **25**(6): 1004–1019.
Bekken K. 1989. Is there 'motherese' in gesture? *Ph.D. Dissertation*, Department of Psychology, University of Chicago.
Blake J, McConnell S, Horton G, Benson N. 1992. The gestural repertoire and its evolution over the second year. *Early Development and Parenting* **1**(3): 127–136.
Butterworth GE, Morissette P. 1996. Onset of pointing and the acquisition of language in infancy. *Journal of Reproductive and Infant Psychology* **14**: 219–231.
Camaioni L, Castelli MC, Longobardi E, Volterra V. 1991. A parent report instrument for early language assessment. *First Language* **11**: 345–359.
Capirci O, Iverson JM, Pizzuto E, Volterra V. 1996. Gestures and words during the transition to two-word speech. *Journal of Child Language* **23**: 645–673.
Caselli MC, Volterra V. 1990. From communication to language in hearing and deaf children. In *From Gesture to Language in Hearing and Deaf Children*, Volterra V, Erting CJ (eds). Springer: New York.
De Ruiter JP. 2000. The production of gesture and speech. In *Language and Gesture*, McNeill D (ed.). Cambridge University Press: Cambridge, MS.
Diggle PJ, Lyang KY, Zeger SL. 1994. *Analysis of Longitudinal Data*. Clarendon Press: Oxford, UK.
Franco F, Butterworth GE. 1996. Pointing and social awareness: declaring and requestioning in the second year of life. *Journal of Child Language* **23**(2): 307–336.
Goldfield B. 1990. Pointing, naming and talking about objects: referential behavior in children and mothers. *First Language* **10**: 231–242.
Goldin-Meadow S, Morford M. 1990. Gesture in early child language. In *From Gesture to Language in Hearing and Deaf Children*, Volterra V, Erting CJ (eds). Springer: New York.
Hampson J, Nelson K. 1993. The relation of maternal language to variation in rate and style of language acquisition. *Journal of Child Language* **20**: 313–342.
Hannan TE. 1992. An examination of spontaneous pointing in 20- to 50-month-old children. *Perceptual and Motor Skills* **74**: 651–658.
Harris M, Barlow-Brown F, Chasin J. 1995. The emergence of referential understanding: pointing and the comprehension of object names. *First Language* **15**: 19–34.

Iverson JM, Capirci O, Longobardi E, Caselli MC. 1999. Gesturing in mother–child interactions. *Cognitive Development* **14**: 57–75.
Lyang KY, Zeger SL, Qaqish B. 1992. Multivariate regression analyses for categorical data. *Journal of the Royal Statistical Society* **B54**: 3–40.
Masur EF. 1983. Gestural development, dual-directional signaling and the transition to words. *Journal of Psycholinguistic Research* **12**: 93–109.
Meltzoff AN. 1988. The human infant as Homo Imitans. In *Social Learning: Psychological and Biological Perspective*, Zentall TR, Galef BG (eds). Erlbaum: Hillsdale, NJ.
McCullagh P, Nelder JA. 1989. *Generalized Linear Models*. Chapman and Hall: New York, NY.
McNeill D. 1992. *Hand and Mind*. The University of Chicago Press: Chicago.
Morford M, Goldin-Meadow S. 1992. Comprehension and production of gesture in combination with speech in one-word speakers. *Journal of Child Language* **19**: 559–580.
Pettito LA. 1993. Modularity and constraints in early lexical acquisition. In *Language Acquisition*, Bloom P (ed.). Harvester Wheatsheaf: New York.
SAS Institute, Inc. 1999. *SAS/STATS User's Guide, Version 8*. SAS Institute: Cary, NC.
Stokes M, Davis CS, Koch GG. 1995. *Categorical Data Analysis Using the SAS System*. SAS Institute: Cary, NC.
Tamis-Lemona C, Bornstein M, Baumwell L. 2001. Maternal responsiveness children's achievement of language milestones. *Child Development* **72**: 748–767.
Tomasello M, Camaioni L. 1997. A comparison of the gestural communication of apes and human infants. *Human Development* **40**: 7–24.
Zeger SL, Liang KY. 1986. Longitudinal data analysis for discrete and continuous outcomes. *Biometrics* **42**: 121–130.
Zinober B, Martlew M. 1985. Developmental changes in four types of gesture in relation to acts and vocalizations from 10 to 21 months. *British Journal of Developmental Psychology* **3**: 293–306.

