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Early communicative behaviors and their relationship to motor skills in extremely preterm infants

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ABSTRACT

Despite the predictive value of early spontaneous communication for identifying risk for later language concerns, very little research has focused on these behaviors in extremely low-gestational-age infants (ELGA < 28 weeks) or on their relationship with motor development. In this study, communicative behaviors (gestures, vocal utterances and their coordination) were evaluated during mother–infant play interactions in 20 ELGA infants and 20 full-term infants (FT) at 12 months (corrected age for ELGA infants). Relationships between gestures and motor skills, evaluated using the Bayley-III Scales were also examined. ELGA infants, compared with FT infants, showed less advanced communicative, motor, and cognitive skills. Giving and representational gestures were produced at a lower rate by ELGA infants. In addition, pointing gestures and words were produced by a lower percentage of ELGA infants. Significant positive correlations between gestures (pointing and representational gestures) and fine motor skills were found in the ELGA group. We discuss the relevance of examining spontaneous communicative behaviors and motor skills as potential indices of early development that may be useful for clinical assessment and intervention with ELGA infants.

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What this paper adds

Extremely premature birth can negatively impact on development in multiple domains, such as language development. Despite the relevance of identifying early predictors of language delay in at-risk populations, very little research has focused on this issue in extremely-low-gestational-age infants (ELGA < 28 weeks) or on their relationship with motor development. This paper adds a detailed description of gestures, vocal utterances, and their coordinations in ELGA infants at 12 months and their relationship with motor skills. The findings reveal that giving and representational gestures were produced at a lower rate by ELGA infants, and that pointing gestures and words were produced by a lower percentage of ELGA relative to FT infants. Less advanced motor and cognitive skills were also found in ELGA relative to FT infants. Pointing and representational gestures were related to fine motor skills in the ELGA group. These findings suggest that follow-up programmes for ELGA infants should include a detailed evaluation of early spontaneous gestural and vocal production and motor skills.

1. Introduction

Because of early sub-optimal biomedical and environmental conditions, premature birth represents an event that can have negative impacts on development in multiple domains. For instance, extremely preterm birth is a risk factor for language impairment (Sansavini, Guarini, et al., 2010; for review, see Sansavini, Guarini, & Caselli, 2011). Identifying predictors of language development is theoretically and clinically important because it can shed light on potential mechanisms underlying language acquisition in a population at-risk for delay and impairment and suggest potential targets for intervention. It is therefore surprising that relatively little work has addressed this issue in preterm infants.

The literature on typically developing (TD) infants has indicated close relationships between language development and both prelinguistic communicative behaviors (e.g., gesture, vocalization, gesture-vocalization coordinations) and fine motor skills (Hill, 2001; Iverson, 2010; Leonard & Hill, 2014). However, relatively few studies have investigated early gestural and vocal abilities in preterm infants and they have not generally examined the production of communicative coordinations, which are an important achievement in early communicative development (Iverson, Capirci, Volterra, & Goldin-Meadow, 2008). Moreover, the existing data are conflicting, potentially due to variation in sample selection criteria and tasks used to assess early production (Barre, Morgan, Doyle, & Anderson, 2011; Marlow, Wolke, Bracewell, Samara, & EPICure Study Group, 2005).

With regard to the relation between language and fine motor abilities, studies of TD infants have found relationships between increasing refinement in infants' object exploration activities, action imitation, and achievements in language development (Lifter & Bloom, 1989; Zambrana, Ystrom, Schjølberg, & Pons, 2013). Thus, delays in motor experiences may constrain learning opportunities (LeBarton & Iverson, 2013) in ways that may impact language development.

1.1. Gestures and vocal utterances in preterm infants

A developmental domain particularly affected in preterm children is language (Barre et al., 2011; Sansavini, Guarini, & Caselli, 2011; Van Noort-van der Spek, Franken, & Weisglas-Kuperus, 2012). A small number of longitudinal studies have investigated whether the risk for language impairment is greater among very preterm children (very low gestational age, VLGA, gestational age < 32 weeks) compared to FT children. These studies indicate that, relative to their FT peers, VLGA children exhibited a higher risk for language delay/impairment in the preschool years. Language delay/impairment was exhibited by 30–34% of VLGA children between the ages of 2 and 4 years, but only by 5–10% of FT children (Sansavini, Guarini et al., 2010; Woodward et al., 2009). In light of this enhanced risk, it is critical to investigate early components of language development that may be informative about possible subsequent language delays in the preterm population.

Early components of language development have been studied extensively in TD infants. The onset of communicative gestures (e.g., Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979; Bavin et al., 2008; Capirci & Volterra, 2008), babbling (e.g., Oller, Eilers, Neal, & Schwartz, 1999; Stoel-Gammon, 1989; Stoel-Gammon, 2011), and first words (e.g., Caselli, Rinaldi, Stefanini, & Volterra, 2012; Reilly et al., 2009) in the first year of life are signs of the typical course of language development. In addition, at around the end of the first year, TD infants begin to combine gestures and vocal utterances into tightly timed communicative coordinations. Relative to isolated gestures and vocal utterances, these coordinations are more effective in eliciting parental responses and may promote joint attention and language acquisition (Goldin-Meadow, Goodrich, Sauer, & Iverson, 2007; Tamis-LeMonda, Bornstein, & Baumwell, 2001; Tomasello, Carpenter, & Liszkowski, 2007).

Less is known about the development of gesture, babbling, first words, and communicative coordinations in infants who are at risk for delayed language development, as are preterm infants. The main studies of gesture and vocal production in this population focused on VLGA infants and generally examined gestures and vocal utterances separately. Regarding gestural production, some studies indicate that relative to FT infants, VLGA infants exhibit slower development of gestural communication at 12 months, as measured via parental questionnaires such as the MacArthur-Bates Communication

Developmental Inventory (MB-CDI) (Ortiz-Mantilla, Choudhury, Leevers, & Benasich, 2008; Sansavini, Guarini et al., 2011; Stolt et al., 2014). However, in an observational study, Suttora and Salerni (2012) did not find significant differences in the number of gestures produced by VLGA and FT infants at 12 months.

Findings on the development of vocalization and babbling in preterm infants have also been somewhat mixed. Research conducted with direct measures (e.g., observation during spontaneous mother-infant play interaction) reported significantly less advanced vocal production in VLGA infants compared to FT infants at 12 months (D'Odorico, Majorano, Fasolo, Salerni, & Suttora, 2011), and in extremely low birth weight infants (ELBW) relative to FT infants at 8, 9, and 10 months of age (Torola, Lehtihalmes, Heikkinen, Olsen, & Yliherva, 2012). By contrast, other research using parental questionnaires did not reveal differences between preterm and FT infants in this kind of production (Gonzalez-Gomez & Nazzi, 2012; Stolt, Lehtonen, Haataja, & Lapinleimu, 2012). These contrasting results may be partly due to differences in the methods used to assess the early productions and in sample criteria selection; some authors also suggested that the emergence of speech-like babbling may be slightly advanced in these infants, as a result of earlier extrauterine exposure to speech input or intervention (Eilers et al., 1993).

With regard to word production in preterm infants, studies using the MB-CDI identified differences between VLGA and FT infants in vocabulary size at 16 months (Ortiz-Mantilla et al., 2008), and at 18 and 24 months (Sansavini, Guarini et al., 2011; Stolt, Haataja, Lapinleimu, & Lehtonen, 2009), but not at 12 months. D'Odorico and colleagues (2011) replicated this pattern of findings in an observational study conducted during mother-infant play interactions at 18 and 24 months. Furthermore, a recent study employing a lexical task found a lower rate of noun and predicate production in ELGA children at 24 months, compared to FT peers (Sansavini, Bello et al., 2015). To our knowledge, however, only one study has shown that differences emerge already at the end of the first year of life in the onset of first words, with delays in ELBW infants with respect to FT infants (Torola et al., 2012).

Finally, relatively little is known about early communicative coordinations in preterm infants. To our knowledge, only two studies to date have investigated the combination of gesture and vocal utterances in VLGA infants. The first study (Suttora & Salerni, 2012) reported that VLGA infants produced fewer gesture-plus-word combinations at 18 and 24 months than did FT infants. The second study (Sansavini, Bello et al., 2015) found a lower rate of spoken-gestural combinations in a task of predicate production in ELGA children compared to FT peers at 24 months. However, whether such differences exist even earlier in development is not known.

1.2. Motor skills in preterm infants and their relationship to early communicative abilities

The motor domain appears particularly vulnerable in preterm infants (De Kievet, Piek, Aarnoudse-Moens, & Oosterlaan, 2009) and some of the difficulties found in language achievements of these infants seem to be related to some aspects of motor development (Sansavini, Guarini, & Caselli, 2011). Studies of motor development in TD infants have shown that improvements in control of head, trunk and limbs, which permit the transition from lying to sitting to standing postures (Spencer, Vereijken, Diedrich, & Thelen, 2000; Touwen, 1976), eye-hand coordination with reaching and grasping movements (Rochat & Goubet, 1995; von Hofsten, 2007), and thumb-fingertip grasp (Jovanovic & Schwarzer, 2011) are signs of the typical course of motor development across the first year of life.

Some studies have found delays in the acquisition of early motor milestones in very preterm infants (De Kievet et al., 2009; Jeng et al., 2008; Van Haastert, de Vries, Helders, & Jongmans, 2006). For example, motor difficulties are evident in VLGA infants with white matter abnormality, who showed gross and fine motor dysfunctions at 12 months (Spittle, Boyd, Inder, & Doyle, 2009), and also in high-risk preterm infants, who exhibited poorer manipulation skills at 9 months with respect to low-risk preterm and FT infants (Ruff, McCarton, Kurtzberg, & Vaughan, 1984). Motor difficulties have also been observed in VLGA infants without cerebral abnormalities compared to FT infants as early as the first months of life, specifically in head and arm control and in looking behaviors (Van Beek, Hopkins, Hoeksma, & Samsom, 1994). Studies of early motor skills in ELGA infants without major cerebral damage are few in number. In one such study Sansavini, Savini et al. (2011) showed that, relative to VLGA and FT infants, ELGA infants obtained lower locomotor, eye-hand coordination, and cognitive performance scores on the Revised Griffith Mental Development Scales-GMDS-R (Griffiths, 1996) at 6, 12, 18, and 24 months of age. Another study (Sansavini et al., 2014) reported that motor, cognitive, and language scores on the Bayley-III Scales (BSID-III, Bayley, 2006) were significantly lower for ELGA infants compared to FT infants at 12, 24 and 30 months, and that the divergence between the motor trajectories of the two groups significantly increased over time. The authors hypothesized that these motor difficulties may negatively affect early communicative abilities, such as face-to-face interaction and joint attention, and consequently they may have negative cascading effects on language acquisition in these infants (Sansavini et al., 2014).

Recent evidence points to the existence of a relationship between motor skills and communicative-linguistic abilities in TD infants (Clearfield, 2011; Ejiri & Masataka, 2001; Iverson, Hall, Nickel, & Wozniak, 2007) and between early motor and communicative delays in infants at risk for developmental concerns (e.g., infants at risk for Autism Spectrum Disorder; Bhat, Galloway, & Landa, 2012; Bhat, Landa, & Galloway, 2011; LeBarton & Iverson, 2013). Given that motor delays are relatively common in preterm infants (De Kievet et al., 2009; Marlow, Hennessy, Bracewell, & Wolke, 2007; Sansavini et al., 2014), it is surprising that no studies to date have investigated the relationship between early motor development and communicative abilities in preterm infants.

1.3. The present study

The present study had two main goals. The first was to examine the production of communicative behaviors during spontaneous mother-infant play in 12-month-old (corrected age) ELGA infants and compare them to FT infants. Spontaneous gestures (requesting/reaching, pointing, showing, giving, conventional, and representational), vocal utterances (vocalizations, babbling, words), and communicative coordinations (i.e., gesture with gaze, vocalization/babbling with gaze and/or gesture, word with gaze and/or gesture) were examined in detail. We expected that, relative to FT infants, ELGA infants would have smaller repertoires of gestures, vocal utterances and communicative coordinations.

The second goal was to examine motor abilities in ELGA and FT infants using the Bayley-III Scales and to explore relationships between communicative behaviors, in particular gestures (which involve motor abilities), and fine and gross motor skills. In order to obtain a complete clinical assessment, cognitive and language skills were also assessed using the Bayley-III Scales in both groups. In line with previous research (Sansavini et al., 2014), we expected that the ELGA group would exhibit poorer fine and gross motor abilities compared with the FT group. Close relationships between gestures and motor skills were also expected. In particular, it was hypothesized that early fine motor difficulties in ELGA infants would reduce opportunities to actively explore objects, gaze to the mother's face, and participate in triadic interactions; thus, they may negatively impact the emergence of communicative behaviors (Leonard & Hill, 2014).

2. Method

2.1. Participants

This study involved 40 monolingual Italian infants: 20 ELGA infants and 20 FT infants. The ELGA group (9 males, 11 females) was born at the Neonatal Intensive Care Unit (NICU) of Bologna University. The NICU was accessible to parents day and night and physical contact between parents and their preterm infants in the incubators was encouraged. Cranial ultrasound scans (US) were carried out for all neonates within the first 4 days of life and then repeated weekly during the first month of life. Those neonates with abnormal US in the first month of life were re-examined weekly until normalization, and then two times per month until discharge. After discharge, all preterm infants returned for re-examination with US at the presumed date of birth and again at 3 months of life (corrected age) and entered a medical and neuropsychological follow-up program at the Day-Hospital of the Unit of Neonatology at Bologna University.

Preterm infants were recruited into the present study if they met three primary medical criteria: (a) GA $\leq$ 28 weeks, determined by the date of the mother's last menstrual period and confirmed by first trimester early ultrasonography; (b) no indication of major cerebral damage as detected by ultrasound (US) and confirmed by magnetic resonance imaging at 40 weeks of GA (i.e., periventricular leukomalacia -PVL-, intra-ventricular hemorrhage -IVH- > II grade, hydrocephalus) or of congenital malformations; (c) no indication of visual (retinopathy of prematurity -ROP- > II grade) or hearing impairment. Infants included in the sample had some medical complications. These included small for gestational age (SGA, $n = 2$, 10%), respiratory distress syndrome needing mechanical ventilation (RDS-MV, $n = 20$, 100%), bronchopulmonary dysplasia (BPD, $n = 13$, 65%, defined as need of supplemental oxygen at 36 weeks of postconceptional age), IVH of grade I or II ($n = 1$, 5%) detected by US, ROP of grade I or II ($n = 13$, 65%), and hyperbilirubinemia treated with phototherapy ($n = 14$, 70%). In addition, 17 (85%) ELGA infants had persistent hyperechogenicity (HE) of white matter ($\geq$14 days), but this had completely resolved by 3 months.

The ELGA infants had a mean GA of 25.7 weeks ($SD = 1.4$, range = 23–28) and a mean birth weight of 803 grams ($SD = 191$; range = 509–1093). In this group, gestational age and birth weight were highly correlated ($r = .683$). Fifteen (75%) infants were first-born and five (25%) were second- or later-born. All were from families living in the Emilia-Romagna region. The group of ELGA infants was equally distributed across the general range of socioeconomic status (SES), as estimated from mothers' highest level of educational attainment: 12 (60%) mothers had a middle/low educational level (completed high school or at least basic education) and 8 (40%) mothers had a high educational level (completed University/Master's degree). The mean age of mothers was 36.2 years ($SD = 4.8$, range = 27–44).

The comparison group consisted of 20 healthy FT infants (11 males, 9 females) born in the same Hospital as the ELGA group. All FT infants had normal births (GA $\geq$ 38 weeks and birth weight $\geq$ 2500 g), and had no history of major cerebral damage, congenital malformations, or visual or hearing impairments. These infants had a mean gestational age of 39.5 weeks ($SD = 1.2$; range = 38–42) and a mean birth weight of 3476 grams ($SD = 464$; range = 2500–4200). Eighteen (90%) FT infants were first-born and two (10%) were second- or later-born. All FT infants were living in the Emilia-Romagna region. Like the ELGA group, these infants' background was equally distributed across SES based on mothers' highest level of education: 8 (40%) mothers had a middle/low educational level and 12 (60%) mothers had a high educational level. Mean age of mothers was 34.6 years ($SD = 3.1$, range = 30–41). The two groups did not differ significantly on gender [χ^2 (1, $N = 40$) = 0.40, $p = .527$], birth order (Fisher exact test; $p = .407$), maternal age [t (38) = 1.285, $p = .208$] or maternal level of education [χ^2 (1, $N = 40$) = 1.60, $p = .206$].

The study met ethical guidelines for human subjects protections, including adherence to the legal requirements of the study country, and received formal approval by the local Research Ethical Committee of the University Hospital of Bologna. Parents of the ELGA and FT infants gave informed written consent for participation in the study, data analysis, and data publication.

2.2. Procedure

The present study is part of a larger longitudinal study on language development in ELGA infants. In this paper, we present data on production of communicative behaviors and motor, cognitive, and linguistic skills in ELGA and FT groups at 12 months of age. As in many studies on preterm infants' development in the first 2 years of life, ELGA infants' age was corrected in order to take into account their level of neuropsychological maturation as assessed via mental and psychomotor scales (Johnson & Marlow, 2006; Pietz et al., 2004; Sansavini, Rizzardi, Alessandroni, & Giovanelli, 1996). The mean corrected age of the ELGA infants at the time of evaluation was 12 months and 6 days ($SD = 9$ days) and the mean chronological age of the FT infants was 12 months and 3 days ($SD = 9$ days). This difference was not statistically significant: $t(38) = 0.49$; $p = .623$.

All ELGA and FT infants were observed in a quiet room designed for neuropsychological evaluation at the Day-Hospital of the Unit of Neonatology at Bologna University.

Gesture, vocal utterance, and communicative coordination observation. A 30-min mother-infant play session was video-recorded. Infants and mothers sat together on a mat close to a mirrored wall and were videotaped playing with age-appropriate toys (e.g., car, ball, animal toys) and picture books. Mothers were asked to interact and play with their infants as they normally would.

Assessment of motor, cognitive, and language skills. Motor, cognitive and language skills were assessed with the Bayley Scales of Infant and Toddler Development, Third Edition (BSID-III, Bayley, 2006). Each of the three scales (motor, cognitive and language) was administered in an approximately 25-minute session by the second author, a neuropsychologist certified on the BSID-III.

The BSID-III motor scale includes two subtests. The fine motor subtest examines visual tracking, reaching, object manipulation, grasping, functional hand skills, and responses to tactile information. The gross motor subtest assesses static positioning (i.e., sitting, standing), dynamic movement (i.e., locomotion and coordination), and balance and motor planning. The BSID-III cognitive scale assesses sensorimotor development, exploration and manipulation, object relatedness, concept formation, memory, and cognitive processing. The BSID-III language scale includes two subtests assessing receptive and expressive communication. The receptive communication subtest assesses preverbal and verbal comprehension, social referencing, and receptive vocabulary. The expressive communication subtest assesses preverbal communication (babbling, gesturing, joint referencing, and turn taking) and expressive vocabulary.

The BSID-III provides standardized motor, cognitive and language composite scores, each with a mean of 100 and *SD* of 15. It also provides standardized scaled scores, each with a mean of 10 and *SD* of 3, respectively for the fine motor, gross motor, receptive communication, and expressive communication subtests. Delay on each of the three scales (motor, cognitive, and language) was defined as a standardized score < -1.5 *SD* below the mean (i.e., ≤ 77), which is a common clinical cut-off (Lobo, Paul, Mackley, Maher, & Galloway, 2013). Behaviors associated with developmental risk are defined in the Appendix B of the BSID-III technical manual (Bayley, 2006). With respect to the motor scale, muscle tone, hand movement, posture and positioning, voluntary movement, and coordination items are considered in identifying infants at developmental risk.

The BSID-III has been shown to be a valid tool in both research and clinical practice; satisfactory reliability and validity have been reported by the authors (Bayley, 2006), with test–retest reliability ranging from .67 to .94, internal consistency coefficients (using the split half method) of .87–.93, and moderate to high correlations with measures of similar domains. With regard to the Italian population, an Italian translation/adaptation of the BSID-III is available (Ferri, Orsini, & Stoppa, 2009) which has been using in research and clinical practice (Sansavini et al., 2014). Since the Italian standardization has not been completed yet, normative values of the original standardization (Bayley, 2006) have been taken as reference for standardized scores, and an Italian FT sample has been included in the present study for purposes of comparison.

2.3. Coding

All spontaneous communicative behaviors (i.e., gestures, vocal utterances, communicative coordinations) produced during the 30-min mother-infant play interaction session were coded from the videotapes by a trained coder blind to infant group membership using a computer-based video interface system (INTERACT version 9, Mangold International GmbH, 2012) that permitted time-intensive coding of the videotapes. Infant communicative behaviors were considered spontaneous unless they were directly elicited by a mother's request. Thus, they included infant's "apparent imitation" (i.e., an infant's communicative behavior occurring after 5 s from the end of the mother's production) and infant's reformulation of mother's productions (see Vihman & McCune, 1994).

Because session length varied slightly among participants ($M = 27.42$, $SD = 5.25$), all frequency variables were converted to rates per 10 min by dividing the total frequency by the length of observation in minutes, then multiplying it by 10.

Gesture. A gesture was considered communicative if it involved clear effort to direct the caregiver's attention (e.g., through use of eye contact, postural shift, repetition, or vocalization; Iverson et al., 2008; Iverson, Capirci, & Caselli, 1994). Deictic, conventional and representational gestures were coded (Capirci, Iverson, Pizzuto, & Volterra, 1996). *Deictic gestures* included *requesting/reaching* (clear extension of the arm with prone or supine open palm or repeated opening/closing of the hand with the aim to request something), *pointing* (clear extension of the index finger toward a proximal or distal object for the purpose of sharing attention or requesting), *showing* (holding up the object toward the partner while making eye contact), and *giving* (extension of the arm with the object in hand and directed toward the hand of another person).

Conventional gestures were ritualized gestures (e.g., blowing a kiss to someone) or culturally defined gestures (e.g., NO with the head, HELLO with the hand). *Representational gestures* stand for a specific referent and their primary semantic content does not change with context. Gestures produced with an object (e.g., DRINK, i.e., the infant pretends to drink bringing a cup to his mouth; CAR, i.e., the infant moves a box pretending that it is a car) and without an object (e.g., TELEPHONE, i.e., the infant pretends to phone bringing his hand close to his ear; BIG, i.e., the infant widens his arms pretending to make a big size) were included in this category.

Vocal utterances. Following Paul and Jennings (1992), vocalization/babbling was coded when the utterance was judged by the parent and the examiner to be non-meaningful; it contained, at a minimum, a voiced vocalic element or a voiced syllabic consonant; it was produced with an egressive airstream; and it was judged to be "speech-like" (i.e., cry and vegetative sounds were not included). Utterances that could not be transcribed confidently after listening to them four times were eliminated. Utterances were coded as separate utterances when they were bounded by 1 second of silence on either side, a breath, adult speech, or falling intonation (Paul & Jennings, 1992, adapted). Vocal utterances were classified into one of three mutually exclusive categories (Stoel-Gammon, 1989): *vocalization* (level 1), characterized by utterances composed of a vowel, a syllabic consonant, a consonant-vowel or vowel-consonant sequence in which the consonant was a glide or glottal; *babbling*, which contained at least one consonant-vowel sequence, in which the place and manner feature of the true consonant did not change (level 2), or at least two true consonants differing in place or manner of articulation (level 3). A vocal utterance was coded as a *word* if it resembled an adult word (plausible phonetic shape), was potentially relevant to the ongoing situation (plausible context of use), and met at least 3 of the following 4 criteria: occurred at least 2 times, was phonetically similar to the target, had a specific referent, or was recognized by the caregiver (Vihman & McCune, 1994).

Communicative coordinations. A communicative coordination was coded when two (or more) communicative behaviors overlapped temporally with one another (Capirci et al., 1996; Parladé & Iverson, 2015). Temporal co-occurrence was defined as any overlap between co-occurring behaviors. Three types of communicative coordinations were coded: gestures combined with gaze directed/shifted to mother (e.g., *giving* plus gaze directed to mother); vocalization/babbling combined with gaze directed/shifted to mother and/or with gesture (e.g. vocalization [a] combined with gaze directed to mother and with *requesting;* babbling [kaku] combined with *pointing*); words produced in combinations with gaze directed/shifted to mother and/or with gesture (e.g. [ba ba], onomatopoeic word meaning "dog", combined with gaze directed to mother; [bu bu] onomatopoeic word meaning "car" combined with CAR, a repeated movement of the hand pretending that it is a car).

2.4. Reliability

Coding was performed by the first author and by a second trained coder, both of whom were blind to infant's group membership. Inter-observer reliability was calculated on 20% of the ELGA and FT dyads. Cohen's kappa calculated to assess inter-coder agreement for categorical decisions was 0.92 for gestures, 0.90 for vocal utterances, and 0.82 for communicative coordinations.

2.5. Statistical analyses

All statistical analyses were carried out using SPSS 21.0 for Windows with an alpha level of 0.05. Prior to conducting analyses, data were checked for violation of assumptions using the Kolmogorov–Smirnov test. Because distributions for some of the communicative behaviors were not normal, Mann–Whitney tests were conducted to assess potential differences in communicative behaviors (gestures, vocal utterances, and communicative coordinations) between the ELGA and FT groups. Effect sizes (r) for Mann–Whitney U tests were calculated using the formula $r = (Z)/(\sqrt{N})$ where N is the total number of participants in the whole sample; the standard values of r for small, medium, and large effect sizes are 0.1, 0.3, and 0.5 respectively (Field, 2009, p. 550). Chi-square tests were also performed to compare the distributions of infants in the ELGA and FT groups who did vs. did not produce communicative behaviors.

Motor, cognitive and language composite scores and fine motor, gross motor, receptive communication, and expressive communication scaled scores were all normally distributed. We therefore conducted a series of ANOVAs to evaluate differences between the ELGA and the FT infants on motor scores (composite score and fine and gross motor scaled scores), composite cognitive score, and language scores (composite score and receptive and expressive scaled scores).

Spearman's correlations were utilized to examine relationships between gestures, fine motor, and gross motor scaled scores, and cognitive composite scores.

3. Results

3.1. Communicative behaviors: gestures, vocal utterances, and communicative coordinations

Gestures. The mean rates per 10 min of gestures are presented in Table 1. Inspection of these data reveals that in the ELGA group, the most frequently produced gesture was requesting; giving, conventional, and representational gestures were infrequent. Mann–Whitney tests showed that the ELGA infants produced significantly fewer giving and representational gestures compared to the FT infants (see Table 1), whereas there were no significant group differences for requesting/reaching, pointing, showing, and conventional gestures. Chi-square tests revealed that a significantly lower percentage of the

Table 1
Comparisons between ELGA and FT groups of the rate per 10 min of gestures (Mann–Whitney test) and of the number of infants producing gestures (Chi-Square test) at 12 months (corrected age for ELGA infants).

		ELGA *(n =20)*	FT *(n =20)*	Mann–Whitney		
		M (SD)	*M (SD)*	*U*	*p*	*r*
Gestures	Requesting/Reaching	6.23 (6.79)	2.50 (1.90)	149	.167	.22
	Pointing	2.12 (3.98)	2.97 (3.74)	133.5	.070	.29
	Showing	1.54 (1.79)	1.38 (2.15)	173.5	.464	.12
	Giving	.26 (.70)	1.52 (2.44)	104	**.004**	.46
	Conventional	.52 (1.10)	1.12 (1.64)	162	.272	.17
	Representational	.28 (.69)	1.59 (2.41)	117.5	**.015**	.39
				Chi-Square		
		n (%)	*n (%)*	χ^2	*p*	*phi*
Gestures	Requesting/Reaching	18 (90%)	18 (90%)	–	1.000^	–
	Pointing	12 (60%)	18 (90%)	4.80	**.028**	.35
	Showing	14 (70%)	12 (60%)	.44	.507	.11
	Giving	4 (20%)	13 (65%)	8.29	**.004**	.46
	Conventional	9 (45%)	11 (55%)	.40	.527	.10
	Representational	6 (30%)	12 (60%)	3.64	.057	.30

Significant results are in bold.
^ Fisher exact test.

ELGA infants produced pointing (60%) and giving (20%) gestures with respect to the FT infants (pointing: 90%; giving: 65%; see Table 1).

Vocal utterances. Mean rates per 10 min of vocal utterances are presented in Table 2. As it is apparent, both ELGA and FT infants mainly produced vocalizations, followed by babbling (see Table 2).

No significant difference was found between the ELGA and FT infants in the rates of production of vocal utterances from each of the categories investigated (see Table 2). However, Chi-square test revealed that a significantly lower percentage of the ELGA infants (35%) produced words relative to the FT infants (70%) (see Table 2).

Communicative coordinations. The mean rates per 10 min of communicative coordinations are presented in Table 3. In both groups, the most frequently produced communicative coordination type was vocalization/babbling combined with gesture and/or gaze directed/shifted to the mother (see Table 3). There were no significant group differences in the rate or presence of communicative coordinations.

3.2. Motor, cognitive, and language skills and relationships between gestures, motor and cognitive skills

Descriptive data from the motor, cognitive and language BSID-III scales and statistical comparisons using ANOVAs are presented in Table 4.

Relative to their FT peers, the ELGA infants obtained significantly lower composite motor scores (see Table 4). Analysis of the sub-tests scaled scores revealed that both fine and gross motor scores were significantly lower for ELGA infants compared to FT infants (see Table 4). Scores on the cognitive scale also differed significantly, with the ELGA infants

Table 2
Comparisons between ELGA and FT groups of the rate per 10 min of vocal utterances (Mann–Whitney test) and of the number of infants producing vocal utterances (Chi-Square test) at 12 months (corrected age for ELGA infants).

		ELGA *(n =20)*	FT *(n =20)*	Mann–Whitney		
		M (SD)	*M (SD)*	*U*	*p*	*r*
Vocal utterances	Vocalization	12.58 (8.10)	14.72 (11.61)	185	.685	.01
	Babbling	4.52 (4.61)	6.66 (6.64)	155	.223	.19
	Word	.99 (2.74)	1.10 (2.12)	138	.076	.28
				Chi-Square		
		n (%)	*n (%)*	χ^2	*p*	*phi*
Vocal utterances	Vocalization	20 (100%)	19 (95%)	–	1.000^	–
	Babbling	17 (85%)	20 (100%)	–	.231^	–
	Word	7 (35%)	14 (70%)	4.91	**.027**	.35

Significant results are in bold.
^ Fisher exact test.

Table 3
Comparisons between ELGA and FT groups of the rate per 10 min of communicative coordinations (Mann–Whitney test) and of the number of infants producing communicative coordinations (Chi-Square test) at 12 months (corrected age for ELGA infants).

		ELGA *(n =20)*	FT *(n =20)*	Mann–Whitney		
		M (SD)	*M (SD)*	*U*	*p*	*r*
Communicative Coordinations	Gesture + gaze	3.02 (2.30)	2.51 (3.04)	153.5	.208	.20
	Vocalization/babbling + gaze and/or gesture	5.19 (4.08)	6.28 (5.92)	194.5	.882	.02
	Word + gaze and/or gesture	.38 (1.51)	.60 (1.22)	148	.074	.28
				Chi-Square		
		n (%)	*n (%)*	χ^2	*p*	*phi*
Communicative Coordinations	Gesture + gaze	19 (95%)	16 (80%)	–	.342^	–
	Vocalization/babbling + gaze and/or gesture	20 (100%)	19 (95%)	–	1.000^	–
	Word + gaze and/or gesture	3 (15%)	8 (40%)	3.14	.077	.28

^ Fisher exact test.

performing more poorly than their FT peers (see Table 4). However, no significant differences were found between the two groups on the language scale and the receptive and expressive subtests.

Examination of the number of infants who exhibited delays (defined as <-1.5 *SD* below the mean) on the BSID revealed that among the ELGA infants, 4 (20%) had a motor delay (among them one had also a language delay) and one (5%) had a cognitive delay; among the FT infants, one (5%) had a motor delay. However, these differences were not statistically reliable. A descriptive examination of the communicative behaviors of the ELGA infants with motor or cognitive delay indicated that they did not produce any of the following communicative behaviors: pointing, giving, representational gestures, or words.

Finally, correlations between gestures, motor, and cognitive skills are presented in Table 5. There were significant associations between fine motor scaled scores and pointing and representational gestures in the ELGA group, and between fine motor scaled scores and giving in the FT group (see Table 5). No significant correlations between gross motor scaled scores and gestures were found for either group, except for an isolated negative correlation with conventional gestures in the FT group. Significant associations were also found between the composite cognitive score and representational gestures in the ELGA group, and between the cognitive composite score and conventional gestures in the FT group (see Table 5).

4. Discussion

This study shows for the first time, via the use of detailed coding schemes and a clinical tool, a slower development of gestures and words as well as of motor and cognitive development in ELGA infants at 12 months of corrected age. This slower communicative development was mainly associated with slower motor development.

4.1. Differences in communicative behaviors between ELGA and FT infants

The first major finding of this study was that the gesture development of ELGA infants was less advanced than that of FT infants. This is consistent with evidence suggesting a weakness in gesture production, as indicated by some studies conducted on VLGA infants at 12 months using the MB-CDI (Ortiz-Mantilla et al., 2008; Sansavini, Guarini et al., 2011; Stolt et al., 2014). The novel contribution of the present study is the detailed description of the typology and frequency of gestures spontaneously produced by ELGA relative to FT infants. Specifically, deictic gestures that involve sharing an object/interest with a partner, were produced significantly less often by ELGA relative to FT infants. This was the case for the giving gesture,

Table 4
Comparisons between ELGA and FT groups on the BSID-III motor, cognitive and language composite and scaled scores with the ANOVA at 12 months (corrected age for ELGA infants).

	ELGA (n = 20)	*FT (n = 20)*	ANOVA		
	M (SD)	*M (SD)*	*F*	*p*	ηp^2
Motor composite score	87.95 (13.24)	100.30 (11.47)	9.94	**.003**	.207
Fine motor scaled score	9.15 (1.81)	11.40 (2.19)	12.54	**.001**	.248
Gross motor scaled score	6.80 (3.46)	8.75 (2.49)	4.19	**.048**	.099
Cognitive composite score	94.50 (11.46)	104.75 (10.70)	8.55	**.006**	.184
Language composite score	97.10 (12.76)	103.55 (12.32)	2.64	.112	.065
Receptive scaled score	9.35 (2.66)	10.85 (2.92)	2.88	.098	.070
Expressive scaled score	9.60 (2.48)	10.40 (2.14)	1.19	.281	.030

Significant results are in bold.

Table 5
Spearman's correlation coefficients between gestures and BDIS-III fine and gross motor scaled scores and cognitive composite score in ELGA and FT groups, at 12 months (corrected age for ELGA infants).

		ELGA (n = 20)									*FT (n = 20)*								
		Fine motor (scaled score)			Gross motor (scaled score)			Cognitive (composite score)			Fine motor (scaled score)			Gross motor (scaled score)			Cognitive (composite score)		
		rs	*p*	rs^2	*rs*	*p*	rs^2	*rs*	*p*	rs^2	*rs*	*p*	rs^2	*rs*	*p*	rs^2	*rs*	*p*	rs^2
Gesture	Requesting	−.039	.871	.002	.093	.697	.009	−.134	.574	.018	−.045	.851	.002	−.114	.631	.013	−.328	.158	.108
	Pointing	**.631**	**.003**	.398	.398	.082	.158	.423	.063	.179	.064	.787	.004	−.200	.397	.040	.147	.535	.022
	Showing	−.034	.886	.001	.218	.356	.047	−.089	.709	.008	.089	.710	.008	−.089	.709	.008	−.167	.481	.028
	Giving	.362	.117	.131	.073	.758	.005	.015	.949	.000	**.446**	**.049**	.199	.359	.120	.129	.187	.431	.035
	Conventional	−.357	.122	.127	−.173	.446	.030	−.347	.134	.120	.290	.215	.084	−**.473**	**.035**	.224	**.624**	**.003**	.389
	Representational	**.623**	**.003**	.388	.234	.320	.055	**.446**	**.049**	.199	.090	.705	.008	−.149	.531	.022	.333	.151	.111

Significant results are in bold.

which was less frequent in ELGA infants than in FT infants, and for the pointing gesture, which was present in a significantly lower percentage of ELGA infants. These findings support our hypothesis of a delay at 12 months in ELGA infants in the onset of these important gestural precursors of language development (Bavin et al., 2008; Capirci & Volterra, 2008; Iverson & Goldin-Meadow, 2005), which in TD infants begin to appear at around 9–10 months of age (Caselli et al., 2012; Lock, Young, Service, & Chandler, 1990; Sansavini, Bello et al., 2010). Representational gestures, which constitute a means for the transition to the use of symbolic communication (Capirci & Volterra, 2008) were also less frequently produced in the ELGA than in the FT group, suggesting that ELGA infants are just beginning meaning construction and sharing at 12 months. A lesser use of representational gestures was also found in a recent study employing a predicate production task which showed that at 24 months ELGA children, differently from FT peers, seldom use representational gestures to express meaning, for predicates which they do not master yet (Sansavini, Bello et al., 2015).

With regard to vocal production, our hypothesis was only partially confirmed. In line with other studies in the literature that did not find differences between preterm and FT infants in the first year of life in vocalization and babbling production (Stolt et al., 2012) and in word production (D'Odorico et al., 2011; Sansavini, Guarini, et al., 20011), we did not find differences between the two groups in the frequency of vocalization, babbling, or words at 12 months of age. As Oller, Eilers, Steffens, Lynch, and Urbano (1994) suggest, interpretation of these findings might depend on the recognition that ELGA infants, examined at their corrected age, have a longer environmental experience than FT infants. Although no differences between the two groups emerged in the frequency of vocal behaviors, in the case of words we found that, relative to FT infants, a significantly lower percentage of ELGA infants produced words at 12 months. Given that, in typical development, the onset of first words at around 12 months of life is a positive prognostic sign for language development (Reilly et al., 2009; Sansavini, Bello et al., 2010) we hypothesize that the delay found in a majority of the ELGA infants in the onset of words may index in a subsequent language delay.

Finally, this research examined communicative coordinations of gesture and gaze, vocalization/babbling and gaze or gesture, words and gaze or gesture at 12 months for the first time in the ELGA population. From our results it appears that at this age, the ELGA and FT infants do not differ in these types of behaviors. This may be the result of the young age of the infants observed in our study. Thus, the question of whether a delay in the spontaneous communicative coordinations in ELGA infants is observable as early as 12 months remains open. Future research is needed to examine communicative coordination production in ELGA infants at later ages.

4.2. Relationship between gestures and motor skills in ELGA infants

With regard to the second aim of the present study, the ELGA infants in our group lagged significantly behind their FT peers in both gross and fine motor skills. This result is in line with the few studies that have recently started to investigate the motor abilities of ELGA preterm infants during the first years of life (Sansavini, Savini et al., 2011; Sansavini et al., 2014), and thus contributes to this emerging research landscape. Furthermore, 20% of the ELGA group exhibited a motor delay, while only 5% presented a cognitive or linguistic delay, suggesting that the motor domain may be most affected by an extremely preterm birth at this age. Nevertheless, less advanced development was also observed in ELGA infants in cognitive skills, but not in linguistic skills as assessed on the BSID-III. These findings suggest that at 12 months corrected age, ELGA infants show apparent difficulties, relative to FT infants, in motor exploration, knowledge, and representation of the world. Although linguistic difficulties were not detectable at this age with a clinical tool assessing receptive and expressive language, they were apparent in the analysis of spontaneous communicative behavior, indicating the importance of integrating clinical tools with observational coding schemes.

A particularly novel and interesting finding from this study has to do with the relationships between fine motor skills and gestures observed in both groups. This result is consistent with a growing body of work indicating that the motor and language domains are closely linked in the brain, particularly in their early developmental stages (Iverson & Thelen, 1999; McNeill, 2005; Zukow-Goldring, 2005). Neurophysiologic evidence on the functioning of the motor system (Arbib, 2005;

Rizzolatti & Arbib, 1998) supports the hypothesis of a tight link between motor programs associated with actions, gestures, and spoken linguistic representations (Bernardis & Gentilucci, 2006; Capirci, Caselli, & De Angelis, 2010). Concerning these relationships, some differences were found between the two groups. In the ELGA group, fine motor scores were positively correlated with pointing and representational gestures, while in the FT group, an association between giving and fine motor skills was found. The associations found in the ELGA group highlight the critical role of fine motor skills for the development of pointing, which is one of the primary early indices of language delay (Bavin et al., 2008; Caselli et al., 2012; Reilly et al., 2009; Sansavini, Guarini et al., 2011; Stolt et al., 2014), and of representational gestures, which are the expression of the transition from action to language (Capirci & Volterra, 2008; Capone, 2007). An association between cognitive skills and representational gestures was also found in ELGA infants, highlighting the interaction between motor, cognitive, and communicative skills in the ELGA infants that has also been observed in other populations with atypical development (Leonard & Hill, 2014). This finding brings evidence in favor of the hypothesis that associations among domains may be more evident in populations with developmental delays (Karmiloff-Smith, 2009). As some authors suggest (Bhat et al., 2012; Gernsbacher, Sauer, Geye, Schweigert, & Goldsmith, 2008; Iverson, 2010), slowed or uncoordinated arm, facial, and articulation movements may limit effective head turning, use of gestures, and vocal utterances. Interestingly, the ELGA infants who exhibited a motor or cognitive delay did not produce pointing, giving, representational gestures or first words.

In the light of these findings, we propose that a developmentally important linkage exists between motor, cognitive, and communication delays in ELGA infants. During early development, it is possible that a relatively small disruption in one of the interacting systems (i.e., the motor system) could have negative escalating effects on other systems related to motor development, such as the language domain (Iverson, 2010; Libertus & Needham, 2011).

4.3. Limitations

Limitations of this work should be noted. First, data from this study are limited to a single age point. There is a need for longitudinal studies aimed at understanding the extent to which gesture and word production abilities contribute to the prediction of language outcomes and provide useful information regarding their value as indices of risk for future language delays in the ELGA population. Moreover, longitudinal studies with several points of assessment permit the identification of differences in the developmental trajectories of ELGA and FT infants (Sansavini et al., 2014; Thomas et al., 2009). As noted above, it is possible that group differences in communicative coordinations were not detected due to the young age of the infants in the study. Thus, subsequent points of assessment are needed to better understand the development of this type of behavior in ELGA infants. The present study, being part of a larger longitudinal study, is a step in this direction.

Second, the sample size utilized in the present study was small, since it was focused on "healthy" ELGA infants. The generalizability of our findings should be carefully considered. The limited sample size may have impacted the ability to detect some differences in communicative behaviors between ELGA and FT infants. Despite the sample size issue, group differences were detected for some communicative behaviors and for motor and cognitive skills. It is possible that group differences for other variables were not detected due to the limited sample size. Replication of the present findings with larger samples is clearly needed in the future.

Third, the present work did not consider the role of the language environment and linguistic input, such as caregivers' responses to infants' communication. From extensive research on mother-infant communicative interaction, it is known that parents who respond to the infant's focus of attention and communicative productions can promote infant's language acquisition (Goldin-Meadow et al., 2007; Tamis-LeMonda et al., 2001; Tomasello et al., 2007). As shown by a recent study (Sansavini, Zavagli et al., 2015), ELGA mother–infant dyads, at 12 months corrected age, have difficulties in sharing symmetric co-regulation, and this was closely related to the infants' level of motor development. A future step would be to examine caregiver responses and their supportive role in fostering the communicative and motor skills examined in this paper.

Fourth, although this study has contributed to our understanding of the relationship among gestures and motor skills in ELGA infants, it did not include a description of the specific types of fine motor behaviors characterizing the two groups. This could be achieved in future research by conducting studies assessing the relative contributions of different types of fine motor skills (e.g., types of object grasping and manipulation, functional hand skills, and eye-hand coordination) to communicative-linguistic development in ELGA infants, by using, besides broad developmental assessment tools, specific motor assessments such as the Alberta Infant Motor Scales (Piper & Darrah, 1994), observational motor coding schemes, and experimental techniques employing sensor-based technology.

5. Conclusion and clinical implications

Our findings highlight a weakness in the development of early communicative behaviors and motor and cognitive skills in ELGA infants and a close relationship between the motor and communicative domains. Clinical assessment of ELGA infants must address early spontaneous communication abilities, in particular gestures and early word production, during naturalistic play interactions. Observation of spontaneous communication should be incorporated into clinical assessment and practice because it seems more effective in detecting early communicative delays in preterm infants at 12 months than clinical tools such as the BSID-III. Our findings also show the value of examining early development in the motor domain. Screening projects, in which infants performing below average on motor development can be identified and followed longitudinally, may increase our understanding of the relationships between motor skills and other domains and help detect infants at risk for neurodevelopmental disorders (Leonard & Hill, 2014).

The accurate identification of communicative and motor delays in the first year of life is an ongoing challenge for ensuring the provision of effective and developmentally appropriate early intervention services to ELGA infants and their families (Lobo & Galloway, 2013). Effectiveness of early interventions may be enhanced by the high degree of cerebral plasticity in the infant's brain, that is the capacity to respond in a dynamic manner to the environment and experience through the modification of neural circuitry (Anderson, Spencer-Smith, & Wood, 2011). More research is needed on the environmental factors that can promote recovery processes and on the efficacy of interventions designed to improve early communicative-linguistic and motor abilities by expanding traditional intervention contexts to include naturalistic interaction with familiar caregivers.

Conflict of interest

The authors of this article have not reported any financial or non-financial conflict of interest.

Authors' contribution

Conceived and designed the study: AS EB JMI MCC. Collected the data: SS RA. Coded the data: EB SS. Analyzed the data: EB AG SS AS. Wrote the paper: EB AS AG SS. Critically revised the paper: AS JMI MCC AG SS. Critically revised the medical parts of the paper: GF RA.

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