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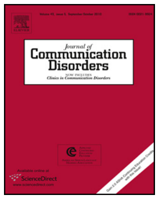

Language, motor and cognitive development of extremely preterm children: Modeling individual growth trajectories over the first three years of life

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ABSTRACT

Survival rate of extremely low gestational age (ELGA) newborns has increased over 80% in the last 15 years, but its consequences on the short- and longer-term developmental competencies may be severe. The aim of this study was to describe growth trajectories of linguistic, motor and cognitive skills among ELGA children, compared to full-term (FT) peers, from the first to the third year of life, a crucial period for development. Growth curve analysis was used to examine individual and group differences in terms of initial status at 12 months and rate of growth through the second and the third year of life with five points of assessment. Twenty-eight monolingual Italian children, of whom 17 were ELGA (mean GA 25.7 weeks) and 11 were FT children, were assessed through the BSID-III at 12, 18, 24, 30 and 36 months for language skills and at 12, 24 and 30 months for motor and cognitive skills. ELGA children presented significantly lower scores than FT peers in language, motor and cognitive skills and they did not overcome their disadvantage by 3 years, even if their corrected age was taken into account. Concerning growth curves, in motor development a significant increasing divergence was found showing a Matthew effect with the preterm sample falling further behind the FT sample. In linguistic and cognitive development, instead, a stable gap between the two samples was found. In addition, great inter-individual differences in rate of change were observed for language development in both samples. Our findings highlight the theoretical and clinical relevance of analyzing, through growth curve analyses, the developmental trajectories of ELGA children in language skills taking into account their inter-individual variability also across motor and cognitive domains.

Learning outcomes: After reading this article, the reader will interpret: (a) characteristics and growth trajectories of ELGA children from the first to the third year of life with respect to FT children in language, motor and cognitive development; (b) the method of growth curve analyses to describe group as well as inter-individual trajectories; (c) the rate of inter-individual variability in language as well as motor and cognitive skills, which gives useful indications for early interventions.

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1. Introduction

Rate of preterm birth, defined by the World Health Organization as a birth that occurs before 37 weeks of gestational age (GA), is about 10–12% in the United States and in Africa, and about 5–9% in Europe and other developed countries (Beck et al., 2010). GA is often used to stratify typologies of preterm children with late (34–36 weeks GA, 60%) and moderate preterm birth (32–33 weeks GA, 20%) being more common, while very preterm (28–31 weeks GA, 15%) and extremely preterm (<28 weeks GA, 5%) representing about one of five preterm births (Goldenberg, Culhane, Iams, & Romero, 2008). Recent results from a multi-site consortium conducting in-depth assessments of the physical and developmental consequences of preterm birth support the notion that GA conveys important information about developmentally regulated changes in the developing fetus (e.g., O'Shea et al., 2009). In particular, for extremely low gestational age (ELGA) newborns, whose survival rate has increased to about 80% in the last 15 years thanks to technological and pharmacological advances, the consequences of their extreme neonatal immaturity on the short- and longer-term developmental competencies are more severe than those observed among children born at later gestational ages (Johnson, Wolke, Hennessy, & Marlow, 2011; Marlow, Wolke, Bracewell, Samara, & EPICure Study Group, 2005; Sansavini, Guarini, & Caselli, 2011). Improving our understanding about the early growth trajectories of language, motor and cognitive development among ELGA children was the principal goal of the present study.

1.1. Early cognitive development among preterm children

Meta-analyses and systematic reviews have shown that preterm children exhibit developmental differences in relation to full-term (FT) peers in general intellect (difference of about 10 standard IQ points; Bhutta, Cleves, Casey, Cradock, & Anand, 2002) and learning abilities (Aarnoudse-Moens, Weisglas-Kuperus, van Goudoever, & Oosterlaan, 2009) over the years of childhood and adolescence on a range of competencies, but also that there are individual differences among preterm children in these competencies. One reason is linked to the level of neonatal immaturity in terms of GA. In fact, differences between preterm and FT children in general cognitive abilities are most pronounced for ELGA (Marlow et al., 2005; Sansavini, Guarini, & Caselli, 2011), less severe for very preterm children (Larroque et al., 2008) and more attenuated for moderate to late preterm children (De Jong, Verhoeven, & van Baar, 2012). For instance, Sansavini, Savini, et al. (2011) described performance of 29 ELGA children at 2 years on a general norm-referenced index of development. They showed a more substantial range in scores (50–131 standard score points), with a standard deviation of 16 points, than that of very low gestational age (VLGA; 29–32 weeks; range in scores: 77–115, *SD* = 8.6) and FT children (GA > 37 weeks; range in scores: 98–116, *SD* = 5.4). Such data indicate the potential need to improve our understanding of individual differences among ELGA children in their development over time.

There have been some efforts to advance understanding of individual differences within groups of preterm children rather than focusing solely on mean differences in competencies as compared to FT peers or among the various typologies of preterm birth (e.g., ELGA vs. VLGA children). In fact, outcomes of preterm children are very heterogeneous because of the complex interaction among biological and environmental constraints characterizing preterm children and the timing in which these constraints occur (Sansavini, Guarini, & Caselli, 2011). Some studies have described the percentage of ELGA children who have significant physical and developmental disabilities (Hack & Fanaroff, 1999; O'Shea et al., 2012) and the characteristics of children and families associated with presence of disabilities, but knowledge on ELGAs' developmental trajectories taking into account individual differences is still lacking.

1.2. Early linguistic development among preterm children

A reasonable body of work has examined the developmental achievements (and risk thereto) of very preterm children through the preschool years (e.g., Sansavini et al., 2010), into kindergarten (e.g., Guarini et al., 2009), primary grades (e.g., Guarini et al., 2010) and adolescence (e.g., Luu, Vohr, Allan, Schneider, & Ment, 2011), showing that one of the more commonly affected domains is communication and language (for reviews, see Sansavini, Guarini, & Caselli, 2011). As revealed by a recent meta-analysis (Barre, Morgan, Doyle, & Anderson, 2011), scores in receptive and expressive lexicon and receptive grammar of very preterm children, analyzed through linguistic standardized tests and parental questionnaires at preschool and school age, lie between 0.38 and 0.77 *SD* below those of control samples. Sansavini et al. (2010) examined the rate of language impairment (LI) among very preterm children (mean GA 30 $\pm$ 2 weeks) finding that about one-third of these children could be characterized as LI at 3.5 years. The predominant predictor of LI was prior history of communicative and linguistic skills as reported at 2.5 years. Such work helps us recognize that there are specific subgroups of preterm children who are most vulnerable for ongoing developmental difficulties and research on their early linguistic acquisition is needed.

In the first two years of life, even by considering corrected age, very preterm children show lower scores than FT children on measures of vocabulary (D'Odorico, Fasolo, Majorano, Salerni, & Suttora, 2011; Ortiz-Mantilla, Choudhury, Leevers, & Benasich, 2008; Sansavini, Guarini, Savini, Broccoli et al., 2011; Stolt et al., 2009). Stolt et al. (2009) followed 32 very low birthweight (VLBW) Finnish preterm children (mean GA 28 $\pm$ 2 weeks), comparing their vocabulary growth to 35 FT peers using the MacArthur-Bates CDI (MB-CDI) long form. The receptive lexicon sizes from 9 to 15 months of the FT children were estimated to be 1.7 times larger than those of preterm ones. Expressive vocabulary was similar between the two samples from 9 to 18 months; by 24 months, however, FT children knew significantly more words than preterm peers, suggesting that differences in expressive language between preterm and FT children become evident around the end of the second year.

Findings reported by Sansavini, Guarini, Savini, Broccoli et al. (2011) for 104 Italian very preterm children (mean GA 29 ± 2 weeks) without neurological deficits as compared to 20 FT peers added new considerations for receptive vocabulary, gesture/action production and expressive vocabulary by employing the MacArthur-Bates CDI short form. Development over time was characterized by a significant increasing divergence which may be referred to as a Matthew Effect, similarly to that observed in children impaired in the reading domain (Stanovich, 1986). This consists in a gap-widening effect in trajectories over time based on initial skill levels, with the more skilled children (in this study the FT ones) growing more rapidly over time than the less skilled children (in this study the very preterm ones). This effect was evident in receptive vocabulary and gesture/action production from 12 to 18 months and in expressive vocabulary from 18 to 24 months. Such findings endorse the perspective of many developmental researchers who argue that the most optimal way to understand developmental disorders is by using trajectory-based studies that assess the way in which phenotypes emerge gradually over time and in transformative ways with age (Thomas et al., 2009).

Ortiz-Mantilla et al. (2008) found as well in 32 VLBW North-American children compared to 32 FT mates a lower repertoire of gestures between 12 and 16 months, and lower scores in expressive and receptive vocabulary from 3 to 7 years. Lower cognitive scores were also found in the above study at the Bayley Scales (BSID-II) with differences becoming larger from 6 to 24 months between the two groups, mostly due to the non linguistic items of the BSID-II. These findings highlight how non verbal aspects of development appear more compromised than verbal ones in the first two years of life and support the hypothesis that differences in language abilities maybe part of a global cognitive deficit.

The studies referenced above focused largely on very preterm children, while studies specifically on ELGA children are scarce. Two studies, run respectively in France and New Zealand with the MacArthur-Bates CDI long form, revealed that lexical production at 2 years corrected age of ELGA children (included those with brain damage), was significantly lower than that of VLGA and FT children (Foster-Cohen, Edgin, Champion, & Woodward, 2007; Kern & Gayraud, 2007). A recent study on extremely low birthweight (ELBW) children, free of major neurological impairment, revealed difficulties in lexical comprehension and lexical and morphosyntactic production at 3 years, partly explained by a decreased general mental functioning (VanLierde, Roeyers, Boerjan, & De Groote, 2009). Longitudinal investigation on early communicative-linguistic abilities on ELGA children, who are at major risk for subsequent LI, is thus needed.

1.3. Early motor development among preterm children

Some of the difficulties found in language and academic achievements of preterm children seem to be mediated by general cognitive functions (Ortiz-Mantilla et al., 2008; Rose, Feldman, & Jankowski, 2009; Van Lierde et al., 2009), but they may also be related to some aspect of motor and visual development (Sansavini, Guarini, & Caselli, 2011). The motor domain appears particularly vulnerable by preterm birth. Motor patterns of preterm children are affected by biological factors, such as interruption of normal brain maturation in utero, and environmental factors, such as postural constraints at the NICU. In fact, a recent meta-analysis (De Kieviet, Piek, Aarnoudse-Moens, & Oosterlaan, 2009) on studies on preterm children's motor development from infancy to adolescence has shown that very preterm children are on average −0.57 to −0.88 *SD* behind their FT peers. While a catch-up of motor milestones (measured by the Bayley Scales BSID-II) has been found in very preterm children between the second and the third year, motor problems in advanced fine and gross motor skills are evident until adolescence. Lower gestational age and birth weight appear strongly related to poorer motor outcomes particularly in the first years of life (De Kieviet et al., 2009) and specific motor deficits persist in ELGA children without cerebral palsy at 6 years with respect to classmates, even after controlling for overall cognitive scores, becoming more evident with environmental demanding requests (Marlow, Hennessy, Bracewell, & Wolke, 2007). In fact, a recent longitudinal study showed that the developmental trajectories of ELGA children with respect to those of VLGA and FT children were increasingly diverging with a Matthew Effect from 6 to 24 months both in global cognitive development and in motor, visuo-motor and performance cognitive abilities (Sansavini, Savini et al., 2011). These results suggest that the developmental trajectories of ELGA children should be carefully analyzed in several specific domains, besides global cognitive development, from the first years of life. A few studies have found delays in the acquisition of motor milestones in very preterm children (Jeng et al., 2008; Van Haastert, de Vries, Helders, & Jongmans, 2006) in the first years of life, but research on ELGA children taking into account motor, cognitive and communicative-linguistic development is needed.

1.4. Modeling trajectories in early development

The key to understanding the consequences of a preterm birth must involve studying how children grow and change with time (Karmiloff-Smith, 1998). The way in which prematurity affects the developing child is likely to change over the course of development: for instance, impairments of basic information processing abilities observed in the first year of life may have cascade effects on later more complex cognitive and linguistic abilities (Rose, Feldman, & Jankowski, 2011). In the present paper, we focus specifically on understanding individual growth trajectories in language, motor, and cognitive abilities from the first to third year of life in ELGA children. By modeling the individual growth trajectories of ELGAs relative to FT peers, rather than comparing means of the two groups at specific time points, we are able to consider whether developmental trajectories in specific competencies differ between and within the two groups.

Historically, the primary tradition for examining longitudinal data has relied on repeated-measures design featuring univariate or multivariate analyses of variance (O'Connell & McCoach, 2004). There are limitations to these general linear models, however, including the requirement that time be a fixed effect and the assumption of sphericity (O'Connell & McCoach, 2004, for elaboration of these requirements as well as others). Multilevel modeling of longitudinal data over time, in which assessment points are nested within individuals, is a more flexible approach to examining development; it allows one to examine the nature of growth among individuals (including examination of individual differences within a group) as well as variables that may be associated with growth. As O'Connell and McCoach (2004) point out, the value in modeling growth in this way is that one can examine "variations in the patterns of individual change... as represented by individual growth curves" (p. 129). There are two parameters of interest with respect to these individual growth curves: the intercept (the estimate for baseline performance) and the slope (the rate and nature of change over time). This more person-centered approach can be informative for modeling differences in growth between groups, such as FT and preterm children, as well as within a group, consistent with an individual differences perspective.

In examining the early trajectories of ELGA children in language, motor, and cognitive development and their comparison with a sample of FT peers, it is useful to consider in advance several possible outcomes of interest (Logan & Petscher, 2010). First, ELGA and FT children may show no difference in initial status (intercept) or growth over time, indicating that developmental trajectories are similar across the two groups and not affected by an extreme prematurity. Second, the ELGA and FT children may differ in initial status but not on slope, such that the two groups would differ at the ending time point only so much as they differed at the initial time point. Such a finding would suggest that extreme prematurity presents an initial disadvantage in language, motor, and cognitive skills but that growth in these skills over time is similar to that of FT mates. Third, the ELGA and FT children may differ only in slope, with two different possibilities of the nature of their growth over time. One possibility is that ELGA children grow more quickly than FT peers, thus implying that ELGAs show a compensatory trajectory of development (Parrila, Aunola, Leskinen, Nurmi, & Kirby, 2005). The other possibility is that the ELGAs grow more slowly than FT peers, indicating that they exhibit a Matthew Effect in their early development, falling further behind that of FT children. Matthew Effects have been observed among other at-risk groups (children with language disorders) in the later growth trajectories (Morgan, Farkas, & Wu, 2011). Fourth, it is also possible that the two groups may differ in both intercept and in slope. Interpretation of growth trajectories along these lines is helpful for understanding whether ELGA children develop in a way that is delayed or atypical relative to other children.

1.5. Aims and contributions of this research

The aim of this study was to characterize the individual growth trajectories of linguistic, motor and cognitive skills among ELGA children, compared to FT peers, from the first to the third year of life when receptive and expressive language start to emerge. Growth curve analysis was used to examine differences within individuals belonging to two samples (ELGA vs. FT) in terms of initial status (skills across the above competencies at the initial assessment point, 12 months) and rate of growth through the third year of life. We aimed to assess whether the growth of ELGA in relation to FT children would be characteristic of a Matthew Effect, that is, an increasing divergence over time between the two groups, as it has been suggested in a few prior papers employing traditional analyses of variance (Ortiz-Mantilla et al., 2008; Sansavini, Guarini, Savini, Broccoli et al., 2011; Sansavini, Savini et al., 2011). An important contribution of this work is that it yields a more accurate estimate of the nature of growth as compared to other more commonly employed methods in the preterm developmental literature. Moreover, it is the first paper of which we are aware to have modeled growth over time specifically for ELGA children.

2. Methods

2.1. Participants

Twenty-eight monolingual Italian children living in the Emilia-Romagna Region of Italy were enrolled for this study. Seventeen children (10 female, 7 male) were ELGA, born from 2007 to 2008 at the Neonatal Intensive Care Unit (NICU) of the University of Bologna, which is a tertiary care level unit equipped with assisted ventilation. The ELGA children were recruited into the study if, at birth, they had 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 when its employment was indicated by the US outcome [i.e., periventricular leukomalacia (PVL), intra-ventricular hemorrhage (IVH) > II grade, hydrocephalus,] and/or congenital malformations, and (c) no indication of visual [retinopathy of prematurity (ROP) > II grade] or hearing impairment. For the present study, children whose families did not speak Italian as their primary home language were not included, as bilingualism has been associated with slower cognitive and communicative-linguistic development in preterm children during the first two years of life (Walch, Chaudhary, Herold, & Obladen, 2009). The mean GA of the ELGA children was 25.7 weeks (SD = 1.4; range = 23–28) and their mean BW 800 grams (SD = 196; range = 509–1093). Although children with major cerebral damage or malformations were excluded from enrolment in the study, those recruited did have some medical complications; these included small for gestational age (SGA, n = 2, 12%), respiratory distress syndrome needing mechanical ventilation (RDS, n = 17, 100%), bronchopulmonary dysplasia (BPD, n = 10, 59%, defined as need of supplemental oxygen at 36 weeks of postconceptional age), IVH of grade I or II (n = 1, 6%) detected by US, ROP of grade I or II (n = 12, 71%), and hyperbilirubinemia treated with phototherapy (n = 13, 76%). In addition, 14 (82%) ELGA children had had persistent hyperechogenicity (HE) of white matter (≥14 days) as indicated by US; however, none of these children had developed PVL because, in all instances, the HE had been completely resolved at 3 months. Mean hospitalization length was 93 days (*SD* = 34; range = 49–152). Twelve (71%) were first-born and 5 (29%) second or later born. The sample of ELGA group is best described as distributed across the general range of socioeconomic status (SES) strata, estimated from parental highest level of educational attainment: 10 (59%) mothers and 13 (77%) fathers had a middle/low educational level (completed high school or at least basic education) and 7 (41%) mothers and 4 (23%) fathers had a high educational level (completed University/Master's degree). The mean age of mothers was 36.1 years (*SD* = 4.8; range = 27–44) that of fathers 36.5 years (*SD* = 6.2; range = 27–46).

The FT comparison group consisted of 11 monolingual Italian healthy at-term children (5 female, 6 male), who had experienced normal birth (GA ≥ 38 weeks and BW ≥ 2500 g), had no history of major cerebral damage and/or congenital malformations, or visual or hearing impairments. The FT children had a mean GA of 39.2 weeks (*SD* = 0.9; range = 38–41) and a mean BW of 3379 grams (*SD* = 429; range = 2500–4120 g). Mean hospitalization length was 2.4 days (*SD* = 0.7; range = 2–4). Nine (82%) were first-born and 2 (18%) second or later born. As with the ELGA group, these infant's background was distributed across SES, based on parents' highest level of education: 6 (55%) mothers and 5 (45%) fathers had a middle/low educational level and 5 (45%) mothers and 6 (55%) fathers had a high educational level. The mean age of mothers was 34.6 (*SD* = 3.5; range = 30–41), that of fathers 36.5 (*SD* = 3.6; range = 30–44). The ELGA children did not differ from the FT peers in terms of gender, birth order, maternal and paternal level of education, as shown by the Fischer exact test, nor in terms of maternal and paternal age, as shown by the independent sample *t*-test.

2.2. Procedure

The study used a longitudinal design (see Table 1), with children ascertained into the study following birth.

All ELGA and FT children were recruited at the Unit of Neonatology of Bologna University respectively the week before their discharge for the ELGA children and within a week from their birth for the FT peers. During the first contact with the parents, the purpose of the study was explained. Information concerning the state of physical health of the children was obtained by personal clinical folder and the educational and social background of the families was obtained during a parent interview. The study met ethical guidelines for human subjects protections, including adherence to the legal requirements of the study country, and received a formal approval by the Research Ethical Committee of the Department of Psychology at the University of Bologna. Moreover, all parents of the ELGA and FT children gave informed written consent for participation to the study, data analysis, and data publication.

All children were followed individually and completed individual assessments in a quiet room of the Day Hospital at the Unit of Neonatology of Bologna at several age points from birth to 36 months of age (corrected for preterm children). For the present study the measures collected at 12, 18, 24, 30 and 36 months were analyzed. Independent samples t-tests on the age of assessment for the children at each time-point revealed that the ELGA and the FT samples did not differ significantly on age of evaluation at any point (corrected age for ELGA children).

2.3. Tools

The Bayley Scales of Infant and Toddler Development, Third Edition (BSID-III, Bayley, 2006) was administered to all children at the following time-points: 12, 18, 24, 30 and 36 months for the Language Scale; 12, 24 and 30 months for the Motor and the Cognitive Scale (see Table 1). Because of infant's illness, at 12 months 2 ELGA children did not perform the BSID-III L, M and C scales and 1 ELGA child did not complete the BSID-III M and C scales; at 18 months 1 ELGA did not perform the L scale.

For language skills, the BSID-III includes two subtests, one assessing Receptive Communication (RC) and the other assessing Expressive Communication (EC). For our purposes, we created a composite raw score to represent Language skills (L) at each time point by summing raw scores on these two subtests RC and EC, justifiable given the strong positive correlation among the measures at the 36-month time-point ($r = .78$, $p < .01$). For motor skills, the BSID-III includes two subtests, one assessing fine motor skills (FM) and the other assessing gross motor skills (GM). For our purposes, we created a composite raw score to represent motor skills (M) at each time point by summing raw scores on these two subtests, justifiable given the moderately strong positive correlation among the measures at the 30-month time-point ($r = .48$,

Table 1
Design, measures and age points of the study.

	Age of evaluation (months)				
	12	18	24	30	36
BSID-III					
Receptive communication	X	X	X	X	X
Expressive communication	X	X	X	X	X
Fine motor skills	X		X	X	
Gross motor skills	X		X	X	
Cognitive skills	X		X	X	

$p < .01$). For cognitive skills (C), the BSID-III includes a cognitive test. The BSID-III has been shown to be a valid tool both in research and in clinical practice; satisfactory reliability and validity are 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 of the BSID-III is available, but the standardization has not been completed yet. For this reason, an Italian FT sample was used as a control.

2.4. Analysis plan

Standard scores were reported for a clinical evaluation of the children in both the ELGA and FT groups. Scores were calculated according to the US normative values, since standardization on the Italian population is not available yet. Note that raw scores were used for analyses in order to describe the growth trajectories of specific skills, as raw scores allow for accurate capture of growth in outcome variables over time. Because standard scores are designed to reflect a child's relative skill level in relation to other children their age (thus providing a normative evaluation of skills), growth will not be reflected in standard scores over time and are therefore not optimal for use in growth curve analysis.

In conducting the growth curve modeling, individual growth curve (IGC) analysis was utilized (Rogosa, 1995). IGC analysis is a continuous process, as it uses all data points available (e.g., three or five depending on outcome in the present study) to represent individual's change over time as a function of both intercept (i.e., level of a trait at any given time) and slope (i.e., rate of change over time; see Francis, Schatschneider, & Carlson, 2000). Furthermore, when using IGC, separate growth curves are estimated for each participant, allowing for examination of individual differences in change as well as change within individuals over time.

Growth curve analysis was conducted using HLM (HLM; Raudenbush & Bryk, 2002) for all models (i.e., language, motor, and cognitive skills). In the HLM program, Level-1 missing data was deleted when running analyses. It must be noted that missing data levels were very low across measures (approximately 3%) and an advantage of growth curve modeling is that it does not require a complete set of data for each child, given that each time point of data is explicitly incorporated into analyses. For the purposes of the present study, time was measured in months. Following the recommendations of Francis et al. (2000) the analyses consisted of two phases: a within-participants (unconditional) phase and a between-participants (conditional) phase.

In the first phase, for each of the three possible outcomes, two alternative sets of linear growth models were assessed to determine the model that best balanced goodness-of-fit and parsimony. The goal of the unconditional phase was to determine the nature of growth and select an appropriate model of children's growth. As an example, for those outcomes for which there were three time points, analyses were limited to linear models, which were represented as

$$Y_{ti} = \pi_{0i} + \pi_{1i}(\text{timept}) + e_{ti}$$

with Y_{ti} representing the dependent variable at any time t for child i with random error e_{ti}; time point representing the month at which the dependent variable was assessed; π_{0i} representing the level of dependent variable for child i at a given time point, and π_{1i} representing the rate of growth for children i at a given time point. The unconditional models were centered at the month during which the first data was collected (i.e., 12 months) and, therefore, represented children's initial scores. The choice of the first time point of data collection as the centering point facilitated interpretability and ensured that the focus was on the main period of interest in the study (Holt, 2008). The first model included a random intercept (i.e., allowed children to vary in the extent of their scores on the relevant measure at the first time point) and a fixed slope (i.e., forced children to change at the same rate). This first model, which represented the simplest growth curve model, was then compared to a less parsimonious model with random intercepts and random slopes (i.e., children were allowed to vary in both intercepts and rate of change). Overall model fit was assessed in the following two ways: (a) through examination of residual plots, and (b) through the −2 log likelihood difference test which is a comparative fit index of goodness-of-fit versus parsimony (Singer & Willett, 2003). The model that best represented the data and was the most parsimonious was selected.

In the second phase, the conditional phase, a set of conditional models was investigated to understand children's growth while controlling for group membership (i.e., ELGA or FT sample). Thus, in this phase the following linear growth models were used:

$$\pi_{oi} = \beta_{oo} + \beta_{01}(\text{group})_1 + r_{0i}$$

$$\pi_{1i} = \beta_{1o} + \ldots \beta_{1z}(\text{group}) + r_{1i}$$

In this linear growth model, children's level (π_{0i}) and growth rate (π_{1i}) are modeled as a function of group membership (β_{01}), plus error ($r_{0\text{i}}$, $r_{1\text{i}}$). The coefficient β_{01} represents the relation of the group membership variable. This variable was explored as a predictor of both the intercept and slope.

Table 2
Descriptive analyses (mean and standard deviation) of BSID-III standard scores for ELGA (n = 17) and FT samples (n = 11).

	12 months $M \pm SD$		18 months $M \pm SD$		24 months $M \pm SD$		30 months $M \pm SD$		36 months $M \pm SD$	
	ELGA	FT	ELGA	FT	ELGA	FT	ELGA	FT	ELGA	FT
L	96.2 ± 14.4	109.8 ± 9.5	94.6 ± 12.8	104.9 ± 9.8	93.8 ± 12.9	103.4 ± 9.9	98.8 ± 11.1	114.4 ± 6.7	98.7 ± 12.9	108.2 ± 5.0
M	89.8 ± 14.7	99.4 ± 10.5	–	–	85.2 ± 6.7	101.5 ± 11.3	83.1 ± 6.6	102.1 ± 10.6	–	–
C	94.3 ± 13.2	108.2 ± 6.8	–	–	85.3 ± 7.4	96.4 ± 8.7	90.9 ± 11.2	100.0 ± 11.4	–	–

Note. L = language skills; M = motor skills; C = cognitive skills.

Table 3
Descriptive analyses (mean and standard deviation) of BSID-III raw scores for ELGA (n = 17) and FT samples (n = 11).

	12 months $M \pm SD$		18 months $M \pm SD$		24 months $M \pm SD$		30 months $M \pm SD$		36 months $M \pm SD$	
	ELGA	FT	ELGA	FT	ELGA	FT	ELGA	FT	ELGA	FT
L	28.3 ± 5.6	32.7 ± 3.5	39.6 ± 7.1	44.3 ± 5.2	52.2 ± 9.5	58.2 ± 6.2	65.0 ± 8.6	75.6 ± 3.5	73.8 ± 9.7	81.6 ± 3.1
RC	14.1 ± 2.6	16.4 ± 1.6	20.5 ± 4.1	22.5 ± 2.9	26.9 ± 4.9	30.0 ± 4.6	32.5 ± 4.1	37.5 ± 2.8	37.3 ± 4.2	39.8 ± 1.5
EC	14.1 ± 3.7	16.4 ± 2.6	19.1 ± 4.1	21.7 ± 4.3	25.3 ± 5.6	28.2 ± 4.3	32.5 ± 5.3	38.1 ± 1.9	36.5 ± 6.2	41.8 ± 1.9
M	65.6 ± 7.6	70.4 ± 4.7	–	–	87.1 ± 3.2	95.4 ± 4.9	94.0 ± 3.8	103.3 ± 5.7	–	–
FM	28.2 ± 2.2	29.9 ± 1.4	–	–	36.7 ± 1.9	40.8 ± 2.2	40.1 ± 2.4	43.3 ± 3.8	–	–
GM	37.4 ± 6.4	40.4 ± 4.1	–	–	50.4 ± 1.9	54.6 ± 3.3	53.9 ± 2.5	60.0 ± 3.5	–	–
C	38.9 ± 4.2	43.3 ± 2.1	–	–	56.1 ± 3.6	61.2 ± 3.8	65.9 ± 6.4	70.4 ± 4.0	–	–

Note. L = language skills; RC = receptive communication; EC = expressive communication; M = motor skills; FM = fine motor skills; GM = gross motor skills; C = cognitive skills.

3. Results

Descriptive data for the BSID-III concerning standard scores and raw scores at each time-point are presented in Tables 2 and 3 for the ELGA and FT children separately. As shown by the descriptive data presented in Table 2, the mean standard scores of ELGA children, although in most cases falling within the normal range, are consistently more than 10 points lower than those of the FT control sample across all domains. Within the ELGA group, the motor domain shows mean standard scores lower than those in the language and cognitive domains. In particular, at 30 months, the motor mean standard score of ELGA children lies more than 1 SD below the mean of the normative data.

Growth curve analysis on raw scores was used to model growth across three outcomes: (a) language skills, (b) motor skills and (c) cognitive skills. Multi-staged analyses were performed to determine the best fitting models of growth (i.e., unconditional models) and then to examine correlates of growth (i.e., conditional models).

3.1. Language skills models

3.1.1. Unconditional models of growth

Unconditional models for the language outcome are presented in Table 4. Inspection of both residual plots and −2 log likelihood model comparison tests for the language skills model supported the random intercept, random slope, fixed acceleration model as being the best, most-parsimonious fit for the data. Evidence for this conclusion included the fact that

Table 4
Unconditional models of growth (centered at 12 months).

	Fixed effects				Random effects	
	Estimate	SE	t	p	Estimate	SE
Language skills						
Intercept	28.98	1.17	24.80	<0.01	20.37**	4.51
Slope	2.33	0.16	14.73	<0.01	0.04*	0.20
Quadratic	−0.01	0.01	−2.01	0.047		
Motor skills						
Intercept	68.01	1.21	56.08	<0.01	24.15**	4.91
Slope	1.71	0.06	28.14	<0.01		
Cognitive skills						
Intercept	40.55	0.91	44.55	<0.01	11.59**	3.40
Slope	1.49	0.05	29.40	<0.01		

* $p < .05$.
** $p < .01$.

Table 5
Conditional models of growth (centered at 12 months).

	Conditional			
	Estimate	*SE*	*t*	*p*
Language skills				
Intercept	27.15	1.37	19.83	<0.01
Group membership	4.63	2.00	2.32	0.03
Slope	2.25	0.17	13.66	<0.01
Group membership	0.19	0.11	1.71	0.10
Quadratic	−0.01	0.01	−2.00	0.05
Motor skills				
Intercept	68.10	1.23	55.44	<0.01
Group membership	4.84	2.27	2.13	0.04
Slope	1.71	0.07	25.41	<0.01
Group membership	0.26	0.12	2.12	0.04
Cognitive skills				
Intercept	38.74	1.01	38.30	<0.01
Group membership	4.50	1.54	3.90	<0.01
Slope	1.49	0.08	18.09	<0.01
Group membership	0.01	0.11	0.12	0.91

the residual plot for the random intercept, random slope, fixed acceleration model revealed that residuals were close to zero and had no pattern. Additionally, the random intercept, random slope, random acceleration model did not fit the data significantly better, χ^2 (3) = 3.90, p = .27, for language scores compared to the random intercept, random slope, fixed acceleration model. The average language score for children at the first time point was 28.98, with instantaneous rate of change at baseline of 2.33 points. However, change in the rate of change decreased by 0.01 each month showing a deceleration with a quadratic function. The variance component for the intercept (20.37) signifies that children significantly varied in language skills scores at the first time point; the variance component for the slope (0.04) signifies that children significantly varied in their rate of growth of language skills.

3.1.2. Conditional models of growth

Once an adequate model of growth was determined, a second set of analyses examined the correlates of growth (conditional models) for children's language scores over time. The variable examined as a predictor variable was group membership (ELGA or FT children). The results for the conditional models for language skills are presented in Table 5. Group membership was found to be a significant correlate of the intercept but not the slope. Average score for ELGA children at 12 months was 27.15. FT children started significantly higher by 4.63 points (at about 31.78 points). ELGA children gained on average 2.25 points each month; they gained lower points (but not significantly) with respect to FT children who gained 2.44 points (0.19 points more) per month. There was significant variance in intercepts and slopes after accounting for group, as already shown by the unconditional model. The change in rate of change over time became smaller by.01 points per month (deceleration expressed by a quadratic function, as shown by the unconditional model) regardless of group membership (ELGA or FT sample) (see Fig. 1 and Table 5).

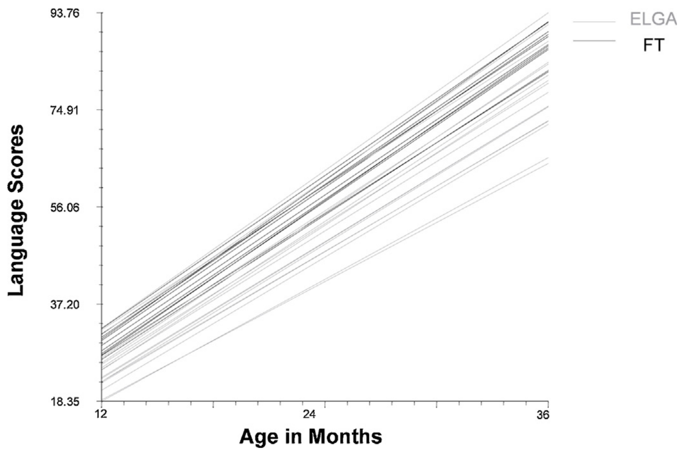

Fig. 1. Language skills growth trajectories (on raw scores) in ELGA and FT samples.

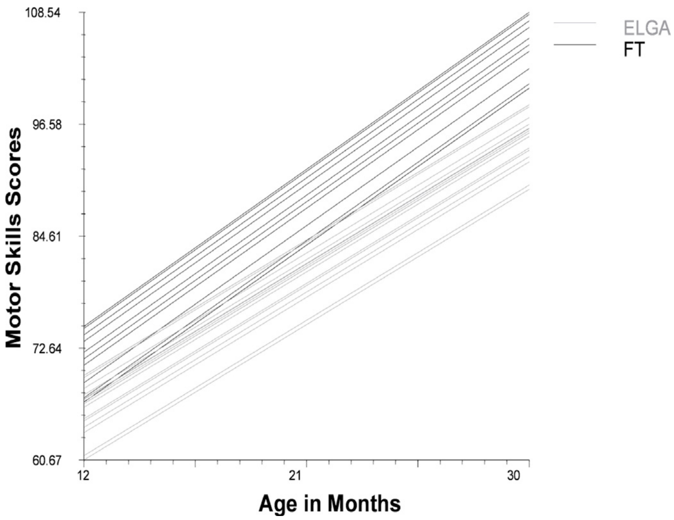

Fig. 2. Motor skills growth trajectories (on raw scores) in ELGA and FT samples.

3.2. Motor skills models

3.2.1. Unconditional models of growth

Unconditional models for the motor skills outcome are presented in Table 4. Inspection of residual plots and −2 log likelihood model comparison tests for the motor skills model supported the random intercept, fixed slope model as being the best, most-parsimonious fit for the data. The residual plot for the random intercept, fixed slope model revealed that residuals were close to zero and had no pattern. Additionally, the random intercept, random slope model did not fit the data significantly better, χ^2 (2) = 1.67, p = .44, for motor skills scores compared to the random intercept, fixed slope model. The average motor score for children at 12 months (the first time point) was 68.01. Children increased by a significant 1.71 points every month. The variance component (24.15) for the intercept signifies that children significantly varied in motor skills scores at the first time point.

3.2.2. Conditional models of growth

After establishing an adequate model of growth, a conditional model examined the correlate of growth (group membership) for children's motor skills scores over time. The results for the conditional models for motor skills are presented in Table 5. Group membership was found to be a significant correlate of both the intercept and the slope. Average motor scores for ELGA children at time 1 was 68.10. FT children started significantly higher by 4.84 points (at about 72.94 points). ELGA children gained on average 1.71 points each month, which differs significantly from FT children who gained about 1.97 points (0.26 points more) per month (see Fig. 2).

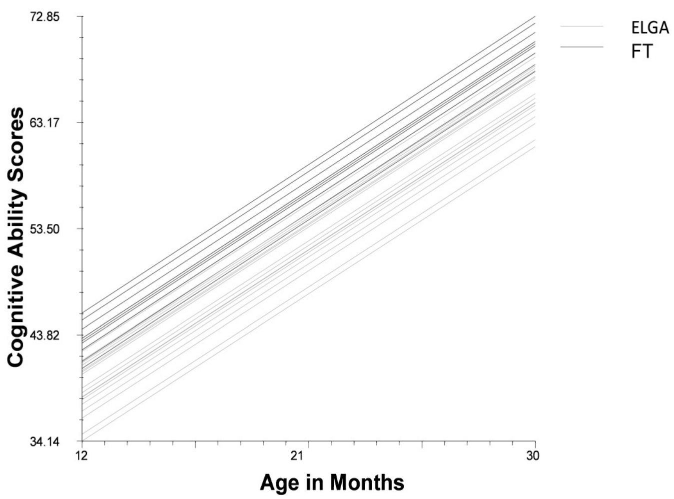

Fig. 3. Cognitive skills growth trajectories (on raw scores) in ELGA and FT samples.

3.3. Cognitive skills models

3.3.1. Unconditional models of growth

Unconditional models for the cognitive skills outcome are presented in Table 4. Inspection of residual plots and −2 log likelihood model comparison tests for the cognitive skills model supported the random intercept, fixed slope model as being the best, most-parsimonious fit for the data. The residual plot for this model revealed that residuals were close to zero and had no pattern. Further, the random intercept, random slope model did not fit the data significantly better, χ^2 (2) = 5.62, p = .06, for cognitive skills scores compared to the random intercept, fixed slope model. The average cognitive skills score for children at 12 months was 40.55. Children increased by a significant 1.49 points every month. The variance component (11.59) for the intercept signifies that children significantly varied in cognitive skills scores at the first time point.

3.3.2. Conditional models of growth

The results for the conditional models for cognitive ability are presented in Table 5. Group membership was found to be a significant correlate of the intercept but not the slope. Average cognitive score for ELGA children at time 1 was 38.74. FT children started significantly higher by 4.5 points (at about 43.24 points). ELGA children gained on average 1.49 points each month; this did not differ significantly from FT children who gained about 1.50 (0.01 points more) (see Fig. 3).

4. Discussion

This study aimed to characterize the individual growth trajectories of linguistic, motor, and cognitive skills among ELGA compared to FT children, from the first to the third year of life. To the best of our knowledge this is the first study that addresses this aim by applying growth curve analyses to the ELGA population, a group of preterm children who is at elevated risk for adverse developmental outcomes (Johnson et al., 2011; Marlow et al., 2005; O'Shea et al., 2012; Sansavini, Savini et al., 2011) and needs therefore to be carefully examined. The need for a careful longitudinal evaluation of the development of the ELGA sample is evident in the present study from the inspection of the standard scores, which are on average more than 10 points lower than those of the FT control sample. Furthermore, although the standard scores of the ELGA sample lie on average within the normal range of the normative data, those of motor development are lower than those in the language and cognitive domains and, at 30 months, lie below −1 SD with respect to the normative data. Thus, descriptive data on standard scores underline the relevance of deepening the knowledge of the developmental trajectories of ELGA children across language, motor and cognitive domains.

The value in using individual growth-curve modeling is that it yields a more accurate estimate of the nature of growth as compared to other more commonly employed methods in the preterm developmental literature (e.g., repeated measure analysis of variance). By modeling growth trajectories in terms of both the initial intercept and the rate of growth, our interest was in assessing whether the growth of ELGA children in relation to the FT peers would be characteristic of a Matthew Effect (an increasing divergence over time between the two groups), and whether this effect would be observed across multiple developmental domains.

4.1. Group and inter-individual differences across domains

Group differences as well as inter-individual differences were found across the considered domains (language, motor and cognitive) with some relevant peculiar distinctions in function of the considered domain. Group differences were evident across language, motor and cognitive skills from the first observational point, that is, 12 months, and continued at all the following age points through the second and third year of life, revealing that ELGA children did not overcome their disadvantage by 3 years, even if corrected age was taken into account. These findings highlight that ELGA children, (i.e. the higher vulnerable group of the preterm population), are characterized by a persistent delay with respect to FT peers concerning multiple domains, even when they are free from major neurological damages. Our findings bring new evidence in favor of the hypothesis that preterm children exhibit diffuse delay (Rose et al., 2009) and linguistic deficits may be associated to delays in other domains such as cognitive skills (Sansavini, Guarini, & Savini, 2011). Besides showing a persistent delay across all the observed domains, the present work gives a relevant contribution by highlighting differences in the growth curves of the examined domains and between the two groups. In particular, significant differences in rate of change over time across the motor but not the linguistic and cognitive domains were found.

4.2. Group and inter-individual differences in motor development

Concerning motor skills, the gap across the two groups increased significantly over time; ELGA children not only did not catch up with time, but they displayed even greater lags in fine and gross motor tasks in the third year than in previous years in comparison to their FT peers. Motor development appears therefore a domain persistently compromised by an ELGA preterm birth up to the third year of life, and this finding concerns all examined ELGA children. According to the neuroconstructivist approach (Karmiloff-Smith, 1998; Thomas et al., 2009), we speculate that the findings of the present study concerning motor deficits may be explained by the interaction between an extreme immaturity of the nervous system and body organs and the physical experience during the prolonged recovery in the NICU and after discharge (Als et al., 2004; Sansavini, Guarini, & Caselli, 2011). In the NICU environment preterm newborns are limited by several postural constraints due to medical care. Health of ELGA children remains very fragile after discharge from the NICU so that these children experience frequent illnesses and consequent limitations in their first years of life. Even if they are usually taken in charge by health services and supported in their motor development through physiotherapy, free motor exploration is frequently not adequately supported (Msall, 2009).

4.3. Group and inter-individual differences in language development

With regard to language skills, a significant stable gap and a lower even if not significant rate of growth characterized the ELGA group with respect to the FT sample up to the third year of life. The developmental trend of language in ELGA children appears peculiar and different from that identified in studies on VLGA children. In fact, the present study found a persistent delay in language in ELGA children from the first to the third year of life, while studies on VLGA children showed that they start to differ gradually from FT children during the second year of life, earlier for comprehension and later for production (Sansavini, Guarini, Savini, Broccoli et al., 2011; Stolt et al., 2009). Since the existing studies on VLGA children have employed repeated measure analyses of variance and mainly indirect assessments based on parental questionnaires, new studies employing person-centered statistical models and direct assessments are necessary to compare, besides ELGA and FT children, also VLGA children with respect to their developmental trajectories. Furthermore, a very recent meta-analysis revealed that very preterm children at preschool and school age show deficits both in simple and complex language functions (Van Noort-Van der Spek, Franken, & Weisglas-Kuperus, 2012), while, in adolescence, they show a catch-up in some simple language functions, but they continue to have difficulties in complex ones (Luu et al., 2011). Our findings suggest thus the need to run cross-sectional and longitudinal studies through subsequent developmental periods specifically on ELGA children in order to verify whether they show a catch-up on simple linguistic skills.

In addition, for language skills, great inter-individual variance was observed across both the ELGA and FT samples in the rate of change from the first to the third year. This wide inter-individual variability in slope could depend on many intervening factors affecting language development. A few studies conducted with very preterm children have shown that linguistic abilities are affected by both neurological and environmental factors, and that the impact of these factors changes depending upon the developmental age and the examined skills. For instance, Landry, Smith, Miller-Loncar, and Swank (1997) showed that maternal interactive strategies supporting joint attention facilitated cognitive and linguistic growth rate of very preterm children observed at 6, 12, 24, and 40 months of age, while a restrictive style hindered it and these effects were stronger for high risk infants (i.e., those with very severe neonatal medical complications). Another study (Luu et al., 2011), run on cognitive and linguistic skills of very preterm children from 8 to 16 years, showed that the receptive vocabulary (but not other linguistic and cognitive skills) in most of the very preterm children approximated the growth of FT peers at 16 years. However, a group of about 25% very preterm children, more likely to have less-educated mothers and a more prominent history of brain injury, showed a divergent developmental pattern (growing more slowly than the other preterm as well as FT children) proving the relevance of the interaction between neonatal and environmental factors in shaping developmental trajectories. It would be thus very relevant to examine in future studies on ELGA children, whose biological risk is much higher than in very preterm ones, up to which point appropriate parental interactive strategies and medium-high parental level of education can overcome their early linguistic difficulties, taking into consideration both the developmental time and the different developing linguistic abilities. A further source of inter-individual variability among children in language development might depend, to some extent, on the structure of the test BSID-III. This examines relevant receptive and expressive skills for each age period through specific items and questions, but it cannot provide complete information on the whole receptive and expressive lexicon acquired and used by the children. Therefore, at least concerning lexical ability, language development as assessed by the BSID-III is very much dependent on whether children have acquired the specific items and words sampled in the test at each age point, which therefore makes it vulnerable to inter-child variability.

4.4. Group and inter-individual differences in cognitive development

With regard to cognitive skills, ELGA children showed a persistent delay over time such that they never compensated for their early gap relative to FT peers, but they did not fall further behind their FT peers over time. A possible explanation for these findings may be advanced. According to the hypothesis of Rose et al. (2009, 2011) some basic information processing mechanisms (such as speed and memory) are impaired in preterm infants because of a different neurobiological maturation and these impaired mechanisms affect also more complex cognitive abilities. A longer longitudinal study examining in ELGA children the same basic information processing mechanism from the first year to school age might show whether some basic delays persist until school age or become even more severe during critical developmental transitions. Again, a comparison with VLGA children by employing a person-centered statistical model would be useful to verify whether ELGA and VLGA children are characterized by different growth curves, since the existing studies which found an increasing divergence between VLGA and FT children in cognitive non verbal development were based only on sample mean scores (Ortiz-Mantilla et al., 2008; Sansavini, Savini et al., 2011).

4.5. Clinical implications

Our findings also give suggestions for clinicians, physiotherapists and other professionals caring for ELGA children and needing to understand how and why children's development varies. Two aspects are particularly relevant, concerning the first individual developmental trajectories, the second language development evaluation in the context of other developmental domains (motor and cognitive). Indeed, group data are useful as a general reference for clinicians, but are not sufficient and, in some cases, may be misleading, either too pessimistic or too optimistic, when making individual developmental prognoses of young children, communicating with parents and planning personalized interventions. Understanding both the extent and the limits of inter-individual variation is therefore critical for bettering and making more effective clinical practice. Furthermore, clinicians working in multi-disciplinary teams are usually aware of the interdependence of language with other developmental domains, but may not know precisely how and in which developmental phases those interdependencies manifest themselves in individual children. Growth curve analysis thus has promise as a tool with which to examine developmental trajectories for theoretical and clinical aims.

Our findings show the value of examining carefully early development in motor, language and cognitive domains and may have relevant implications for further research and clinical issues on the effects of early interventions within and across the above domains. As hypothesized by some authors (Capirci & Volterra, 2008; Iverson, 2010; Sansavini, Guarini, Savini, Broccoli et al., 2011), motor actions performed in interactive social contexts can be considered as a ground for building the referential function, which becomes gradually expressed by representational gestures and words. Early interventions on motor skills on ELGA children might thus bring benefit not only on these skills which appear those more compromised in the first years of life, but also on cognitive and linguistic skills grounded on motor skills.

4.6. Limitations

Limitations of this work should be noted. First, the sample size utilized in the present study was small. The generalizability of our findings beyond the study sample should thus be carefully considered. Additionally, the limited sample size may have impacted the ability to detect differences in growth between ELGA and FT infants. In order to explore this possibility, power estimates were calculated using Optimal Design Software (Spybrook, Raudenbush, Liu, Congdon, & Martínez, 2011). Analyses assumed an alpha level of.05 and small impacts with a minimally detectable effect size of.2. The resulting power estimate (0.18) confirmed the possibility that our study may not have been sufficiently powered to detect differences in growth between ELGA and FT infants. Despite power and sample size issues, group differences were detected on the intercepts for all three outcome measures (language, motor and cognitive skills) and on the slopes for the motor skills outcome. However, it is possible that group differences on the slopes for the language and cognitive skills outcomes were not detected due to the limited sample size utilized in the present study. Therefore, replication of the present findings over larger samples will be a necessary future step for researchers.

Second, Italian normative values are not available yet for the BSID-III. With regard to this point, evidence from the US BSID-III normative values supports the validity and reliability of the tool; furthermore, a longitudinal FT control sample was included in the present study as reference. Further examination of growth among ELGA children with other measures, besides the BSID-III, might seek convergence with the present findings. Finally, here we focused on children's specific abilities. A further step would be to examine these data in relation to measures of parental interactive modalities which could be supportive of the abilities examined in this paper.

5. Conclusion

To sum, the results of this study support the conclusion that the early linguistic, motor, and cognitive development of ELGA children differs in important ways from that of FT peers.

On one side, ELGA children show diffuse delays across several domains. On the other side, differences in growth curves are specific for each domain. Most marked, is the different pattern of growth seen in motor development, such that ELGA children develop motor skills more slowly than FT peers, showing an increasing delay (i.e., a Matthew effect) which might give rise to an atypical developmental path. Instead, for language and cognitive skills, ELGA children show consistent delays relative to FT peers, but their growth rate over time is not so different from that of FT children until the third year. However, language skills present a peculiar growth curve, with a great inter-individual variance which suggests that some ELGA children might persist in their delay, some might gradually recover and some might fall further behind showing later an atypical pattern.

Future longitudinal studies that follow children over longer time periods might thus show whether or not divergence continues to increase in regard to motor development and becomes significant at later ages in language and cognitive development with persistent delays or atypical patterns. Furthermore, it would be relevant to utilize growth curve analyses in studies examining several typologies of preterm children in function of neonatal immaturity and parental interactive strategies and educational level to verify whether the level of GA affects differently the growth rate of language, motor and cognitive development taking into account the modulation of environmental factors.

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Conflict of interest statement

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Appendix A. Continuing educations questions

CEU Questions

(1) From the first to the third year ELGA children presented significantly lower scores than FT peers:
  (a) only in motor skills until 3 years
  (b) in language, motor and cognitive skills until 3 years
  (c) in language, motor and cognitive skills at 1 year, but no longer by 3 years
  (d) in language, motor and cognitive skills at chronological, but not at corrected age
(2) From the first to the third year growth curves of the ELGA sample with respect to the FT sample showed:
  (a) an increasing divergence in motor, language and cognitive development
  (b) a stable gap in motor and cognitive development and an increasing divergence in language development
  (c) an increasing divergence in cognitive and language development and a stable gap in motor development
  (d) an increasing divergence in motor development and a stable gap in language and cognitive development
(3) Individual growth curve analysis allows to:
  (a) Examine the nature of growth among individuals as well as variables associated with growth
  (b) Compare means of two groups at specific time points
  (c) Represent individual's change over time only as a function of a random intercept
  (d) Represent individual's change over time only as a function of a random slope
(4) Great inter-individual differences in the rate of change were observed in:
  (a) Language and motor skills in both ELGA and FT samples
  (b) Language skills in both ELGA and FT samples
  (c) Language and motor skills only in the ELGA sample
  (d) Language, motor and cognitive skills in both ELGA and FT samples
(5) For ELGA children in the first years of life, interventions should be planned:
  (a) first in the motor domain, then in language and cognitive domains
  (b) only in the motor domain
  (c) in the motor, language and cognitive domains when a slowed individual rate of growth is identified
  (d) in none of the domains since delays are gradually overcome

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