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Evidence of a continuum in foundational expressive communication skills☆

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ABSTRACT

Progress monitoring measurement is increasingly needed in early childhood to inform practitioners when an intervention change is needed and as a tool for accomplishing individualization and improving results for individual children. The Early Communication Indicator (ECI) is such a measure for infants and toddlers 6–42 months of age. A greater understanding of the ECI key skills (i.e., gestures, vocalizations, single- and multiple-word utterances) could lead to further improvements in the sensitivity and utility of the decisions made compared to ECIs composite total communication score. Thus, we examined the pattern of growth within and between the ECI's four foundational skills in a large sample of children served in Early Head Start. Results confirmed a unique pattern of growth and change within each skill trajectory in terms of (a) age at skill onset and (b) peaks in each trajectory defining an inflection point or change from acceleration to deceleration. Using these inflection points as intercepts with before and after trajectory slopes, we tested the fit of an adjacent-skills temporally ordered growth model. Results indicated good fit. Implications of a continuum of foundational ECI skills to future validation and decision making utility of the measure are discussed.

Children need communication skills in early childhood to gather information, express needs, grow cognitively and linguistically, and to interact appropriately with others in the environment (Warren & Walker, 2005). Learning to express one's wants and needs using language and social communication is a desired outcome of early childhood (Priest et al., 2001). Converging evidence suggests that language proficiency is a precursor to early literacy (Cabell, Justice, Konold, & McGinty, 2011; Snow, Burns, & Griffin, 1998; Whitehurst & Lonigan, 1998) and later success learning to read (Catts, Fey, Zhang, & Tomblin, 2001; National Reading Panel, 2000; Shanahan & Lonigan, 2008; Walker, Greenwood, Hart, & Carta, 1994). The relationship between early language, literacy, and social competency is similarly compelling because of its importance to school readiness (Chard & Kameenui, 2000; Miles & Stipek, 2006; Mistry et al., 2010), and successful peer relationships (Doctoroff, Greer, & Arnold, 2006; Hester & Kaiser, 1998).

Failure to use words is the most common reason for referring school-aged children for special education services (American Speech-Language & Hearing Association, 2006). Over three quarters of children eligible for special education between 24 and 36 months of age received speech and language services (Hebbeler et al., 2007). Because the prevalence of communication problems is so widespread, not addressing it will result in significant cost (Kaiser, Hancock, & Nietfeld, 2000; Warren et al., 2008).

Thus, it is vital that communication and language delays be identified as early as possible so that appropriate intervention services targeting the prevention of childhood language disabilities may be initiated (Oller, Eilers, Neal, & Schwartz, 1999; Warren & Walker, 2005). Unfortunately, delays in expressive communication too often are not identified before preschool, in part because of the reliance on assessments that are not sensitive to earlier communication delays (Crais, 2011; Gibbs & Teti, 1990; Wetherby & Prizant, 1992). While all sectors of early childhood list language and communication as outcomes of their programs, the likelihood of success in the absence of measures with short-term sensitivity to growth in children's early communication is reduced (Greenwood, Bradfield et al., 2011).

Increasingly the field is moving toward program-wide, prevention-oriented early intervention systems that encourage individualizing children's learning experiences, use

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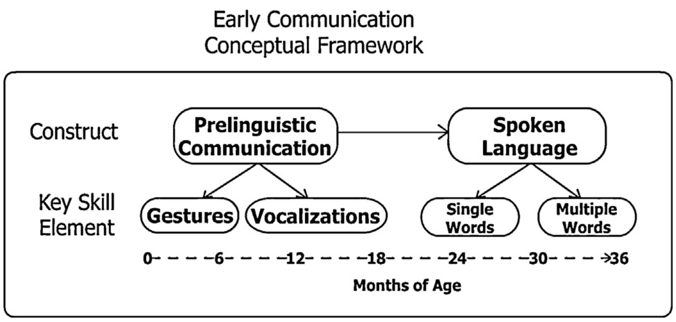

Fig. 1. Conceptual framework for ECI foundational skills.

evidence-based intervention practices, and use formative measurement to identify, need, and modify intervention (Advisory Committee on Head Start Research & Evaluation, 2012). The Designation Renewal System (Office of Head Start, 2012), for example, makes renewal of Head Start and Early Head Start (EHS) program grants contingent on programs using child results to individualize instructional strategies that support each child's development (45 CFR Sec 1308.3(b)(2)(ii)). Another example is the joint position statement on the Response to Intervention (RTI) prevention-oriented approach that embraces progress monitoring measurement published by the National Association for the Education of Young Children (NAEYC), Division of Early Childhood (DEC), and the National Head Start Association (NHSA) (NAEYC, DEC, & NHSA, 2012).

Progress monitoring measurement is uniquely defined by the repeated measurement of performance on a single instrument (Fuchs, 2004; Fuchs & Deno, 1991). It is used to inform practitioners when an intervention change is needed and as a tool in accomplishing differentiation and improving results for individual children. Progress monitoring measures are uniquely brief and repeatable and are intended for use by teachers, caregivers, home visitors, and interventionists (DEC, 2007; Deno, 1997; Fuchs & Deno, 1991). Progress monitoring measures are designed to be leading indicators of growth and development of a few key skills in a domain; and as such, they are not intended to provide comprehensive reports on a child's status on all skills in the domain (Fuchs & Deno, 1991).

The ECI is a progress monitoring measure of growth in early expressive communication developed for use with infants and toddlers ages 6–42 months (Carta, Greenwood, Walker, & Buzhardt, 2010; Greenwood, Carta et al., 2011). The ECI was developed to address the need for a measure with short-term sensitivity to young children's growth in communication skills (Carta et al., 2002; Luze et al., 2001). A challenge faced in developing the ECI was identification of appropriate communication skills beginning as early as 6-months of age that were conceptually and empirically integrated with competent performance at a future point in time (e.g., 36 months) (Fuchs, 2004). The first step was a systematic sampling of the skills constituting the domain to ensure that each assessment represents the entire outcome domain over the age range equivalently (Fuchs, 2004). The second step was to identify a task associated with the domain of interest and likely to evoke the skills of interest. The authentic tasks selected for the ECI from many common toys that were evaluated were the Fisher-Price© House and Barn. The ECI is administered using the House or Barn in a 6-min play session with a non-directive, familiar adult (Walker & Carta, 2010).

From the literature, the domain skills selected for ECI measurement were gestures, vocalization, single word, and multiple-word utterances that together form a composite total communication score on the ECI (Greenwood, Carta, Walker, Hughes, & Weathers, 2006; Luze et al., 2001) (see Fig. 1). Gestures were defined as physical movements made by the child in an attempt to communicate with the partner. Vocalizations were non-word verbal utterances voiced by the child to the play partner, occurring alone or with gestures. Single-word utterances were either singular-voiced or signed words by the child that are recognized and readily understood by the partner. Multiple-word utterances were two or more different-voiced or signed words by the child that are readily understood by the partner (Walker & Carta, 2010).

Theory and evidence supported inclusion of these skills on the path toward learning to communicate using sentences and multiple-word conversations by 36 months. These skills emerge in the repertoires of most typically developing children over time with the onset of each skill observed to occur within the first 3 years of development. For example, prelinguistic communication skills in the form of gaze, gesturing and babbling emerge long before spoken language (Yoder, Warren, & Macathren, 1998). Together, these appear to reflect a continuum of skills that have been identified in the literature to overlap or co-occur (i.e., gestures and vocalizations). Around 12 months of age, children begin using gesturing with naming or to produce words (single words). As toddlers approach 20 months of age, they begin combining words (multiple-word utterances) to make sentences and eventually to have conversations by the time they reach 36 months of age (Bates & Dick, 2002; Rowe & Goldin-Meadow, 2009).

These skills are also substantiated by research reports demonstrating predictive relationships to later language, literacy, and social outcomes. For example, early gesture use predicted later vocabulary development (Acredolo & Goodwyn, 1988; Brady, Marquis, Fleming, & McLean, 2004; Iverson, Longobardi, & Caselli, 2003; Rowe & Goldin-Meadow, 2009). Rowe and Goldin-Meadow (2009) reported that gesturing by infants at 18 months predicted vocabulary at 42 months. Predictive relations between gestures and two-word combinations have been reported (Vandereet, Maes, Lembrechts, & Zink, 2011) and between early word use and later social-emotional development (Vallotton & Ayoub, 2010). Delay in the onset of some forms of babbling has been associated with a higher risk for speech and language-related disorders (Oller et al., 1999; Yoder et al., 1998), as has delay in onset of early words (Fenson et al., 1994) or word combinations (Zubrick, Taylor, Rice, & Slegers, 2007). Paul and Roth (2011) reported that early risk factors for future language delays included fewer gestures, vocalizations, babbling, and later onset of speech sounds and word combinations (Dale, Price, Bishop, & Plomin, 2003; Rice, Taylor, & Zubrick, 2008). These predictive relationships and their extensions to later school readiness and early literacy (Storch & Whitehurst, 2002; Walker et al., 1994) highlight their importance to the validity of the ECI.

Initial research developing the ECI began with a small cross-sectional sample (Luze et al., 2001) and examination of construct validity. Children younger than 12 months used gestures and vocalizations to communicate. Children at 24 months were using single-word utterances, maintaining gestures, but declining in use of vocalizations. Children at 36 months were using multiple-word utterances, maintaining gestures, and declining in vocalizations, and single-word utterances. In a subsequent sample, ECI data for individual children collected longitudinally over 9 months suggested that these cross-sectional patterns were reflecting complex developmental trajectories (Luze et al., 2001). In a much larger sample, we recently described these ECI key skills trajectories using growth curve modeling (Greenwood, Walker, & Buzhardt, 2010). Results indicated that these individual skill trajectories were curvilinear rather than linear. Each skill had a unique (a) age at onset, (b) age at peak or inflection point where acceleration changed over to deceleration in the trajectory, and (c) mean intercept at 36 months of age. Overall, a sequential process of change within skills over time was observed. This pattern across skills suggested adjacent

Table 1
Children's social demographic characteristics.

Variable	Statistic	Entire EHS sample	EHS sample with 3 occasions
Children	Count	5883	2299
Children State 1	Count	3190	1430
Children State 2	Count	2693	869
Age at 1st ECI assessment	Mean	18.4	14.1
	SD	9.3	7.4
	Min	6	5
	Max	36	31
Gender	% Male	48	52.5
	% Female	52	47.5
Home language	% English	90	90
	% Spanish	9	9
	% Other[a]	1	1
Individual Family Service Plan (IFSP)	% No	92	91
	% Yes	8	9

[a] *Notes*. A range of other languages were indicated (e.g., Arabic, Vietnamese, Somali, etc.). Abbreviations are: ECI = Early Communication Indicator, EHS = Early Head Start.

temporal ordering of gestures, vocalizations, single- and multiple-word utterances.

The purpose of this investigation was to follow-up these preliminary findings with a more thorough examination of these dynamic patterns of growth and change in skills to advance the construct validity of the ECI. A second purpose was to test whether or not these cross-skill patterns reflect a continuum or temporal ordering of foundational skills, knowledge that might be used in subsequent research to improve the sensitivity and predictive utility of the ECI. For example, Good, Simmons, and Kameenui (2001) reported using a continuum of foundational early literacy skills instead of a composite score, in their progress monitoring and intervention decision making approach with children in kindergarten through third grade.

Monitoring children's progress in developing individual foundational skills as compared to the total composite may enable earlier identification and decision making for several reasons. One is that children lingering longer in their use of prelinquistic skills in favor of development of more proficient skills in the continnum may be more transparently indicated by tracking key skills compared to just composite total communcation. Another is that knowledge of key skill patterns seems likely to contribute more useful information to practitioners seeking recommendations of the most useful interventions, for example, those for advancing prelinguistic skills compared to those for emerging versus advanced forms of spoken language. This knowledge may be lost when only total communication is monitored. Thus, we asked two questions using latent growth curve modeling (LGCM):

1. What dynamic relations exist within each key skill, and do these relations support and inform the ECIs conceptual framework?
2. What dynamic relations exist across the key skills, and do the resulting adjacent, cross-skills predictive pathways support a continuum of foundational skills?

1. Method

1.1. Participants

This investigation was a secondary analysis of data from a previously reported sample of children served in EHS. The two earlier reports focused on child-level ECI growth norms (Greenwood et al., 2010) and program-level influences on children's growth in ECI communication growth trajectories (Greenwood, Buzhardt, Walker, Howard, & Anderson, 2011). Participants were infants and toddlers recruited from EHS programs representing urban, suburban, and rural localities across two Midwestern states. Because of the planned examination of individual curvilinear growth trajectories in this report, the inclusionary criteria used required that a child had at least three or more repeated ECI measurements to be included in the study. From the total 5883 enrolled children in 27 programs, $N = 2299$ met the inclusionary criterion and were included in this analysis. Table 1 provides a comparison of the socio-demographics of the smaller sample to the larger, original sample.

Children in the smaller sample were served by13 EHS programs in State 1 ($n = 1430$; 62.2%) and 14 EHS programs ($n = 869$; 37.8%) in State 2. As shown in Table 1, these children were similar in socio-demographics in most respects to the larger sample. The exception being that these children were 4.3 months younger on average at $M = 14.1$ months of age (SD = 7.4), ranging from 5 to 31 months at first ECI. Males accounted for 52.5% ($n = 1208$) of participants, and English was the primary language spoken in the home for 89.8% ($n = 2056$) of participants. From a subsample of 516 EHS children for whom race/ethnicity status was known, the distribution was: Euro-American (White) (39.3%), Hispanic/Latino (31.8%), African American (Black) (17.1%), Multi-Race (11.2%), Asian (4.2%), and Pacific Islander (0.4%).

All children served in EHS were from families meeting poverty guidelines. For a family of three, poverty in 2007 was defined as annual income at or below \$17,170 or \$18,530. EHS policies also mandate that 10% of EHS program participants be devoted to children with Individualized Family Service Plan [IFSPs] without consideration of family income. Nine percent ($n = 210$) of EHS participants received IDEA Part C early intervention special education services as indicated by an IFSP.

1.1.1. Early Head Start (EHS)

The EHS programs provided community-based, home visitation services for low-income families and their children from pregnancy up to 36 months of age, respectively. EHS policies require that 10% of the families served by EHS programs serve children with a disability. All participating programs provided weekly home-based services to families, fulfilling program standards for EHS programs using home-visiting in that they "Provide one home visit per week per family (a minimum of 32 home visits per year) lasting for a minimum of 1 and a half hours each. . .maintain an average caseload of 10–12 families per home visitor with a maximum of 12 families for any individual home visitor," (HS Program Performance Standards [45 CFR 1306.33]).

1.1.2. EHS home visiting staff

In all, 508 EHS home visiting staff members were involved in administering and scoring the ECI during 2002–2007. All home visitors were female. The distribution of levels of early childhood preparation were reported by home visitors as follows: 41.2% reported some early childhood training beyond high school but no degree, 23.5% had a Child Development Associate's degree, 8.8% had an Associate's degree, 22.1% had a Bachelor's, 1.5% reported the Master's degree, and 1.5% reported "Other."

1.2. Measures

The Early Communication Indicator (ECI) is a 6-min play-based measure of individual children's growth in expressive communication (Carta et al., 2010). The ECI is administered quarterly for universal screening and as frequently as monthly to monitor the impact resulting from a change in a child's intervention. The original five-year ECI development and validation effort for infants/toddlers (Greenwood, Carta, & Walker, 2005; Greenwood & Walker, 2010) involved: (a) a national survey of parents of children with special needs and professionals in early childhood (EC) and early childhood special education (ECSE) that socially validated expressive communication as an important general outcome of early intervention for young children (Priest et al., 2001), (b) studies documenting the psychometric properties and feasibility of the ECI, including sensitivity to growth over time (Greenwood et al., 2006; Luze et al., 2001), (c) studies showing sensitivity to short-term early interventions (e.g., Greenwood, Dunn, Ward, & Luze, 2003; Kirk, 2006) and (d) a website to support scalability.

The ECI's criterion validity coefficient for total communication was reported to be $r = .62$ with the Preschool Language Scale-3 (Zimmerman, Steiner, & Pond, 1992) and $r = .51$ with a parent rating of the child's language skills (Luze et al., 2001). In this same sample, the split-half reliability for the ECI's total communication score was $r = .89$ for mean level and $r = .62$ for slope. Alternate forms reliability was reported to be $r = .72$. An estimate of the inter-rater agreement on the scoring of ECI records was 90% overall for total communication, ranging from a mean of 70% for single words to 81% for gestures.

In a recent ECI report, the shape of the mean ECI total communication trajectory was positively accelerating (Greenwood et al., 2010). The mean ECI total communication linear growth rate for children in EHS was 1.0 communications per minute per month. Each month, children on average were producing six more communications in the 6-minute assessment. The ECI total communication mean at 6 months of age was 2.6 communications per minute and grew to 21.6 communications per minute (or 130 responses in 6 min) by 36 months of age.

Analyses of covariates indicated that gender and home language (dual language status) where not significant influences on growth in ECI keys, while IFSP status was a significant influence. Children with IFSPs were significantly lower and slower in developing ECI communication skills (Greenwood et al., 2010). ECI total communication has been reported to be sensitive to home-based language interventions supervised by EHS home visitors and implemented by parents at home (Buzhardt et al., 2010, 2011). Effect sizes of $d = .47$ after 6 months of intervention and $d = .79$ after 9 months between groups' mean intercepts were detected favoring the home-based language intervention group.

1.2.1. ECI key skills elements

Four key communication skills were recorded by an observer in the course of interaction with an adult play partner during a 6-min ECI assessment. These were: Gestures, Vocalizations, and Single- and multiple-word utterances (Greenwood et al., 2005). For the ECI, gestures are defined as physical movements made by the child in an attempt to communicate with the partner. Examples include: giving a toy, reaching toward an adult, pushing away, pointing, showing, nodding head, taking something from the play partner, etc. Vocalizations are non-word verbal utterances voiced by the child to the play partner. They may occur alone or with gestures. Examples include babbling, cooing, "ah," da," animal sounds, etc. Single words are either single-voiced or signed words by the child that are recognized and readily understood by the person hearing them. Multiple-word utterances are two or more different-voiced or signed words by the child readily understood by the coder. To count as a multiple-word utterance, the words/signs must fit together in a meaningful way to approximate a statement or sentence. At least two or more of the words/signs need to be understandable (Walker & Carta, 2010). The frequency of occurrence of each key skill element is recorded on a paper and pencil data sheet over a 6-minute assessment. The observed frequency is subsequently divided by 6 min to obtain the number of responses per minute. These raw data are entered into the online data system for scoring and reporting results.

1.2.2. Administration

Administration of the ECI involves a familiar adult who is taught to interact as a play partner with a child using either the Fisher-Price Barn (Form A) or Fisher-Price House (Form B). These two toy sets were shown to be equivalent alternate forms for evoking early communication in play (Luze et al., 2001). Familiarity of the play partner is important because of the potential for reactivity due to the stranger effect common in very young children (Greenwood et al., 2008).

The ECI assessment session takes place in a convenient setting with few distractions present in the home or early education program. The assessor times the session for 6 min using a digital timer. Initially, if assessors were not familiar with the child, as in case of new home visitors, they engaged in a number of play sessions prior to ECI assessments to become familiar. Familiarity was reached when the child willingly engaged in play with the adult.

The play partners' role during an ECI session was to encourage the child's communication by following the child's lead and commenting on the child's actions and words. Because the goal is to capture the child's typical communication performance, assessors did not direct or take the lead but instead supported the child's communicative behavior through encouragement and interest.

The ECIs were administered and scored using one of the following scenarios: (a) the EHS home visitor served as the play partner and videotaped the assessment for later scoring, (b) another certified staff member scored the assessment live while the home visitor served as the play partner, or (c) the parent/caregiver served as the play partner while the home visitor scored it live. The administration scenario used depended primarily on the program's resources (e.g., availability of a video camera or additional staff for the home visit), availability of assessors who could speak the child's primary language, and the parent's ability to follow the administration protocol. In cases where the parent served as the play partner, the home visitor reviewed the administration instructions with the parent related to engaging with the child during the assessment, modeled how to engage with the child, and asked the parent to practice with his/her child with coaching from the home visitor prior to begin the 6-minute assessment.

Accommodations recommended for children with sensory and/or physical impairments include: moving toys closer to the child, supported positioning for the child in a manner that orients the child toward the toys and enables best access to them, and where needed, using toys that are larger, more identifiable, and make recognizable sounds. In these situations, the adult play partner may carry out the following: introduce the toys to the child allowing him/her to touch and manipulate them, provide more movement of toys, and tell the child where the toys have been placed if needed.

Procedures for children whose primary home language was not English required a play partner who could engage with the child in his/her primary language, and a coder who was fluent in both English and the child's home language capable of discriminating utterances from single words and multiple words as well as utterances that were not words in both languages (Walker & Buzhardt, 2010). It should also be noted that the scoring of the ECI was not designed to provide results in different languages. ECI scores are simply the sum of all words said regardless of language used.

1.2.3. Program data collection and staff management

ECI assessors were EHS local program staff assigned by their program's director to conduct ECI measures. Using the program management tools in the website, the state directors enrolled local program directors within their state. Local directors, in turn, enrolled their program staff (e.g., home visitors and other service providers) so that they could enter and manage data for children in that program. In this process, they were provided a password-protected account in the online data system that enabled them to enroll children and add data as needed. Local directors typically assigned a staff member to supervise other staff and, sometimes, another member to enter data for service providers who administered and scored the ECI with children on their caseload. Otherwise, staff entered their own data into the secure online data system. The expectation was that data would be entered into the system shortly after collection so that home visitors, program directors, and state EHS directors could view current information online. Thus, ECI scores were nested under children, who were nested under EHS programs within states. Program staff could only access data for their own program.

1.2.4. ECI training and certification

EHS staff members learned to use the ECI in a trainer-of-trainers model supported by the ECI developers and website resources (Walker & Buzhardt, 2010). At least one local staff member from each program attended a workshop by the ECI developers where they were certified to administer the ECI, code children's communicative events, and interpret results. These staff returned to the local program and certified additional staff using materials given to them at the workshop or downloaded from the website.

Certification required accomplishing two tasks meeting standards of calibration. The first was coding or scoring of children's communication skills, the second was fidelity of administration. To certify as an ECI coder, trainees coded two videos each with an 85% reliability standard. Trainees accessed the two videos at the website (http://www.igdi.ku.edu/training/ECI_training/ECI_videos/), coded them, and entered results into the online data system. The system provided them an immediate calculation of their reliability (overall and for each key skill element). In our experience, most trainees achieved this standard within 2–4 attempts for each video.

1.2.5. Fidelity of administration

Trainers observed each trainee's administration of the ECI (live or videotaped) to ensure that the trainee administered at least 13 of the 16 ECI administration steps (Walker & Carta, 2010). Most assessors achieved this standard on their first administration given instructions and coding of two administrations previously discussed. Overall, certification was completed in 2–4 h: 1–2 h for learning the coding and administration guidelines, 1–2 h for coding certification, and 30–60 min for administration certification.

1.2.6. ECI score reliability

In addition to their initial certification as an ECI coder, assessors in local programs were encouraged to conduct annual paired inter-assessor coding agreement checks. These checks were a dual coding of a videotaped administration of the same child on the same date such that agreement between a reliability assessor and a primary assessor could be checked. Program directors were encouraged to review the reliability checking of their program staff and provide input to individual assessors based on reports available to them at the website. Not all programs conducted reliability checks after initial certification, however.

A total of 246 paired inter-observer assessments were completed by program staff. Because the data analyzed in this report consisted of ECI rate scores, analysis of inter-rater reliability focused on ECI score reliability rather than inter-rater agreement (Hartmann, 1977). Pearson r was used to estimate the covariation in primary and reliability assessors' ECI rate per minute scores. The observed r values were .91, .91, .96 and .98 for gestures, vocalizations, single words, and multiple words, respectively, indicating a pattern of strong similarity between assessors' ECI skill score (see Table 2). The equivalence of the raters' ECI key skills scores was estimated by calculating the mean difference between the two rater groups and the corresponding 95% confidence intervals. Of interest was how close to 0 were the mean differences. The differences were uniformly small, ranging from .02 (multiple words) to .09 (single words) of a response per minute (see Table 2). According to Seaman and Serlin (1998), perfect equivalence is indicated by the inclusion of 0 within the confidence interval. The low-end confidence intervals were −.01, −.06, and −.04 for gestures, vocalizations, and multiple words, respectively, indicating near equivalence in rater's score estimates for all skills but single words. Because 0 was not within the confidence interval of single words (CI = .03–.16) it did not meet this test. However, the mean difference of .09 words per minute for single words was considered too small to be practically significant.

1.3. Statistical analyses

The basic raw data across all children were comprised of quarterly ECI assessments linked to each child's birthday. Across states, 16,688 ECI assessments were collected (State 1: n = 10,496, 63%; State 2: n = 6162, 37%). These data were collected beginning in 2002 through 2007 in the context of accountability and an interest in a RTI model of services. Quarterly ECI assessments were considered a universal screen of all children. Complete data for a child in a program consisted of 11 occasions (separated by 3 months starting on the child's first birthday). A small percentage of children identified as below benchmark on ECI total communication in these screens were assessed as frequently as monthly as part of progress monitoring.

1.4. Data screening and missing values

Prior to analysis, variables of interest in the original data set were screened for accuracy using SAS 9.3 statistical software program. Results indicated that data did not contain extreme collinearity; therefore, there were no correlations large enough among ECI measurements to bias the standard errors and significance tests in planned analyses (Shin, Davidson, & Long, 2009).

Univariate outliers were inspected with frequency distributions of z-scores. The absolute values of all z-scores greater than 3.0 were considered univariate outliers and were deleted. Multivariate outliers were evaluated with Mahalanobis distance-squared (D^2). According to the D^2 statistic (assuming a conservative $p < .001$), no extreme multivariate outliers were noted among the variables after removing all univariate outliers.

Evaluation of incomplete ECI data related to attrition and missed measurement occasions indicated that all variables had at least one missing value on a child, 2280 of the 2299 children had at least one missing value on a variable, and 39,976 of the 71,269 values (children x variables) were missing, for a total of 56% data missing.

Table 2
ECI key skill score reliability correlations and equivalence ($N = 246$).

ECI Key skill	*r*	M01	M02	*M* diff	95% confidence interval		
					Lower	Upper	df
Gestures	0.91	1.33 (1.11)	1.29 (1.09)	0.05	−.0118	.0147	245
Vocalizations	0.91	2.80 (2.19)	2.74 (2.23)	0.06	−.0611	.1756	245
Single words	0.96	1.61 (1.87)	1.52 (1.79)	0.09	.0269	.1628	245
Multiple words	0.98	1.17 (2.09)	1.15 (2.10)	0.02	−.0390	.0771	245

Note. M01 = primary observer, M02 = reliability observer, ( ) = SD.

The missing data patterns were dispersed among children in a seemingly random fashion (Enders, 2006; 2010); however, greater missingness occurred at the 36-month measurement occasion.

Because a complete dataset is required for planned analyses using latent growth curve modeling (LGCM; Carter, 2006; Preacher, Wichman, MacCallum, & Briggs, 2008), we used the Full Information Maximum Likelihood (FIML) procedure in the M*plus* version 6.1 software package (Muthén & Muthén, 1998–2011) to address data missing at random. FIML uses all available data producing more accurate fit indices and parameter estimates than most alternatives (Enders, 2010; Enders & Bandalos, 2001). Auxiliary variables also were incorporated into the FIML estimation with the AUXILIARY (m) option (via the saturated correlates model; Asparouhov & Muthén, 2008; Graham, 2003). Auxiliary variables support the missing at random assumption, help retain optimal power, and decrease bias and standard errors (Collins, Schafer, & Kam, 2001; Enders, 2010; Enders & Peugh, 2004; Graham, 2003).

Review of the missing data literature suggests that FIML performs as well (Schlomer, Bauman, & Card, 2010) or better (Graham, Olchowski, & Gilreath, 2007) than multiple imputation (MI) techniques. Both are favored over traditional methods for addressing missing data (Collins et al., 2001; Enders, 2010) and are recommended based on theory and because they arrive at a similar solution when the models are identical in analyses and auxiliary variables (Buhi, Goodson, & Neilands, 2008). FIML also is an appropriate approach given the observed missing data rate (i.e., 56%; Collins et al., 2001; Graham et al., 2007; Littvay, 2009; Newman, 2003; Schlomer, Bauman, & Card, 2010; Yeh, 2007; Zhang & Walker, 2008). As a check, we also used MI, and results indicated similar estimates and standard errors in comparison to FIML.

To reduce the size of the planned analyses, we examined the appropriateness of compositing ECI occasions to reflect mean estimates separated by three months between the chronological ages of 5–37 months instead of the monthly data (see Table 3). Analyses comparing the functional form of each ECI key skill trajectory based on monthly versus composited 3-month occasions confirmed equivalence. Thus, the composited data were used.

The mean raw data plots are shown in Fig. 2 separated for children with an IFSP (right panel) and those without an IFSP (left panel). As seen in these plots, single- and multiple-word usage did not occur until children were 12 and 18 months of age, respectively. Because of small variance in single- and multiple-word measurements before 12 or 18 months of age, the earlier occasions for these key skills were not included in planned analyses.

1.5. Descriptive statistics

As can be seen in Fig. 2, the skill trajectories approximated roughly the conceptual framework in terms of skill onset timing (see Fig. 1). For example, gestures and vocalizations were present beginning at 6 months of age, they grew over time, and particularly so, the rate of vocalizations for children without IFSPs (Fig. 2, left panel). Onset for single words occurred later at 12 months, and subsequently for multiple words at 18 months. Similar onsets were found for children with IFSPs (Fig. 2, right panel).

The sequencing of observed peaks in the trajectories (i.e., the intercepts) also supported a progression in adjacent skills. For example, the progression of intercepts for the non-IFSP group was gestures at 15 months, vocalizations at 18 months, single words at 24 months, and multiple words at the end-point of 36 months (see Fig. 2). These peak values were similarly ordered for the IFSP group but generally occurred three to nine months later than the non-IFSP group. IFSP group peak values were reached at 18 months for gestures, 24 months for vocalizations, 33 months for single words, and 36 months (the end-point) for multiple words.

Children with IFSPs on average were slower starting, slower growing, and slower declining in their use of simpler skills (i.e., vocalizations, single word utterances) compared to children without IFSPs (Greenwood et al., 2010). Children with IFSPs also were

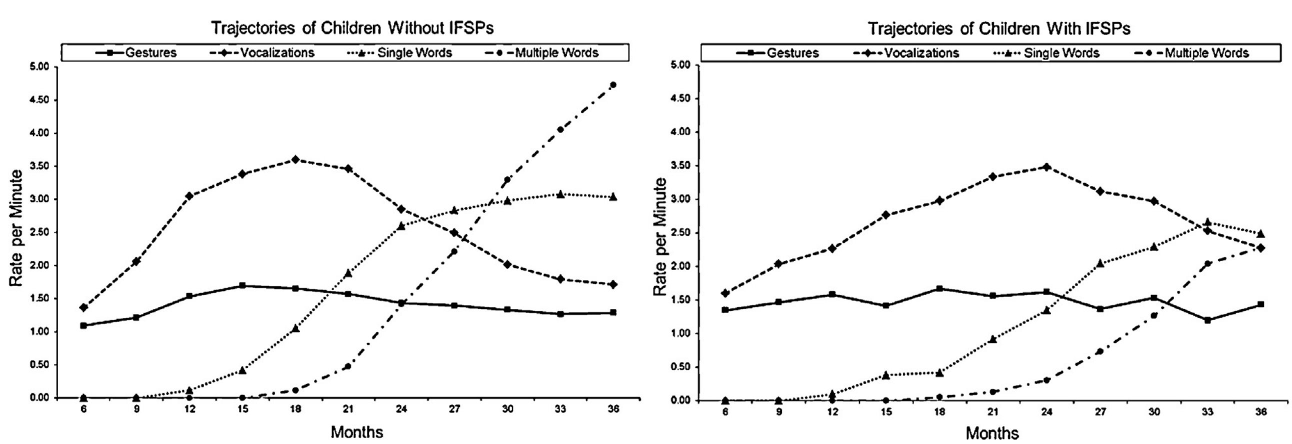

Fig. 2. Unfitted mean trajectories for the four ECI key skill elements at 3 month intervals between 6 and 36 months of age for children with No IFSP (left panel) and IFSP (right panel).
Note. Abbreviation IFSP = Individual Family Service Plan.

Table 3
ECI descriptives by ages at test and monthly and monthly composited occasions.

Age at test (Mos)	*N* ECIs	Monthly estimates									Composited monthly estimates							
		GS		VO		SW		MW			GS		VO		SW		MW	
		M	SD	*M*	SD	*M*	SD	*M*	SD	*N* ECIs	*M*	SD	*M*	SD	*M*	SD	*M*	SD
5	220	1.11	0.98	1.15	1.47	0.01	0.09	0.00	0.04									
6	621	1.15	0.99	1.39	1.48	0.01	0.13	0.01	0.09	604	1.14	0.97	1.39	1.57	0.02	0.21	0.02	0.53
7	317	1.18	1.18	1.52	1.63	0.01	0.10	0.00	0.00									
8	400	1.15	1.03	1.86	1.60	0.01	0.08	0.00	0.01									
9	620	1.32	1.24	2.05	1.77	0.03	0.15	0.00	0.03	833	1.24	1.11	2.07	1.80	0.06	0.50	0.03	0.37
10	333	1.28	1.06	2.35	1.84	0.03	0.12	0.00	0.00									
11	456	1.52	1.27	2.87	2.22	0.06	0.20	0.01	0.12									
12	664	1.56	1.23	2.93	2.19	0.12	0.29	0.01	0.09	1019	1.54	1.22	3.05	2.29	0.11	0.38	0.02	0.35
13	376	1.53	1.24	3.06	2.18	0.19	0.47	0.02	0.18									
14	489	1.61	1.25	3.17	2.34	0.30	0.63	0.02	0.13									
15	643	1.67	1.33	3.26	2.43	0.38	0.71	0.03	0.20	1109	1.66	1.29	3.38	2.36	0.40	0.76	0.04	0.30
16	391	1.71	1.32	3.36	2.24	0.55	0.90	0.03	0.16									
17	518	1.60	1.22	3.36	2.24	0.81	1.07	0.09	0.37									
18	647	1.60	1.26	3.45	2.38	0.99	1.27	0.10	0.30	1160	1.66	1.29	3.57	2.31	1.00	1.37	0.11	0.38
19	401	1.68	1.36	3.46	2.45	1.24	1.39	0.17	0.52									
20	509	1.56	1.22	3.44	2.44	1.63	1.62	0.30	0.72									
21	679	1.51	1.28	3.28	2.24	1.73	1.68	0.46	0.92	1168	1.57	1.22	3.46	2.28	1.82	1.73	0.44	0.96
22	402	1.56	1.25	3.16	2.10	2.10	1.88	0.69	1.13									
23	507	1.44	1.25	2.93	2.24	2.21	1.94	0.98	1.53									
24	727	1.40	1.32	2.72	2.23	2.46	2.02	1.33	1.91	1229	1.46	1.28	2.91	2.18	2.47	2.19	1.31	1.97
25	425	1.55	1.41	2.66	2.16	2.41	1.87	1.66	2.18									
26	523	1.42	1.27	2.56	2.10	2.62	1.99	1.66	1.95									
27	699	1.39	1.25	2.44	2.09	2.64	1.81	2.16	2.25	1195	1.40	1.25	2.55	2.09	2.74	1.98	2.05	2.26
28	421	1.42	1.31	2.33	2.01	2.77	2.04	2.41	2.33									
29	521	1.35	1.33	2.22	2.25	2.88	1.95	2.63	2.48									
30	717	1.37	1.24	2.03	1.90	2.68	1.86	2.99	2.62	1116	1.36	1.24	2.13	2.01	2.89	1.90	3.07	2.70
31	386	1.20	1.17	1.94	1.93	2.69	1.81	3.32	2.71									
32	490	1.33	1.36	2.00	1.93	2.78	1.95	3.27	2.70									
33	663	1.22	1.23	1.82	1.72	2.75	1.79	3.71	2.95	935	1.26	1.25	1.87	1.72	3.03	2.02	3.90	3.01
34	358	1.28	1.24	1.84	1.82	2.65	1.72	3.68	2.72									
35	474	1.27	1.27	1.77	1.72	2.84	1.73	4.02	2.96									
36	366	1.40	1.29	1.71	1.75	2.82	1.69	4.28	2.70	662	1.31	1.24	1.77	1.64	2.96	1.68	4.37	2.85
37	193	1.41	1.27	1.86	1.81	2.98	1.70	4.08	2.63									
Total	16,156	1.42	1.24	2.48	2.03	1.53	1.23	1.34	1.26	11,030	1.44	1.24	2.67	2.20	1.65	1.96	1.34	2.32

Notes. Abbreviations are as follows: Mos = months, ECI = Early Communication Indicators, GS = gestures, VO = vocalizations, SW = single words, MW = multiple words.

talking later and were slower developing multiple word communication proficiency by 36 months of age.

1.6. Latent growth curve modeling

Latent growth curve modeling (LGCM) was used to address the two research questions regarding relations within and between the ECI key skills and the continuum of growth. LGCM was an appropriate choice because it supports evaluation of growth trajectories based on repeated observations. Also, factors in LGCM represent individual differences over time, estimating predictors of individual differences as well as associations between growth parameters. Disability status was included as a predictor of slope and intercept factors in both the measurement model and the predictive model to account for mean-level differences in these factors between children with and without IFSPs.

To measure or estimate growth within each key skill over time, linear splines were used to model the observed nonlinear trajectories for gestures, vocalizations, and single words. A spline model fits two different slope factors, one before a chosen intercept and one after the chosen intercept, in order to demonstrate how development may differ before and after a certain point of theoretical importance. In this case, we used the observed peaks from Fig. 2 (left panel) and past research (Greenwood et al., 2010) to locate the intercept values for typical growth and development; these intercepts were set at 12, 18, and 24 months of age for gestures, vocalizations, and single words, respectively. The modeling fit linear patterns of growth, one for each child, up to the intercept and away from the intercept for each key skill. Not only were average estimates of growth, peak, and decline available, but also the variance of each estimate among the children. Because 36 months of age is a policy-linked age for some early intervention services (e.g., end of EHS; beginning of Head Start or preschool; end of Part C; beginning of Part B IDEA services) and an inflection point had not yet reached for multiple words, the intercept was placed at 36 months, and a linear pattern of growth up to this intercept estimated.

Addressing the first research question, we fit a measurement model that estimated all possible covariance between the slope and intercept factors. This provided a test of the appropriateness of the growth constructs themselves, as well as a clear and unmediated interpretation of the impact of IFSP status. We addressed the second research question by evaluating the fit of a continuum in cross-skills development based on the direction (i.e., positive or negative) and statistical significance of relevant regression pathways. In all of these analyses, we used the following goodness of fit indicators: the root mean square error of approximation (RMSEA), the non-normed fit index (NNFI), and the comparative fit index (CFI). For RMSEA, values less than or equal to .08 are preferred. Values greater than .90 are generally considered acceptable for the NNFI and CFI. The chi-square fit statistic was also reported.

To reveal the patterns of growth for each key skill (Question 1), loadings on the slope constructs (other than those at the beginning and end of the slope) were allowed to be estimated. This technique, called a Level-and-Shape model (McArdle, 1988), does not restrict the slope of growth to be perfectly linear, but rather estimates the cumulative proportion of total change between the first and last time points of each slope for each time point. In other words, it

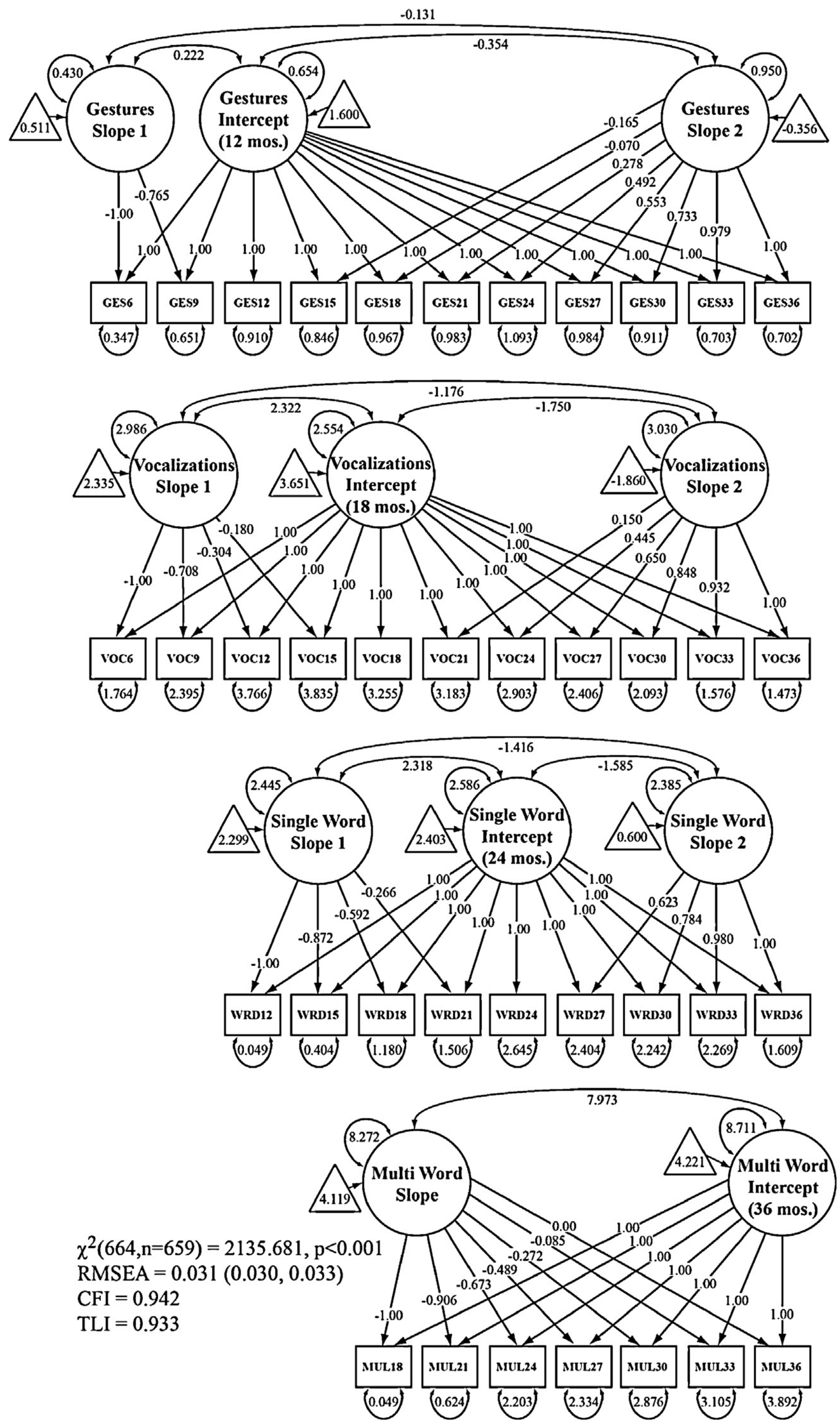

Fig. 3. Key skills 2-piece latent growth measurement models (i.e., gestures, vocalizations, single and multiple words). Note that the inter-skill covariances are not shown.

allowed examination of the precise speed of change in skills at certain time points (see Fig. 3).

To investigate the temporal ordering of cross-skills development (Question 2), the inter-skill (as opposed to intra-skill) covariances were eliminated and replaced with structural pathways (see Fig. 4). These regression pathways predicted the slopes and intercept of a more advanced skill by the slopes and intercept of the adjacent, more basic skill, thus forming an adjacent-skills model (i.e., gestures predicting vocalization, vocalizations predicting single-word constructs, and single-word predicting multiple-word constructs). The only exceptions to the inter-skill covariance replacement were the covariances between the slope after the intercept of a more basic skill and the slope before the intercept of a more advanced skill. Said differently, a predictive pathway here would be inappropriate, because this would mean predicting backward in time. Covariances between the two aforementioned elements were retained in the adjacent skills model; however, these covariances were not of interest in this study and are not discussed further. The adjacent-skills model was the model in which the continuum hypothesis was tested. Pathway estimates were displayed in terms of rate-per-minute change scores (unstandardized beta estimates) and as effect sizes (standardized beta

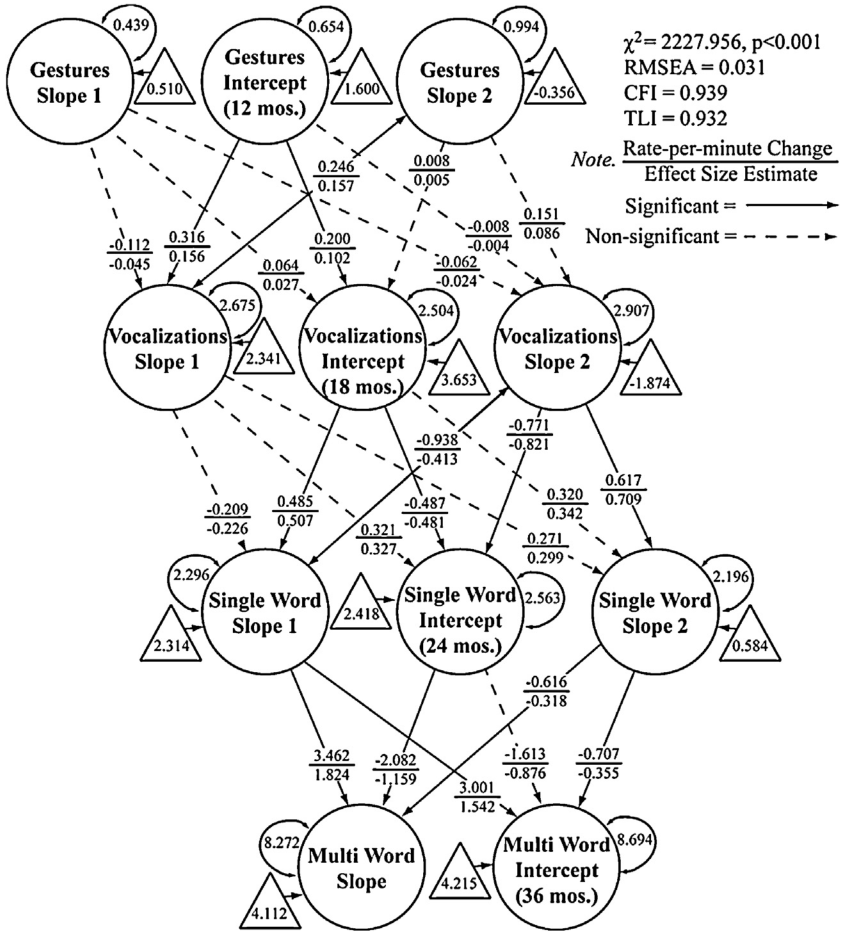

Fig. 4. Fitted theoretical continuum model.

estimates). The significance of paths was tested using the chi-square difference test wherein the effect of removing the path from the full model is tested for significance against the full model (Chen, Sousa, & West, 2005; French & Finch, 2006; Hancock & Mueller, 2006; Kline, 2010; Little, 1997).

2. Results

2.1. Question 1. What Dynamic Relations Existed Within Each Key Skill, and do these Relations Support and Inform the ECI's Conceptual Framework?

In the context of this study, the latent growth measurement model answered important questions about the pattern of individual differences among each of the key skill intercepts and slopes and was the basis for more elaborate testing to follow (Brown, 2006). The initial measurement model, consisting of intercepts and slopes set as previously described, fit the data reasonably well, χ^2 (664) = 2135.681, $p < .001$, *RMSEA* = .031 (90% *CI*: 0.030, 0.033), *TLI* = .933, *CFI* = .942 (see Fig. 3). The model means, variance, and correlation estimates are summarized in Table 4 and indicated no salient areas of strain in the solution, and within- and cross-key skill relations among the intercepts and slopes were reasonable. Additionally, all intercept and slope means and variances were statistically significant ($p < .01$). These results indicated that a range of individual differences in children's slopes and intercepts within and across each key skill were captured. Of particular interest were the consistent Slope 1-to-Intercept correlations within skills that were positively related (.421, .843, .980, and .994 for gestures, vocalizations, single and multiple words, respectively) compared to these relationships between intercept and Slope 2 values that were consistently negative (−.452, −.645, −.678 for gestures, vocalizations, and single words, respectively) reflecting the increasing and decreasing trends within each skill over time (see Table 4).

2.2. Gestures

The gestures mean rate at 12 months was 1.600 (*SE* = 0.029) responses per minute. Growth increased linearly at an average rate of 0.511 (*SE* = 0.042) gestures per minute between every quarter (i.e., three months) between the ages of 6 and 12 months. Thereafter, growth decreased linearly at an average rate of −0.356 (*SE* = 0.046) gestures per minute per quarter between 12 and 36 months. As expected, the correlation (i.e., standardized covariance) between before and after slopes was −0.208, indicating that greater growth before 12 months in gestures is associated with greater decline in gestures after 12 months. IFSP was not a significant predictor of change in gestures ($\Delta\chi^2$ $p = 0.3039$, .4547, and 0.0805 for regressions onto Gestures Intercept, Slope 1, and Slope 2, respectively); thus, children with disabilities were not significantly different in the use of gestures than their peers without developmental delays.

2.3. Vocalizations

The mean rate of vocalizations at 18 months was 3.651 (*SE* = 0.061).

Table 4
Measurement model means, correlations, and covariances.

	Gestures			Vocalizations			Single words			Multiple words	
	Slope 1	Intercept	Slope 2	Slope 1	Intercept	Slope 2	Slope 1	Intercept	Slope 2	Slope 1	Intercept
Mean (non-IFSP)	0.511	1.600	−0.356	2.335	3.651	−1.860	2.299	2.403	0.600	4.119	4.221
Mean (IFSP)	0.405	1.513	−0.138	2.096	3.263	−0.507	0.980	1.065	1.482	1.792	1.826
GS-S1	**0.430**	0.421	−0.208	−0.101	0.049	−0.046	−0.064	−0.081	0.257	0.028	0.003
GS-I	0.223	**0.654**	−0.452	−0.010	0.068	−0.010	0.094	0.097	0.068	−0.025	−0.033
GS-S2	−0.133	−0.356	**0.950**	0.128	−0.034	0.104	−0.161	−0.122	0.103	−0.089	−0.072
VO-S1	−0.115	−0.014	0.215	**2.986**	0.843	−0.400	0.250	0.242	0.188	0.060	0.028
VO-I	0.052	0.088	−0.053	2.330	**2.554**	−0.645	0.344	0.353	0.047	0.201	0.179
VO-S2	−0.052	−0.014	0.176	−1.203	−1.794	**3.030**	−0.631	−0.652	0.462	−0.621	−0.605
SW-S1	−0.065	0.119	−0.246	0.675	0.860	−1.716	**2.445**	0.980	−0.626	0.815	0.839
SW-I	−0.085	0.125	−0.192	0.673	0.906	−1.826	2.464	**2.586**	−0.678	0.822	0.856
SW-S2	0.260	0.085	0.155	0.502	0.116	1.242	−1.512	−1.683	**2.385**	−0.584	−0.640
MW-S	0.052	−0.059	−0.249	0.298	0.924	−3.108	3.664	3.803	−2.592	**8.272**	0.994
MW-I	0.005	−0.079	−0.207	0.142	0.846	−3.108	3.870	4.062	−2.918	8.435	**8.711**

Note. GS = gestures, VO = vocalizations, SW = single words, MW = multiple words; S1 = slope before intercept, I = intercept, S2 = slope after intercept; below-diagonal values are unstandardized covariances, above-diagonal values are standardized correlations, and diagonal values (bold) are unstandardized construct covariances. Covariances can be interpreted as the unit increase in one variable for each unit increase in the other variable. (Ex: An utterance-per-minute-per-three-months increase in VO-S1 is associated with a 2.33 utterance-per-minute increase in VO-I). Correlations are interpreted differently from covariances, and are more easily comparable as a standard scale. (Ex: The −0.678 correlation between SW-S2 and SW-I shows that SW-S2 decreases more steeply when SW-I is greater. This relationship is stronger than that between SW-S2 and MW-S, which has a correlation of −0.584).

Growth in vocalizations increased linearly by 2.335 (SE = 0.090) responses per minute per quarter (i.e., 3-month span) between the ages of 6 and 18 months. Thereafter, it decreased at an average rate of −1.860 (SE = 0.086) vocalizations per minute per quarter between 18 and 36 months. As with gestures, the correlation between vocalization slopes before and after the intercept was negative at −0.400.

While IFSP did not predict growth in vocalizations between 6 and 18 months ($\beta = -.239$; $SE = 0.299$; $\Delta\chi^2(1) = 0.64$; $p = .424$), it was a significant predictor of the vocalization mean intercept at 18 months ($\beta = -.388$; $SE = 0.174$; $\Delta\chi^2(1) = 4.992$; $p = .026$) and subsequent rate of decline per quarter between the ages of 18 and 36 months ($\beta = 1.353$; $SE = 0.224$; $\Delta\chi^2(1) = 36.223$; $p < .0001$). These significant pathways mean that children with IFSPs were lower in vocalization use by 0.388 responses per minute at 18 months compared to non-IFSP peers, and they had a 1.353 response-per-minute shallower decrease in vocalizations after 18 months.

In other words, children without IFSPs on average decreased their use of vocalizations more rapidly than children with an IFSP after 18 months.

2.4. Single-word utterances

The mean rate of single-word communication at 24 months was 2.403 (SE = 0.059) words per minute. Growth in single-word usage increased linearly between 12 and 24 months at an average rate of 2.299 (SE = 0.060) words per minute per quarter, after which the observed growth of single-word utterances decreased substantially to an average growth of 0.600 (SE = 0.075) words per minute per quarter between 24 and 36 months. As with both gestures and vocalizations, the relationship between single-word slopes before and after the intercept was negative at −0.626. IFSP predicted less growth in single-word utterances between 12 and 24 months ($\beta = -1.319$; $SE = 0.116$; $\Delta\chi^2(1) = 62.744$; $p < .0001$), lower mean intercept at 24 months ($\beta = -1.338$; $SE = 0.162$; $\Delta\chi^2(1) = 68.085$; $p < .0001$), and less decline in single-word utterances after 24 months ($\beta = 0.882$; $SE = 0.203$; $\Delta\chi^2(1) = 62.744$; $p < .0001$). Children with an IFSP demonstrated a 1.319 utterance-per-minute smaller increase in single words prior to 24 months, had 1.338 fewer utterances-per-minute at 24 months, and showed a 0.882 utterance-per-minute smaller decrease in single word usage after 24 months, compared to their peers without an IFSP.

2.5. Multiple-word utterances

The mean rate of multiple-word communications at 36 months was 4.221 (SE = 0.112) words per minute. Growth in multiple-words increased linearly between 18 and 36 months at an average rate per minute of 4.119 (SE = 0.112) words per quarter. IFSP was a significant predictor of lower mean rate of multiple-word usage at 36 months ($\beta = -2.395$; $SE = 0.257$; $\Delta\chi^2(1) = 86.616$; $p < .0001$), as well as less growth in multiple-word utterances between 18- and 36-months ($\beta = -2.327$; $SE = 0.257$; $\Delta\chi^2(1) = 81.899$; $p < .0001$). Compared to children without an IFSP, children with an IFSP had a lower mean rate of 2.327 utterances-per-minute in multiple words, and a 2.395 utterance-per-minute lower mean rate of multiple word usage at 36 months, respectively.

2.6. Question 2. What Dynamic Relations Existed Across the Key Skills; and Specifically, Did the Resulting Predictive Pathways Support a Continuum of Foundational Skills?

The appropriateness of the measurement model allowed for further testing of the structural relations among the adjacent key skill intercepts and slopes. The theoretical adjacent-skills model also fit the data reasonably well, χ^2 (664) = 2227.956, $p < .001$, $RMSEA$ = .031 (90% CI: 0.030, 0.033), TLI = .932, CFI = .939 (see Table 5 and Fig. 4). Inclusion of the predictive paths for the adjacent skills model did not produce salient areas of strain in the solution as indicated by estimates of latent means, variances, and correlations in Table 5. Results indicated that this model captured a range of individual differences in children's slopes and intercepts across the key skills. Also, the within-skills relationship between the first slope and its intercepts, and between the intercepts and second slope were nearly identical with those previously reported for the measurement model (see Table 4).

Overall, 10 out of the 22 theoretical pathways in the model provided statistically significant support for the continuum of adjacent-skills hypothesis and across the four skills, at least two pathways (gestures to vocalizations) or more were significant (see Table 6). These relationship patterns were complex, however, because some pathways were negative as well as positive. For example, lingering to use an earlier skill was associated with a delay in using a more advanced skill in the continuum (see Fig. 4). For gestures predicting vocalizations, significant positive predictive pathways were observed between gestures intercept at 12

Table 5
Adjacent skills model latent means, variances, and correlations.

	Gestures			Vocalizations			Single words			Multiple words	
	Slope1	Intercept	Slope2	Slope1	Intercept	Slope2	Slope1	Intercept	Slope2	Slope1	Intercept
Mean	0.510	1.600	−0.356	2.341	3.653	−1.874	2.314	2.418	0.584	4.112	4.215
GS-S1	**0.439**										
GS-I	0.412	**0.654**									
GS-S2	−0.201	−0.454	**0.944**								
VO-S1				**2.675**							
VO-I				0.853	**2.504**						
VO-S2				−0.342	−0.636	**2.907**					
SW-S1							**2.296**				
SW-I							0.985	**2.563**			
SW-S2							−0.607	−0.677	**2.196**		
MW-S										**8.272**	
MW-I										0.993	**8.694**

Note. GS = gestures, VO = vocalizations, SW = single words, MW = multiple words; S1 = slope before intercept, I = intercept, S2 = slope after intercept; below-diagonal values are standardized correlations and diagonal values (bold) are unstandardized construct variances.

months and vocalizations Slope 1 and vocalizations intercept at 18 months of age. All other predictive pathways between gestures and vocalizations were small and not significant. Each unit increase in gestures at 12 months predicted (a) a .316 (*SE* = .110; $\Delta\chi^2(1) = 7.892$; $p = 0.005$) utterance per-minute increase in vocalization Slope 1 as children using more gestures at 12 months grew faster in vocalizations Slope 1, and (b) a .200 (*SE* = .096; $\Delta\chi^2(1) = 4.117$; $p = .042$) utterance per-minute increase in vocalizations intercept at 18 months.

For vocalizations predicting single words, a significant predictive pathway was located between the 18-month vocalization intercept and single-word Slope 1. Each unit increase in vocalizations at 18 months predicted a 0.485 (*SE* = 0.111; $\Delta\chi^2(1) = 11.724$; $p = 0.001$) utterance per-minute increase in the single-word Slope 1 between 12 and 24 months. Children demonstrating more vocalizations at 18 months had higher single-word utterance growth between 12 and 24 months.

Vocalizations intercept at 18 months was also a significant negative predictor of single-word intercept at 24 months of age. A unit increase in the vocalizations intercept predicted a loss of −.487 (*SE* = 0.283; $\Delta\chi^2(1) = 5.361$; $p = 0.021$) in the single-word intercept. Vocalizations Slope 2 was another significant negative predictor of the single-word intercept at 24 months ($\beta = -0.771$; *SE* = 0.132; $\Delta\chi^2(1) = 14.481$; $p < 0.001$), but a significant positive predictor of single-word Slope 2 ($\beta = 0.617$; *SE* = 0.107; $\Delta\chi^2(1) = 6.634$; $p = 0.010$). Children who did not decrease their use of vocalizations after 18 months were more likely to have a smaller peak in single words than those whose vocalizations did decrease.

For single words predicting multiple words, single-word Slope 1 was a significant positive predictor of both multiple-word slope and intercept at 36 months. Every unit increase in single-word Slope 1 predicted a 3.462 (*SE* = 1.070; $\Delta\chi^2(1) = 17.1$; $p < 0.001$) utterances per-minute increase in multiple-word slope, and a 3.001 (*SE* = 1.035; $\Delta\chi^2(1) = 13.06$; $p < 0.001$) utterance per-minute

Table 6
Regression pathways in the adjacent skills model.

Predictor		Predicted	Regression estimate	Standardized estimate	S.E.	*z*-Value	*p*
Gestures Slope 1	to	Vocalizations Slope 1	−0.11	−0.05	0.24	−0.47	0.637
		Vocalizations intercept	0.06	0.03	0.19	0.34	0.733
		Vocalizations Slope 2	−0.06	−0.02	0.16	−0.39	0.699
Gestures intercept	to	*Vocalizations Slope 1*	*0.32*	*0.16*	*0.11*	2.87	*0.004*
		Vocalizations intercept	*0.20*	*0.10*	*0.10*	2.09	*0.037*
		Vocalizations Slope 2	−0.01	0.00	0.11	−0.07	0.941
Gestures Slope 2	to	Vocalizations intercept	0.01	0.01	0.09	0.09	0.928
		Vocalizations Slope 2	0.15	0.09	0.10	1.45	0.147
Vocalizations Slope 1	to	Single words Slope 1	−0.21	−0.23	0.13	−1.64	0.101
		Single words intercept	0.32	0.33	0.25	1.28	0.202
		Single words Slope 2	0.27	0.30	0.20	1.33	0.182
Vocalizations intercept	to	*Single words Slope 1*	*0.49*	*0.51*	*0.11*	*4.37*	*0.000*
		Single words intercept	−0.49	−0.48	0.28	−1.72	0.086
		Single words Slope 2	0.32	0.34	0.23	1.42	0.157
Vocalizations Slope 2	to	*Single words intercept*	*−0.77*	*−0.82*	*0.13*	*−5.81*	*0.000*
		Single words Slope 2	*0.62*	*0.71*	*0.11*	*5.74*	*0.000*
Single words Slope 1	to	*Multiple words slope*	*3.46*	*1.82*	*1.07*	*3.24*	*0.001*
		Multiple words intercept	*3.00*	*1.54*	*1.04*	*2.90*	*0.004*
Single words intercept	to	*Multiple words slope*	*−2.08*	*−1.16*	*1.06*	*−1.97*	*0.049*
		Multiple words intercept	−1.61	−0.88	1.03	−1.57	0.116
Single words Slope 2	to	*Multiple words slope*	*−0.62*	*−0.32*	*0.17*	*−3.62*	*0.000*
		Multiple words intercept	*−0.71*	*−0.36*	*0.17*	*−4.18*	*0.000*

Note. Values in italic are those with pathways significant at $p = .05$ or less.

increase in multiple-word intercept at 36 months of age. Of note is that these two pathways were the strongest in the model in terms of rate-per-minute change and effect size. Single-word intercept at 24 months was a significant negative predictor of multiple-word slope ($\beta = -2.082$; $SE = 1.058$; $\Delta\chi^2(1) = 5.419$; $p = 0.020$). Single-word Slope 2 also was a significant negative predictor of multiword-slope ($\beta = -0.616$; $SE = 0.170$; $\Delta\chi^2(1) = 21.248$; $p < 0.001$) and intercept at 36 months ($\beta = -0.707$; $SE = 0.169$; $\Delta\chi^2(1) = 30.338$; $p < 0.001$). Similar to the relationship observed between vocalizations and single words, children who lingered longer in their use of single words were more likely to be lower in both multiple-word growth and outcome at 36 months.

3. Discussion

The purpose of this investigation was to strengthen the validity of the ECI through a detailed examination of growth and change in its four key skills in a large sample during the 6–36 month age span. We sought to improve our knowledge of the dynamic patterns of change occurring within and across ECI skills that in composite comprise the ECI total communication score. We also sought evidence of temporal ordering among adjacent skills or a continuum of growth in communication proficiency that might be used in future research as a basis for improving the predictive utility of the ECI in intervention decision making. Some of the strengths of this work included the large sample, the use of repeated assessments, the focus on growth trajectories, the inclusion of relevant covariates, and the use of latent growth modeling.

For the first research question, we fit a two-piece latent growth measurement model that considered age at skill onset and centered the intercept values at the inflection points of each skill using the trajectories demonstrated by children without IFSPs. Because earlier findings confirmed that that IFSP status was a significant influence on children's growth in children's early communication while gender and home language were not (Greenwood et al., 2010), we included IFSP status in these analyses. As a covariate in analyses, IFSP status facilitated our goal of creating age-based benchmarks for typically developing children that might be used in future identification of children falling below these benchmarks and at-risk of making future performance benchmarks without intervention.

The first model tested included all possible associations within and between skills and fit the data reasonably well as indicated by the RMSEA, NFI, CFI, and chi-square goodness of fit tests. In agreement with theory and extant literature, results confirmed that young children's development of the ability to express their wants and needs in communication measured by the ECI was complex, varying, and changing from simple to more advanced over time. At 6 months of age, children were using both gestures and vocalizations. After 12 months of age, they were using gestures, vocalizations, with single words emerging, and after 18 months of age, children were using all four key skills with multiple words emerging. On average, no skill declined to zero at any time up to the end-point of 36 months of age, however, many individual children did decline to zero on a particular skill. Even though children were increasingly adding new skills (i.e., words and multiple words) and decreasing their use of others (i.e., gestures and vocalizations); in most cases they continued to rely on their full range of communication skills over time. These sequential patterns of onset, acceleration to a peak, and attenuation across skills (gestures to vocalizations to single words to multiple words) were consistent with the ECI conceptual framework and convergent with prior reports the emergence of simpler language skills prior to more advanced skills (Bates & Dick, 2002). These patterns were delayed for children with IFSPs compared those without IFSPs. Children with IFSPs began using skills later, were slower to grow in each skill, and lingered longer using more basic skills (see Table 4).

This knowledge of the prototypical pattern and timing of growth in these ECI skills over this significant span of development creates an empirical basis for knowing whether or not an individual child is on track to becoming a proficient communicator – an important outcome of early childhood. Knowledge of the particular skills children use to communicate at particular ages and when they were emerging, reaching a peak, and attenuating in favor of more proficient skills emerging supported the construct validity of the ECI.

Results from the second research question produced evidence of adjacent temporal ordering of skills in terms of model fit and because nearly half of possible pathways in the model were significant. These accelerative pathways were strongest between single and multiple words, with effect sizes of 1.820 and 1.542 between single-word Slope 1 and multiple-word Slope 1 and intercept at 36 months, respectively. Similar predictions between vocalizations to single words were on the order of .507 and smaller between gestures to vocalizations (.102) (see Fig. 4).

Additional support came in the form of adjacent skill reductions or attenuations as newly developing communication skills replaced earlier prelinguistic skills to a greater extent. The negative, attenuating pathways from the second slopes of vocalization and single words to the intercepts of single and multiple words, respectively, indicated that children who continued to use earlier communication skills later in time were slower in developing their repertoire of more advanced communication skills. Of interest was the fact that progress to a peak in a skill, and the rate of attenuation in those skills also were important predictors of children's success in becoming proficient communicators over time.

Selection of a few foundational key skills to measure for progress monitoring during an age span is a standard practice in progress monitoring measurement development. However, the additional knowledge that they function as a continuum of key skills contributes additional useful information linked not only when changing intervention decisions but also to determining the most feasible interventions for a particular skill at a particular time. For example, knowing which key skills emerge earlier assists in more accurate, earlier identification of children not making expected rates of progress on skills typical of children the same age. A continuum is also useful in planning appropriate interventions; that is, those that may promote progress in firming up emerging or existing skills, and that may advance the next new skills. A continuum also supports the ECI's predictive validity because significant pathways exist between children's earlier performance on a simpler skill to a future performance on a more advanced skill. Additionally, as reported for the ECI, it provides evidence of a network of these predictive relationships between the early simpler skill, to a next more advanced skill, ending with the increasing use of multiple-word utterances and sentences in spoken language, the most proficient skill assessed by the ECI at 36 months. These results provide a basis for knowing whether or not a child is on track for reaching a future skill proficiency based on their earlier performance.

Collectively, results supported the hypothesis that the ECI key skills share properties of a continuum in growth between gestures, vocalizations, single- and multiple-word utterances. Future research designed to utilize this knowledge for benchmarking progress in learning to communicate and intervention decision making during the 6–36 age span is warranted and may prove more sensitive and useful than the ECI total communication measure currently used for these purposes. Research is needed establishing the predictive validity of these skills at 36 months of age to other criterion measures of child language, communication, and early literacy beyond 36 months of age into preschool.

4. Limitations

The dataset analyzed in this report were both cross-sectional and longitudinal in nature with missing data due to the quarterly assessment protocol linked to each child's birthdate, the start and exit of individual children from the program, and attrition. Interpreting developmental trajectories from data that are not entirely longitudinal data involves some caution in that cross-sectional data will not be fully representative of longitudinally collected data (Kraemer, Yesavage, Taylor, & Kupfer, 2000; Maxwell & Cole, 2007). However, this concern is attenuated in our combined design by the fact that all children had at least 3 or more longitudinally collected repeated measures.

The findings generalize to the population of children served by EHS in two Midwestern states, and because of standard federal eligibility policies (i.e., poverty level family income and IFSP status) perhaps generalize to the U.S. EHS population. It was not possible to examine race/ethnicity subpopulation effects in the data because this information was not collected. Future research including more advantaged samples is needed to extend these findings more broadly in the direction of a national normative sample.

The data were also collected by over 508 practitioners in 27 EHS programs during the study period rather than by professional assessors. Even though these practitioners met standards in their training and reliability, some may be concerned that this poses a risk of bias in the data. The design and intention of progress monitor measurement is that practitioners will administer the assessment and use the information to make intervention decisions. The ECI was designed for use by early childhood practitioners and they collected data at large scale in programs for this multiyear investigation. In our view, the fact that these data and findings replicated much of what is reported about children's early communication skills and growth in language strongly supports the validity of these practitioner-collected data.

While many of the theoretical pathways supported a continuum of ECI skills, not all did, and it was not clear why this was the case. The latent growth modeling approach used was based on the use of linear splines, one on each side of the intercept. Perhaps some artifact of this application to curvilinear trajectories was responsible for some counter-theoretical relationships and some alternative approaches may overcome this problem.

We also note that these data were descriptive and not experimental such that knowing whether or not an increase in one skill was causally related to increase or decrease in a subsequent skill was not possible. For example, we do not yet know if specific interventions targeting one or more of these key skills will lead to increased performance as expected as for example in an RTI approach to service delivery. This awaits additional research.

5. Implications for future research and practice

This study is important to the field because the development of progress monitoring measurement is a relatively new enterprise particularly for use with children younger than kindergarten (NAEYC, DEC, & NHSA, 2012) and the demand for it is increasing (Office of Head Start, 2012). In our opinion, these new ECI results provide an example to the field of the development, refinement, and use of such measures for universal screening and progress monitoring (Greenwood, Carta et al., 2011). This new evidence of a continuum of ECI key early communication skills illustrates a potentially important step in advancing validity, leading to additional research using these new findings to make improvements. This will, in turn, lead to better decisions about the needs and progress of individual children. We think that the questions asked provide a model for how similar prevention-oriented measures and linked intervention systems can be developed for other important domains and outcomes of early intervention, early childhood special education, and early education.

Clearly, validity studies of progress monitoring measures are needed that demonstrate sensitivity to growth over time as well as predictive validity with a future end-outcome (Fuchs, 2004). However, we also need to know whether or not these skills have any predictive relationships with one another over time (Good et al., 2001). Where a continuum of skills is shown to exist, we believe that it likely provides additional sensitivity and utility in short-term intervention decision making. This is because children who are slower to develop new skills and linger longer using earlier, less complex skills are at risk of not developing the next, more advanced skill in the continuum. These children may be at risk of achieving expected multiple-word sentences in their social conversations at the end of the ECI predictive continuum at 36 months of age and beyond.

These findings contribute to what we know about young children's language development, which is often based on smaller samples and less repeated measurement, because these ECI findings produced by practitioners align with much that is reported in the language development literature. These results also have implications for prevention-oriented intervention systems because measures like the ECI have the properties needed to support the approach (Greenwood, Bradfield et al., 2011). In conclusion, these findings extend and advance what we know about the ECI, and its ability to display growth in young children's communication. They also demonstrate progress toward a scalable approach to the collection and use of technically adequate progress monitoring data for use in prevention-oriented intervention systems like RTI. The benefit of this knowledge awaits further developments in research and practice.

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