# FROM BABY BABBLE TO CHILDHOOD CHATTER:

# PREDICTING INFANT AND TODDLER COMMUNICATION OUTCOMES

# USING LONGITUDINAL MODELING.

BY

Elizabeth K. McConnell

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Chairperson, Todd D. Little, PhD

Committee members

______________________________
Charles R. Greenwood, PhD

______________________________
Jay F. Buzhardt, PhD

The Thesis Committee for Elizabeth K. McConnell certifies
that this is the approved version of the following thesis:

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Date approved: ____________

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# Abstract

The importance of early communication development for later literacy, school achievement, and social interaction cannot be understated, according to a large body of literature. There is a consensus in the field of childhood communication that intervention could be applied earlier to prevent developmental delays from becoming disabilities. The Early Communication Indicator (ECI) measures Gestures, Vocalizations, Single Word Utterances and Multiple Word Utterances in infants and toddlers. Important information to be gained from the ECI is how key skills may predict themselves of other skills at later measurements on the ECI, which would give information to when would be the best window of intervention for children. Kansas Early Head Start programs administered the ECI quarterly to 4445 non-disabled children as part of an accountability program. Multiple imputation procedures were done on the data to recover key information. Longitudinal structural equation modeling lends itself well to this type of developmental data. Univariate panel models were applied to each of the key skills, a multivariate panel model was applied to all of the key skills integrated into a complete model, and a growth curve was used to model the growth in Total Communication (composite ECI score). Key skills predicted significantly to themselves at subsequent time points in the univariate panel model, and to themselves and others in the multivariate panel model. Total communication growth between the ages of 6 and 15 months was a significant predictor of status at 42 months. Limitations and future directions are discussed.

From Baby Babble to Childhood Chatter: Predicting Infant and Toddler Communication Outcomes Using Longitudinal Modeling

Table of Contents

List of Tables

# List of Figures

# From Baby Babble to Childhood Chatter: Predicting Infant and Toddler Communication Outcomes

Children use the symbolic system of language and communication as the primary method of understanding and operating within their physical, social, and conceptual worlds (Harwood et al., 1995). Early literacy development benefits from oral language development and preliteracy experiences prior to preschool (Hart & Risley, 1995, 1999; Wagner & Torgesen, 1987; Walker, Greenwood, Hart & Carta, 1994), and the language learning outcomes of infants and toddlers vary according to the amount of talk and diversity of vocabulary that they are exposed to (Warren & Walker, 2005; Warren, Yoder, & Leew, 2002; Yoder & Warren, 2001).

Both language and early literacy development are key to children's overall school readiness, predicting significant variance in reading achievement and overall school adjustment in the earliest elementary grades, and long-term outcomes much later in a child's school career (Snow, Burns & Griffin, 1999; Whitehurst & Lonigan, 1998). Intervention should be done as soon as possible to minimize any further effects. Waiting for failure in children means missed opportunities to develop critical skills. Language and communication disabilities are the most prevalent concerns regarding young children (Hebbeler, 2002; Hebbeler et al., 2001), and account for up to 70 percent of identified disabilities in children from ages 3 to 5 (Casby, 1989). Early intervention helps prevent developmental delays from becoming disabilities.

*Current Lack of Valid and Sensitive Measures*

Crucial for a successful intervention is the knowledge of when the best time is to intervene. A second key issue is discovering which skill the individual is having difficulties with. More specifically concerning childhood communication and language, which indicators at which time best predict early literacy later? Unfortunately, our ability to promote early language and subsequent early literacy is hampered by the lack of valid, sensitive measures of growth and progress in early communication skills. Existing measures of infants and toddlers abilities are notoriously poor predictors of later development (Gibbs & Teti, 1990). We lack the knowledge of the relevant early skills that are the precursors of later skills in preschool.

*Progress Monitoring*

There have been advances, however, in the development of a valid and sensitive measurement tool for early communication that identify those specific foundations. These newer continuous measures of progress concentrate on a few critical skills, rather than focusing mainly on being comprehensive like traditional assessments. The most appropriate and feasible of tools in special education for both individual progress and outcome reporting are continuous progress monitoring (Deno, 2002; Fuchs & Deno, 1991; Thurlow, Wiley, & Bielinski, 2003). Progress monitoring measures are constructed to be indicators, and are specifically designed for use by interventionists who use them to determine which children are not making adequate short-term progress. The underlying assumption with progress measurement is that current functioning points to future success or failure in future functioning. The goal is to individualize instruction or intervention based on the information gained from these assessments (Deno, 1997; Fuchs & Deno, 1991).

*ECI as a Progress Monitor*

The Early Communication Indicators (ECI) is one progress monitoring measure used to assess the gestures, vocalizations, single words, and multiple words of infants and toddlers. Still in development, the ECI currently meets the majority of the technical standards set by the National Center of Progress Monitoring (NCPM) and the National Council of Measurement in Education Joint Committee on Standards for Educational and Psychological Testing.

The ECI is a six minute, semi-structured, play-based assessment that uses standard toy sets as alternate test forms to monitor children's growth in expressive communication when measured on a monthly or quarterly basis. Four theoretically structured early communication skills representing prelinguistic and spoken expressive communication are coded in the course of each ECI assessment, based on review of infant and toddler communication literature (Luze et al., 2004). The skills measured are gestures, vocalizations, single words, and multiple word utterances. Gestures and vocalizations are considered prelinguistic communication, while spoken language occurs when the child begins speaking single and multiple words (Carta et al., 2004; Greenwood, Carta & Walker, 2004). The frequency of occurrence of each key skill element is recorded and converted to a rate per minute (fluency) score. A Total Communication score is computed by a weighted combination of Gestures, Vocalizations, Single Words (event frequency multiplied by 2), and Multiple Words (even frequency multiplied by 3). Weighting is used in the calculation of Total Communication to create a growth-based total communication metric given that a reduction in gestures and vocalizations occurs over time as children are acquiring spoken communication and greater proficiency with respect to desired communication outcomes. The weighted calculation also approximates an absolute estimate of total words produced by the child. Because research indicates that assessors' ability to count all words within each multiple word utterance is difficult and unreliable as word utterances became more frequent (Luze et al., 2001), single and multiple word events were used in the ECI instead of total word frequency.

*ECI Administration*

Administration of the 6-minute play-based ECI involves a familiar adult who is trained to interact as a play partner with a child. The play session takes place in a home or a child care classroom in a setting with minimized distractions. The assessor times the session duration for six minutes using a digital timer capable of recording minutes and seconds. During an ECI session, the play partner encourages 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 expressive communication, the play partner does not direct or lead, but instead supports the child's communicative behavior through encouragement and interest.

*Technical Adequacy of the ECI*

Current ECI development and validation is based on (a) a national survey of parents of children with disabilities and professionals in early childhood and early childhood special education to identify a set of socially valid and desired general outcomes for young children (Greenwood et al, 2004; Priest et al, 2001), (b) studies documenting the basic psychometric properties and feasibility of the indicators, including longitudinal, cross-sectional studies illustrating sensitivity to growth over time (Carta et al, 2004; Greenwood et al., 2004; Greenwood et al, 2002; Luze, Greenwood, Carta, Cline & Kuntz, 2002; Luze et al., 2001), and (c) single-case design studies showing sensitivity to short-term exposures to specific early interventions (Greenwood, Dunn, Ward & Luze, 2003; Kirk, 2006; Kosanic, 2000; Murray, 2002).

*Reliability and Validity of the ECI*

Reported indices of the reliability of the ECI include inter-observer agreement (90% mean overall) and test-retest total communication score reliability ($r$=.89) based on odd vs. even measurement occasions (Greenwood et al., 2004). In addition, the reported concurrent validity of ECI Total Communication is $r$=.62 with the Preschool Language Scale (PLS-3) and $r$=.51 with a researcher developed parent checklist for child communication skills (Greenwood et al., 2004). A similar finding with the ECI Total Communication and the PLS-4 indicated correlations of $r$=.74 when looking at the PLS age equivalent score (Walker, Carta & Baggett, 2006).

*ECI's Sensitivity to Growth*

The measurement of growth in early communication over time is clearly demonstrated with the ECI (Greenwood, Carta, Walker, Hughes et al., 2006; Greenwood et al., 2003). Mean 36-month intercept and linear slope for children four to thirty six months are: 19.1 communications per minute and 0.59 per minute per month for the normative sample ($N$=1,486), 20.5 per minute and 0.64 per minute per month for the normative sample of children without identified disabilities (*n*=1297), and 13.9 per minute and 0.47 per month for the normative sample of children with some type of identified disability.

*Need for Predictive Validity*

The ECI has been shown here to be a reliable, valid, and sensitive instrument to measure early childhood communication. However, studies have not been conducted to demonstrate its predictive validity. Predictive validity is the extent to which a score on a scale or a test predicts scores on some later criterion measure. Specifically related to the ECI, it is the property of a key skill taken in the early stages of child development to predict communication and literacy outcomes later in childhood. Based on predictive relationships, cut points on progress monitoring measures can be used as decision-making benchmarks (Good, Simmons, & Kameemei, 2001; Good, Simmons, Kameemei, Kaminski & Wallin, 2002).

*Research Aims*

The demonstration of predictive validity requires a longitudinal multivariate study of growth and development over time. The specific aim of this research effort was to conduct such a study capable of providing the needed predictive validity evidence in support of ECI progress monitoring for infants and toddlers. The four ECI key skill elements (gestures, vocalizations, single words and multiple word utterances) and total communication fluency scores recorded longitudinally in a sample of infants and toddlers 6 through 36 months of age should predict subsequent early language and literacy outcomes. Examining predictive relationships both within and between key skills through a variety of statistical techniques will provide information about how key skills may predict to themselves, and to other key skills.

Although this specific study has not been conducted previously, there are smaller-scale, preliminary findings that help guide the hypotheses. Certain patterns are expected to emerge for each of the key skills, including stages of rapid growth and periods of relative stability. Since measurement begins at the infancy stage, the frequency of gestures and vocalizations will be much higher compared to single words and multiple word utterances. The period between 6 and 12 months of age consists of pre-linguistic communication. Meaningful growth for single words should begin around 15 months of age, while multiple words will start to dramatically increase around 20 months. If these increases occur, this would also mean that the computed Total Communication score would improve as age increases as well.

Gestures are hypothesized to be predictors of subsequent vocalizations. Gestures occur at about one per minute at six months of age, with this rate remaining relatively stable throughout the entire age range up to forty-two months. Vocalizations, however, typically demonstrates a rapid acceleration that begins to peak soon after twelve months of age. At this age, spoken communication (single words and multiple words) have not yet emerged for most children. This known information suggests that gestures may be a predictor and benchmark for subsequent growth in the use of vocalizations in communication.

The communication profile in the 12 to 24 month period begins with a rapid acceleration in vocalization fluency while children have not yet produced single or multiple words. By 24 months, vocalization fluency has begun a decline, as single word fluency begins rapid acceleration. This acceleration in multiple word fluency begins seven to eight months later. This knowledge suggests that vocalizations may be a predictor and benchmark for subsequent success using single words.

Communication changes markedly in the period between 24 and 36 months of age. Single word fluency accelerates rapidly in this period while multiple word fluency is just beginning to grow. By 36 months the rate of multiple word utterances has surpassed the rate of single word utterances, which has stabilized. These findings suggest single word fluency may be a predictor and benchmark for subsequent success communication in phrases and sentences (multiple word utterances).

Combining the demonstration of predictive validity with existing evidence of the technical adequacy of the ECI will improve our understanding of its technical properties. Advancing the technical standards of the Early Communication Indicator will also improve this progress monitoring measure’s decision-making utility.

The current research is innovative in several ways. It builds on and extends ground breaking development of progress monitoring measures for infants and toddlers. This work will lead to an improved understanding of the precursors of language and literacy, the continuum of skills from infancy into preschool. This improved understanding will advance a practical measurement approach where early interventionists can achieve greater individualization in the programs with children who have special needs. By tuning into the key skills in infants and toddlers which best predict later communication and literacy outcomes, it will promote alignment of early education and the early childhood special education system with the K-12 school system in goals, objectives, and practice. The long-term goal of this research agenda is to reduce the number of children who are not ready for school because of delays and disabilities in language, communication, and pre-literacy skills that can be identified during the infant and toddler years.

# Method

## Participants

All children and parents are from a population of children enrolled in 13 participating Kansas Early Head Start programs reflecting urban, suburban, and rural localities. The average number of children in an Early Head Start program is 68, ranging from 26 to 144. The total number of children participating in this data collection was 4826. 08% of children enrolled in KEHS are identified as having some type of developmental delay. Children are identified as having a disability based on whether or not they are party of an Individualized Family Service Plan (IFSP), which is intended to assist those with developmental delays in the EHS system. However, these children with that distinction were not included in these analyses; the current study aimed to examine typically-developing children only. The number of children included, after removing those with a disability from analyses, was N=4445.

Children were randomly selected to represent gender and ethnicity from all thirteen programs. 54% of the children were female. Children were from families reporting their race as Euro-American, 51%; Hispanic, 18%; African American, 16%; bi-racial or multi-racial, 11%; other or unspecified, 2.5%; Native American 1%; and Asian 0.5%. English was spoken as the primary language at home for 89.3% of children, followed by 10.2% Spanish, and 0.5% other. The ages of the children, guided by the design of the study, range from 6 months to 42 months of age. The mean age of children at the beginning of the study was 11.2 months. From 13 local programs, 111 local staff members (ranging from 1 to 19 per program) became certified ECI assessors, meaning they were certified to administer and score the ECI.

## Administrative Procedures

*Assessors and training.* Assessors (program advocates and/or home visiting staff) learned to administer the ECI and code children's key skill elements to required standards of reliability. To be certified as an administrator, assessors were required to practice administering the ECI using standard procedures (following the ECI Administration Fidelity Checklist, see Appendix A), then submit a videotape of their administration for review and scoring by ECI developers. Text materials, followed by repeated practice with a certified ECI assessor was used to scaffold each learner's progress and provide corrective feedback. Certification as an ECI administrator was achieved when a score of 85% or greater was obtained on the ECI Administration Fidelity Checklist. To be certified to record child communication skills during ECI administrations, trainees were required to calibrate scoring of the key skill elements against two master-coded videotape standards. Certification was achieved when agreement scores of 85% or higher were recorded for child communication during an ECI administration.

ECI assessors were trained by the research team to a criterion of 85% overall agreement on videotapes that had been master coded by ECI developers. In addition to this ECI assessor training, staff were taught to use the ECI in a trainer-of-trainers model. Following initial training at each program site, each trainee was calibrated on their ECI administration fidelity and accuracy recording of child communication to the certification standard.

*IGDI website data collection.* Data collected from Kansas Early Head Start programs were entered into a security protected website and populated a central Oracle database containing the data from all programs. Direct entry of data into the child data system by assessors is online at *http://www.igdi.ku.edu/data_system/index.htm* (see Appendix A). User ID and password are required to access the child data system. This website also contains administration and scoring instructions and procedures online at *http://www.igdi.ku.edu/training/ECI_training/ECI_Administration_Checklist-2005.pdf* and *http://www.igdi.ku.edu/measures/ECI_Meausres/scoring.htm*.

*Interrater agreement*. The mean frequency ratio agreement overall was 94% for Total Communication (range 88 to 100% across programs). Similar agreement values for the key skill elements were Gestures, 87%; vocalizations, 89%; single-word utterances, 95%; and multi-word utterances, 96%.

*Observations*. The goal for frequency of ECI administration was once per month if the child fell below benchmark. All programs screen all children quarterly with the ECI as part of the ongoing program services and accountability plan.

The expected standard for ECI administration time is 6 minutes. This minimum criterion led to the removal of 9 data points with durations less than 5 minutes. The examination of distributional properties of the children's total communication scores to identify outliers resulted in removal of 52 (1%) outliers falling higher than 3 SD's above the raw mean. This upper limit was set at 43 communications per minute, with the most extreme observed outlier score at 73.5.

Analytic Procedures

In order to assess the predictive validity of the four key skill elements (Gestures, Vocalizations, Single Words, and Multiple Words) and Total Communication for the ECI, a variety of techniques within the structural equation modeling framework are employed. Missing data imputation was done before other analyses were executed.

*Missing data imputation.* Developmental research, which is often done by collecting longitudinal data, is especially vulnerable to missing data due to nonrandom attrition. This present study is no exception. Managing missing data in regard to either the individual or the context allows the researcher and analyst to recover key information (Schafer & Graham, 2002).

The total possible number of ECI observations is 16,020 if every one of the 1,335 children had received all 12 ECI assessments. The median number of ECI observations per child was 3, ranging from 1 to 12. The total number of ECI observations contributing to data analyses (before missing data imputation) was 3952. The mean number of data points available per each month of age at test was 115.

There are several methods for estimation of missing data. For a more thorough discussion, please see Hofer & Hoffman, 2007. Multiple imputation (MI; Rubin, 1987) fills in missing values based on regression-predicted values, where all other variables in the missing data model serve as predictors, along with a random error term. A series of “complete” data sets are generated from the missing data model, and then aggregated into a final data set. For the present ECI data, multiple imputation was carried out in the SAS program version 9.1.3 with the PROC MI procedure. Through a series of 13 imputations in the multiple imputation process, key information was recovered for every measurement at three-month intervals. Three month intervals were used as opposed to every month time point to ease in model estimation. In addition, in the imputation process, these three-month intervals had the most original data (corresponding roughly to the quarterly measurement process), and more accurate data recovery was done by imputing at these time points.

*Using structural equation modeling.* One of the goals of longitudinal structural equation modeling is to evaluate any hypothesized direct or indirect effects over time. Panel data, also called cross-sectional time series data, are data where multiple cases (in this instance an infant or toddler) were observed at two or more time periods. This data provides both between and within subjects information (Little, Preacher, Selig, & Card, in press). The present study with longitudinal data from ECI observations was a natural fit for this type of modeling.

*Longitudinal panel model: univariate.* Before examining the relationships between the four key skills, it was important to note the relationship across time within each of the elements themselves. Modeling one key skill at a time while including all 12 data time points (6 through 42 months) allowed us to examine how a data point at one occasion of measurement may be related to information in a subsequent measurement occasion. For example, looking at how gestures at 9 months are related to gestures at 18 months of age. Four models were run for each of the key skill elements and total communication, for a total of twenty univariate longitudinal models (see Figure 2). The $R^2$ coefficient, or the Squared Multiple Correlation, indicates the amount of variance explained. The significance of amount of explained variance for each month within each model was noted. Judging the significance of the different autoregressive pathways in the univariate model provides us with foundational information for modeling these same pathways in the multivariate model. In addition to providing information about the individual key skills which is useful in and of itself, the univariate longitudinal panel model assists in the more complex model which includes all of the key skills.

*Longitudinal panel model: multivariate.* In addition to modeling direct or indirect effects over time, longitudinal structural equation modeling allows the examination of cross-lagged effects as well. Cross-lagged effects are employed in multivariate longitudinal panel models to examine relationships among time points between different variables. For example, examining how vocalizations at six months may influence multiple word utterances at 18 months.

The present data were set up into a large multivariate panel model with all time points of each of the four key skill elements included. The observed data were treated themselves as latent constructs (i.e., Etas), which provided a total of 48 Eta’s. For each of the four key skills, first and second order autoregressive relationships were permitted. In addition to these relationships for all time points, third and fourth order autoregressive relationships were permitted to predict to the 42 month outcome variables. Second order cross-lagged relationships were estimated for vocalizations to single words and single words to multiple words. Modification indices for Beta were examined after running this initial model. For a modification index greater than 100 where the relationship was of first, second, or third order status, the parameter was freed whenever if there was already a prediction occurring closer in time. Following this model, all modification indices above a value of 500 (a total of 5) were subsequently freed.

*Growth curve model: Total Communication*. In order to examine the change of total communication over time, which is a composite score of the other four key skills of the ECI, a growth curve model determines the trajectory of scores over time. The latent growth curve model represents the change (shape), status (intercept) and change points (when indicated) for total communication. Determining the points of change is easily done by examining a plot of the means as they progress over time. The most reasonable change points (intercepts) were determined to occur at 18 and 36 months. Data from 6 to 15 months leads to the status at 18 months, and observations between 21 and 33 months lead to the status at 36 months. These two level and shapes all lead to the outcome at 42 months. All analyses for the panel models and the growth curve model were carried out in LISREL version 8.80.

# Results

A simple examination of the means shows that the hypothesized growth as time progresses for the four key skills and total communication occurred in the manner which was expected. Gestures were relatively stable across time. Vocalizations experience a burst of growth between 6 and 15 months, level off until 21 months, then gradually decrease for the duration of the study. Both single and multiple word utterances experience rapid growth after several months, with the onset of multiple words experiencing later onset and a faster rate of growth when compared to single words. See Figure 1 and Table 1.

## Univariate Longitudinal Panel Model

Analyzing the four key skills and total communication individually as to how they predict to their own subsequent time points involved a univariate longitudinal panel model, and examination of the significant of the R-square statistic. All four key skills and total communication models were run using first-, second-, third-, and fourth-order predictive pathways.

These twenty individual models produce Squared Multiple Correlation Coefficients (R-squared), which provide information about the amount of variance explained. For the first-order models, every pathway was found to be significant for all key skills and total communication. The majority of pathways in the second, third, and even fourth order models were statistically significant. See Table 2. When looking at the model that includes first- through fourth-order pathways (see Figure 3), we can see the relationships between the time points for each key skill and total communication individually. All of the outcome measures have prior data significantly predicting to them; all time points are significant predictors for vocalizations, multiple words, and total communication. Gestures and single words have the vast majority of their data time points significantly predicting to 42 months. In order to interpret these effects in the broader context when they are all included in the same model, the multivariate longitudinal panel model is employed. Not only do these models give us information about the individual components of the ECI, they aid in the estimation of the multivariate model. The consistent significance of the fourth-order pathways justifies the inclusion of this type of pathway in the larger model.

Multivariate Longitudinal Model

The multivariate longitudinal panel model includes all of the four key skills in order to estimate indirect and direct effects both within elements and between. The model, which is set up to conceptualize all elements as latent despite their direct observation, is detailed in Figure 4. This sizeable figure can be systematically reduced for interpretation to the direct effects within key skills, indirect relationships within key skills, direct relationships removed by one time point between key skills, the third- and fourth-order pathways predicting to 42 months, and finally the significant pathways estimated because of a large modification index.

The direct, first-order pathways within key skills reveal the influence that a measurement at a specific time point may have on an adjacent time point. The relationships between adjacent time points appear to be fairly stable across time within key skills. There is less of a relationship between the 6 and 9 month measurement occasions for vocalizations, single words, and multiple words. Between 9 and 36 month measurements the Beta's are consistent within a range of 0.20 and 0.56. Beta pathways between 36 and 42 months become small, with the ones for gestures and vocalizations in the negative range (Table 3).

Second-order pathways within key skills show the same type of information that the first-order pathways do, only the prediction is further out in time. Within each key skill, second-order autoregressive relationships are allowed. Examining these pathways shows that the majority of these are significant, even when removed one time point from one another (Table 4). Single and multiple words contain the only non-significant pathways, which occurs during the time of childhood before talk has started.

Vocalizations were hypothesized to predict subsequent single word utterances, and single word utterances to subsequent multiple word utterances. Thus, direct relationships removed by one time point were estimated for these by key skills. It should be noted that a relationship where gestures predict to vocalizations was hypothesized also, but the pathways are non-significant in the model, and were subsequently removed. For vocalizations to single words however, there are significant Beta pathways. Every second-order cross-lagged pathway between vocalizations and single words was found to be significant. There were similar results for single words predicting to the next time point of multiple words, and even for two time points removed. After estimating the second-order cross-lagged relationships between single and multiple words, third-order relationships were added to the model based on a consistent pattern of large modification indices (Table 5).

All key skills had third- and fourth-order predictive elements added, that predict to the 42 month outcome variables. Each of these Beta pathways are significant, meaning that the 42 month measurement is significantly influenced by the 27 and 30 month measurement occasions for each of the key skills (Table 6).

After all previously discussed pathways were estimated, the modification indices for this model were examined. A modification index aids in the identification of non-estimated pathways that may actually be of true significance in the model. Every pathway with a modification index greater than 100 for Beta was estimated if it was theoretically sensible. The types of pathways estimated based on this information are cross-lagged and generally more than one time point removed from one another (Table 7 for complete information).

Growth Curve Model for Total Communication

The growth curve model for total communication seeks to determine the trajectory of growth over time. The “notch” points, or the times at which the pattern of growth changes, are at 18 and 36 months for the total communication score. The two level and shape models predict out to a 42 months status point.

The estimates in the model accurately recreate the means for the different occasions of measurement (within rounding error), and capture an upward trend of growth as time continues. The grand mean is 21.61; the change between 6 months and 18 months is equal to 5.02, and the change from 21 to 36 months is 11.13. The shape (slope) between 6 and 18 months is a significant predictor of the total communication score at 42 months, as is the status of a child at 18 months. The slope between 21 and 36 months and status at 36 months are not significant predictors of total communication at 42 months. See Figure 5.

## Discussion

Through the simple visual inspection of the plot of means, not only does it confirm that children generally improve in communication skills over time, it also tells us that this sample of 1,335 children was appropriately responsive to the ECI measurement. The trends obtained by this Kansas Early Head Start sample match those reported as normative data from the ECI (Carta et al., 2004; Greenwood, Carta & Walker, 2004). This allows for confidence in subsequent data interpretation.

In the univariate models for each individual key skill and total communication, nearly all $R^2$ coefficients are significant. The information in Table 2 indicates the very few estimates that are non-significant. These numbers tell us that a time point that is four measurement occasions removed (one year in this data) can still have a significant predictive impact on a later data point. For example, in the model with fourth-order relationships for vocalizations, the rate of vocalizations at 18 months is a significant predictor of that same key skill at 30 months of age. This information provides further support for the need of frequent developmental measurement and intervention as soon as possible to identify deficits and to prevent further delays (Hebbeler, 2002; Hebbeler et al., 2001).

The large amount of data collected for these children is most concisely portrayed by the multivariate longitudinal model. The wealth of information presented in this model is describing many relationships between the four elements that compose the ECI.

Significant direct pathways within key skills show that one time point has a strong influential relationship with the subsequent data point for that same skill. For instance, the significant Beta of 0.51 between gestures at 9 and 12 months indicates that 12-month olds' gestures have a significant positive relationship with 9-month olds' gestures. This same type of influence is repeated through the majority of the direct pathways, with the exception of two. The 36 and 42-month pathways for both gestures and single words are on-significant. For these two relationships, there are evidently no significant predictions made from the 36 month data. For these two key skills, children appear to be either gaining or losing abilities not based on the previous measurement at this age. The 42-month data do have significant predictors for all key skills however, even if it was not the previous time point at 36 months. Both 27 ($4^{th}$ order relationship) and 30 month ($3^{rd}$ order relationship) were significant predictors of the outcome variable (Table 6). The indirect pathways within key skill show how one time point can influence not only the measurement occasion directly following, but skills further out in time as well. Nearly all of these types of pathways within the model are significant (Table 4).

The cross-lagged relationships can be interpreted in much the same way, although they are referring to relationships between skills and not within. These types of pathways were estimated for gestures predicting to one time point later of vocalizations, vocalizations predicting to one time point later of single words, and single words predicting to one and two time points later of multiple words (Table 5). The relationships between gestures and vocalizations were non-significant, and thus removed from the model. This finding rejects the idea that gestures predict subsequent vocalizations, as previously hypothesized for this study.

It appears however that the hypotheses for vocalizations predicting to single words and single words predicting to multiple words are supported. Not only do single words predict multiple words one measurement occasion later, but there is a consistent pattern of large modification indices indicating that this relationship held for the second-order cross-lagged effect as well. Vocalizations predicting to single words is an interesting relationship, since this is a non-linguistic act predicting a linguistic action. Language development does require prior learning, and talking starts with sounds and not automatic words. This data would suggest that the non-word sounds aid in the development of simple verbal communication. This same type of logic can be applied to single words predicting multiple words. Single words are the building blocks that children (and other aged populations) need for phrase and sentence formation, so it is very logical that successes with single words could lead to successes using multiple words. The idea of simpler elements of speech being precursors and supporters of more complex statements is supported by many noted and widely-accepted theories of language (Santrock, 2001).

Within this model after estimating the pathways included in the hypotheses, it was expected that there would be some significant relationships which also require estimation. Relying on the information from modification indices, these pathways were freely estimated (Table 7). Many of these pathways were for more complex skills predicting to "easier" skills within one to three time points from one another.

For example, multiple words at 15 months significantly predicts a negative relationship to gestures at 18 months. As children become more proficient at linguistic behaviors, they appear to need simpler expressions like gestures and vocalizations less since they can now more effectively communicate using words. An example of a different kind of relationship, one of a positive nature, can be seen between multiple words at 15 months to single words at 24 months. Even though single words are the foundation for phrase-forming, multiple word rate is influencing subsequent single words. This relationship could be evidence in support of a general underlying ability, where children who are doing well in one key skill generally perform well on others and vice versa. Multiple words at 36 months is one measurement that appears to be incredibly influential on multiple outcomes (i.e., all of the 42 month key skill measurements). Theoretically, around 36 months of age is a crucial time period for language development. Age three is generally when most children begin preschool, show phonological awareness, notice rhymes, and recognize morphological rules. They become much more sensitive to the sounds of spoken words (Santrock, 2001; National Research Council, 1999). Success in multiple words at this age could lead to a better understanding of all skills at the next time point of measurement.

Total communication, the composite score of the other four ECI elements, experiences near steady growth as time continues between 6 and 42 months. It appears that only the slope (rate of change) between 6 and 18 months and the status at 18 months are significant predictors of total communication at 42 months. The child’s rate of change between 21 and 36 months of age and their status at 36 months are not significantly predicting to 42 months. It appears that, for total communication, the early months are predicting more stronger than the months directly prior to the outcome measurement.

The major overarching goal of this study was to demonstrate the predictive validity of the ECI. Predictive validity is the extent to which a score on a scale or a test predicts scores on a later criterion measure. The ability of early measurements to predict 42-month outcomes has been repeatedly demonstrated in this data for all four key skills. This longitudinal multivariate study of growth and development over time provides validity evidence in support of ECI progress monitoring for infants and toddlers, and improves understanding for an advancement from the current measurement approach.

## Limitations

The large sample size in this data collection and previously mentioned findings provide support for the generalizeability of this study to children enrolled in Early Head Start, but it is possible that the same patterns of growth and change would not hold for a truly typical sample. Early Head Start children are generally characterized by a disadvantaged socioeconomic status.

The growth curve model for total communication does provide much information about the rate of change and predictive qualities of the total communication measure. However, each of the key skills has its own unique pattern of growth. Repeating a growth curve model for each of the four key skills would be a more accurate portrait of the way these measures are truly behaving.

Although these models collectively provide a wealth of information regarding the predictive qualities of the ECI language measure, there are many possibilities for this data. These models concentrate on data from both males and females. A comparison of models done individually for males and females could lead to a better understanding of possible gender differences existing in communication development. Also, these models concentrate on a population identified as developing with normal progression, possessing no identified disabilities or significant developmental delays. There is a large population of children with identified disabilities, who deserve the same amount of quantitatively sound research as those in the "normal" population. This modeling of that type of data could be very helpful in aiding the instruction and monitoring of those children with disabilities. This type of scientific rigor applied to specific populations of children with disabilities would be the optimal method.

## Conclusions

Specifically, I have shown that a child's performance at an early time point not only influences their ability to perform at the subsequent measurement, but much further out in time as well. Predictive relationships are not isolated to within a specific skill on the ECI measure; scores have the capability of predicting to other key elements. Skills which are building blocks of more complex language are necessary before moving onto elements such as phrase-building. Even the successes of difficult tasks at an early age influence how a child may perform on a more basic skill at a later date. This knowledge is reaffirmed when examining the strong predictors in the growth curve model of the composite total communication score. Armed with this information, educators, caregivers, and other strategists can make the case for early monitoring and interventions.

The long term goal of this research, which is to reduce the number of children who are not ready for school because of delays and disabilities in language, communication, and literacy skills that have precursors in the years prior to preschool, is now closer because of the knowledge gained from the longitudinal ECI data.

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Table 1

*Means and Standard Deviations for Key Skills and Total Communication*

| Month | Gestures | | Vocalizations | | Single Words | | Multiple Words | | Total Communication | |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 1.18 | (1.10) | 1.37 | (1.55) | 0.01 | (0.26) | 0.03 | (0.57) | 2.66 | (3.01) |
| 9 | 1.32 | (1.20) | 2.05 | (1.90) | 0.05 | (0.44) | 0.03 | (0.34) | 3.57 | (2.82) |
| 12 | 1.51 | (1.30) | 3.13 | (2.39) | 0.14 | (0.43) | 0.03 | (0.34) | 5.01 | (3.37) |
| 15 | 1.71 | (1.31) | 3.32 | (2.41) | 0.43 | (0.87) | 0.09 | (0.58) | 6.18 | (4.08) |
| 18 | 1.68 | (1.36) | 3.38 | (2.43) | 1.08 | (1.35) | 0.15 | (0.54) | 7.66 | (4.79) |
| 21 | 1.57 | (1.25) | 3.32 | (2.31) | 1.90 | (1.80) | 0.59 | (1.21) | 10.46 | (6.70) |
| 24 | 1.44 | (1.31) | 2.81 | (2.29) | 2.48 | (2.30) | 1.41 | (2.17) | 13.45 | (9.66) |
| 27 | 1.35 | (1.31) | 2.37 | (2.00) | 2.78 | (2.05) | 2.27 | (2.50) | 16.10 | (9.65) |
| 30 | 1.27 | (1.24) | 1.98 | (1.95) | 2.79 | (1.91) | 3.23 | (3.35) | 18.52 | (11.58) |
| 33 | 1.33 | (1.26) | 1.70 | (1.74) | 2.86 | (1.86) | 4.09 | (3.35) | 21.02 | (11.59) |
| 36 | 1.34 | (1.32) | 1.65 | (1.79) | 2.81 | (1.68) | 4.45 | (3.20) | 21.98 | (10.74) |
| 42 | 1.59 | (1.76) | 1.22 | (2.02) | 2.91 | (1.79) | 5.21 | (4.07) | 24.25 | (12.62) |

Table 2

*Significance of $R^2$ for Univariate Longitudinal Panel Models*

| | 1st Order | 2nd Order | 3rd Order | 4th Order |
|---|---|---|---|---|
| **Gestures** | | | | |
| 6 months | - - | - - | - - | - - |
| 9 months | 0.18 | - - | - - | - - |
| 12 months | 0.27 | 0.29 | - - | - - |
| 18 months | 0.10 | 0.14 | 0.15 | - - |
| 21 months | 0.16 | 0.17 | 0.18 | 0.18 |
| 24 months | 0.11 | 0.15 | 0.15 | 0.16 |
| 27 months | 0.23 | 0.26 | 0.26 | 0.26 |
| 30 months | 0.20 | 0.23 | 0.23 | 0.24 |
| 33 months | 0.15 | 0.17 | 0.17 | 0.17 |
| 36 months | 0.23 | 0.24 | 0.25 | 0.25* |
| 42 months | 0.22 | 0.22 | 0.23 | 0.23 |
| **Vocalizations** | | | | |
| 6 months | - - | - - | - - | - - |
| 9 months | 0.02 | - - | - - | - - |
| 12 months | 0.06 | 0.07 | - - | - - |
| 18 months | 0.12 | 0.13 | 0.13 | - - |
| 21 months | 0.16 | 0.16 | 0.17 | 0.17 |
| 24 months | 0.14 | 0.15 | 0.15 | 0.15 |
| 27 months | 0.15 | 0.21 | 0.21 | 0.21 |
| 30 months | 0.21 | 0.23 | 0.23 | 0.23 |
| 33 months | 0.15 | 0.18 | 0.18 | 0.19 |
| 36 months | 0.21 | 0.25 | 0.26 | 0.26 |
| 42 months | 0.19 | 0.22 | 0.23 | 0.23 |
| **Single Words** | | | | |
| 6 months | - - | - -* | - -* | - -* |
| 9 months | 0.02 | - - | - - | - - |
| 12 months | 0.04 | 0.04 | - - | - - |
| 18 months | 0.10 | 0.11 | 0.11 | - - |
| 21 months | 0.08 | 0.08 | 0.08 | 0.08* |
| 24 months | 0.22 | 0.24 | 0.24 | 0.24 |
| 27 months | 0.17 | 0.17 | 0.20 | 0.20 |
| 30 months | 0.23 | 0.25 | 0.25 | 0.25 |
| 33 months | 0.11 | 0.13 | 0.13 | 0.13 |
| 36 months | 0.17 | 0.18 | 0.19 | 0.19 |
| 42 months | 0.16 | 0.17 | 0.18 | 0.18 |
| **Multiple Words** | | | | |
| 6 months | - - | - - | - - | - - |
| 9 months | 0.00 | - - | - - | - - |
| 12 months | 0.38 | 0.38 | - - | - - |
| 18 months | 0.25 | 0.51 | 0.52 | - - |
| 21 months | 0.17 | 0.17 | 0.17 | 0.17 |
| 24 months | 0.11 | 0.17 | 0.19 | 0.19 |
| 27 months | 0.25 | 0.26 | 0.26 | 0.26 |
| 30 months | 0.36 | 0.37 | 0.37 | 0.38 |
| 33 months | 0.31 | 0.33 | 0.33 | 0.33 |
| 36 months | 0.50 | 0.51 | 0.51 | 0.51 |
| 42 months | 0.37 | 0.40 | 0.42 | 0.42 |

* *All $R^2$ significant unless noted.*

Table 3

*First-order Beta Pathways from the Multivariate Panel Model*

| | 6 to 9 | 9 to 12 | 12 to 15 | 15 to 18 | 18 to 21 | 21 to 24 | 24 to 27 | 27 to 30 | 30 to 33 | 33 to 36 | 36 to 42 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gestures | 0.45 | 0.51 | 0.20 | 0.35 | 0.21 | 0.44 | 0.35 | 0.31 | 0.44 | 0.44 | -0.03* |
| Vocalizations | 0.19 | 0.29 | 0.33 | 0.35 | 0.33 | 0.28 | 0.34 | 0.28 | 0.32 | 0.34 | 0.26 |
| Single Words | -0.50 | 0.21 | 0.45 | 0.40 | 0.55 | 0.48 | 0.37 | 0.23 | 0.36 | 0.32 | 0.03* |
| Multiple Words | -0.30 | 0.50 | 0.44 | 0.38 | 0.22 | 0.54 | 0.45 | 0.56 | 0.59 | 0.37 | -0.12 |

* *All Beta estimates significant as determined by the z-score unless noted.*

Table 4

*Second-ordert Beta Pathways of the Second Order for the Multivariate Panel Model*

| | 6 to 12 | 9 to 15 | 12 to 18 | 15 to 21 | 18 to 24 | 21 to 27 | 24 to 30 | 27 to 33 | 30 to 36 | 33 to 42 |
|---|---|---|---|---|---|---|---|---|---|---|
| Gestures | 0.16 | 0.25 | 0.15 | 0.23 | 0.17 | 0.19 | 0.14 | 0.31 | 0.09 | 0.15 |
| Vocalizations | 0.11 | 0.11 | 0.08 | 0.07 | 0.24 | 0.13 | 0.18 | 0.28 | 0.17 | 0.15 |
| Single Words | 0.14 | 0.05* | 0.04* | 0.08 | 0.09 | 0.18 | 0.14 | 0.23 | 0.10 | 0.05 |
| Multiple Words | -0.14 | 1.22 | -0.01* | 0.63 | 0.24 | 0.02* | 0.17 | 0.56 | 0.22 | 0.25 |

* *All Beta estimates significant as determined by the z-score unless noted.*

Table 5

*Beta's for Cross-Lagged Relationships in Multivariate Panel Model*

| | Vocalizations predicting to Single Words | Single Words predicting to Multiple Words |
|---|---|---|
| 6mo. to 9 mo. | 0.02 | -0.05* |
| 6mo. to 12mo. | - - | 0.45 |
| 9mo. to 12mo. | 0.02 | 0.11 |
| 9mo. to 15mo. | - - | -0.20 |
| 12mo. to 15mo. | 0.03 | 0.12 |
| 12mo. to 18mo. | - - | 0.01* |
| 15mo. to 18mo. | 0.09 | 0.06 |
| 15mo. to 21mo. | - - | 0.08 |
| 18mo. to 21mo. | 0.09 | 0.27 |
| 18mo. to 24mo. | - - | 0.25 |
| 21mo. to 24mo. | 0.08 | 0.33 |
| 21mo. to 27mo. | - - | 0.38 |
| 24mo. to 27mo. | 0.10 | 0.37 |
| 24mo. to 30mo. | - - | 0.04 |
| 27mo. to 30mo. | 0.05 | 0.16 |
| 27mo. to 33mo. | - - | 0.15 |
| 30mo. to 33mo. | 0.13 | 0.19 |
| 30mo. to 36mo. | - - | 0.10 |
| 33mo. to 36mo. | 0.10 | 0.09 |
| 33mo. to 42mo. | - - | 0.31 |
| 36mo. to 42mo. | 0.32 | -0.13 |

* *All Beta estimates significant as determined by the z-score unless noted.*

Table 6

*Beta's for Third and Fourth Order Pathways Predicting to 42mo. Outcomes, Multivariate Panel Model*

| | 30mo. predicting to 42mo. | 27mo. predicting to 42mo. |
|---|---|---|
| Gestures | 0.29 | 0.16 |
| Vocalizations | 0.08 | 0.05 |
| Single Words | 0.31 | -0.10 |
| Multiple Words | 0.27 | 0.21 |

*All Beta estimates significant.*

Table 7

*Beta Pathways for Estimations Based on Modification Indices*

| Estimated Pathway | Beta Estimate |
|---|---|
| Single Wrds. 6mo. to Voc. 9mo. | -0.50 |
| Multiple Wrds. 6mo. to Voc. 9mo. | -0.30 |
| Multiple Wrds. 6mo. to Single Wrds. 42mo. | -1.11 |
| Multiple Wrds. 9mo. to Voc. 18mo. | -0.96 |
| Multiple Wrds. 12mo. to Single Wrds. 15mo. | 0.45 |
| Multiple Wrds. 15mo. to Gestures 18mo. | -0.46 |
| Multiple Wrds. 15mo. to Single Wrds. 24mo. | 0.60 |
| Multiple Wrds. 15mo. to Voc. 42mo. | -1.36 |
| Voc. 18mo. to Multiple Wrds. 27mo. | 0.11 |
| Gestures 21mo. to Multiple Wrds. 42mo. | -0.81 |
| Voc. 21mo. to Gestures 42mo. | -0.23 |
| Single Wrds. 24mo. to Voc. 27mo. | -0.12 |
| Single Wrds. 33mo. to Voc. 42mo. | -0.33 |
| Gestures 33mo. to Single Wrds. 42mo. | 0.19 |
| Gestures 36mo. to Multiple Wrds. 42mo. | 0.57 |
| Multiple Wrds. 36mo. to Single Wrds. 42mo. | 0.11 |
| Multiple Wrds. 36mo. to Voc. 42mo. | 0.04 |
| Multiple Wrds. 36mo. to Gestures. 42mo. | -0.12 |

*All Beta estimates significant.*

*Figure 1.* Means by key skill over time.

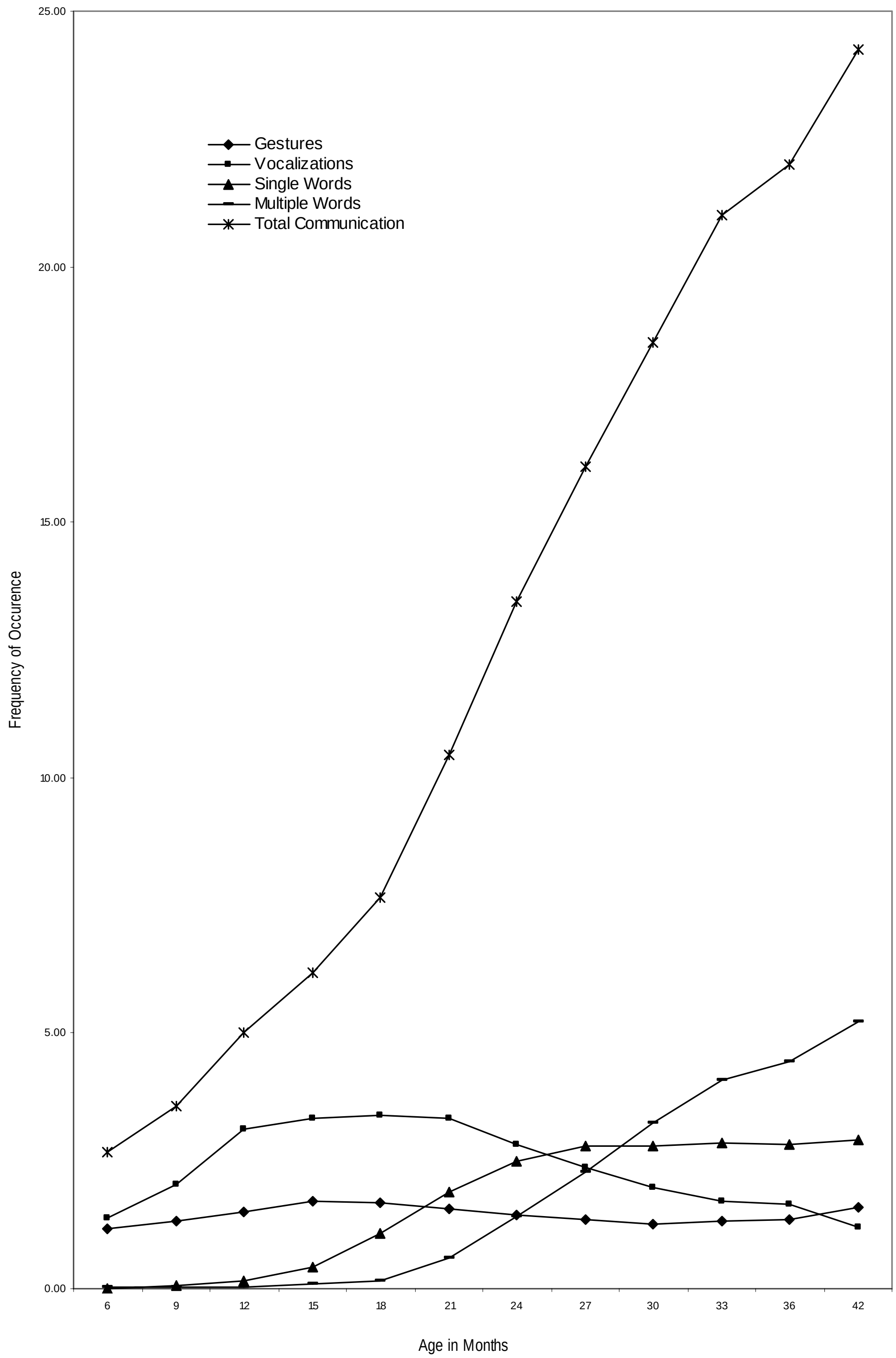


*Figure 2.* Univariate longitudinal panel models with varying degrees of autoregressive pathways

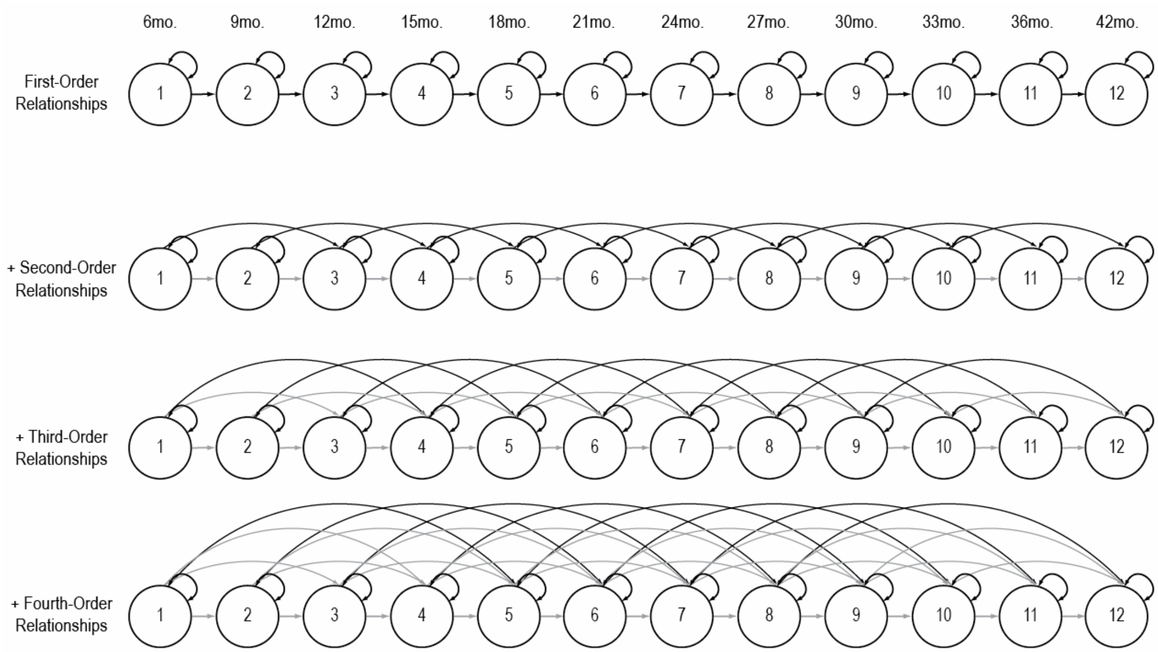


*Figure 3.* Beta estimates for the univariate longitudinal panel models with fourth-order relationships

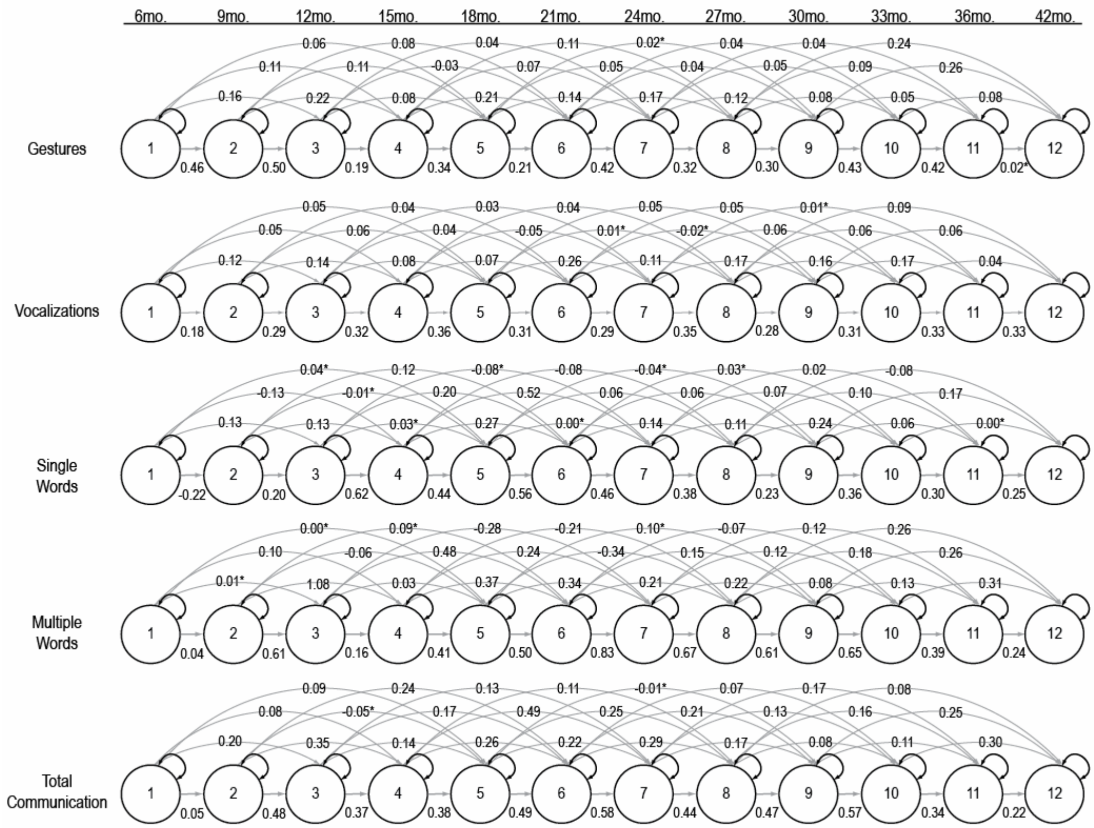


*Figure 4.* Multivariate Longitudinal Panel Model, Conceptual

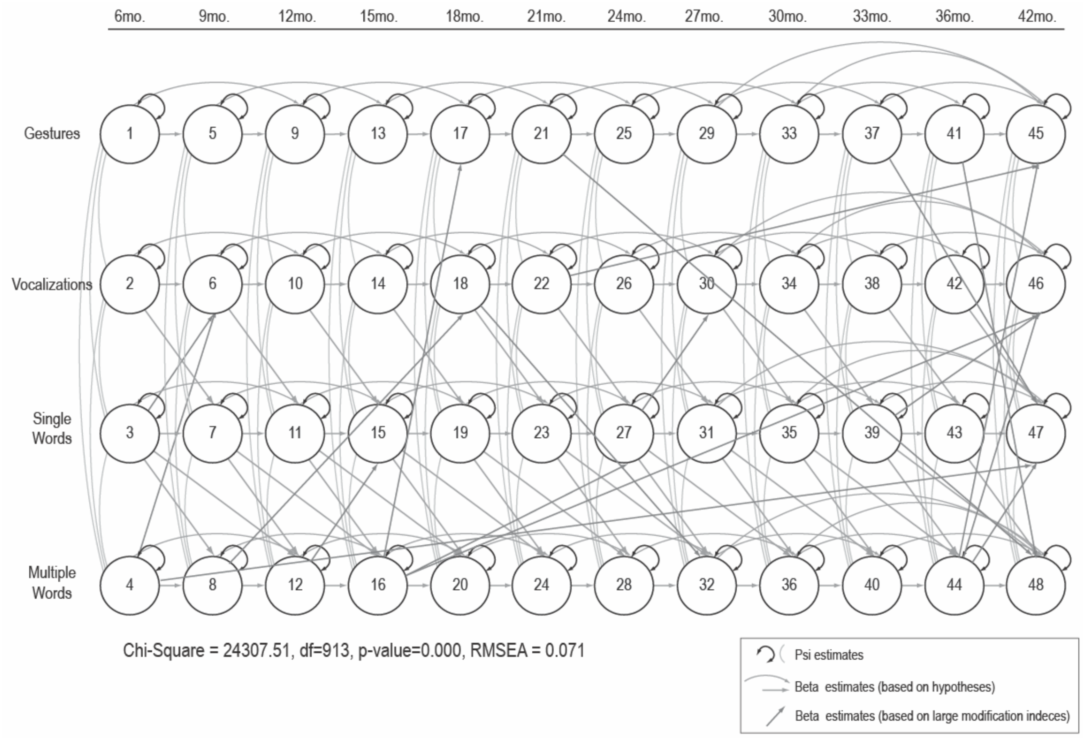
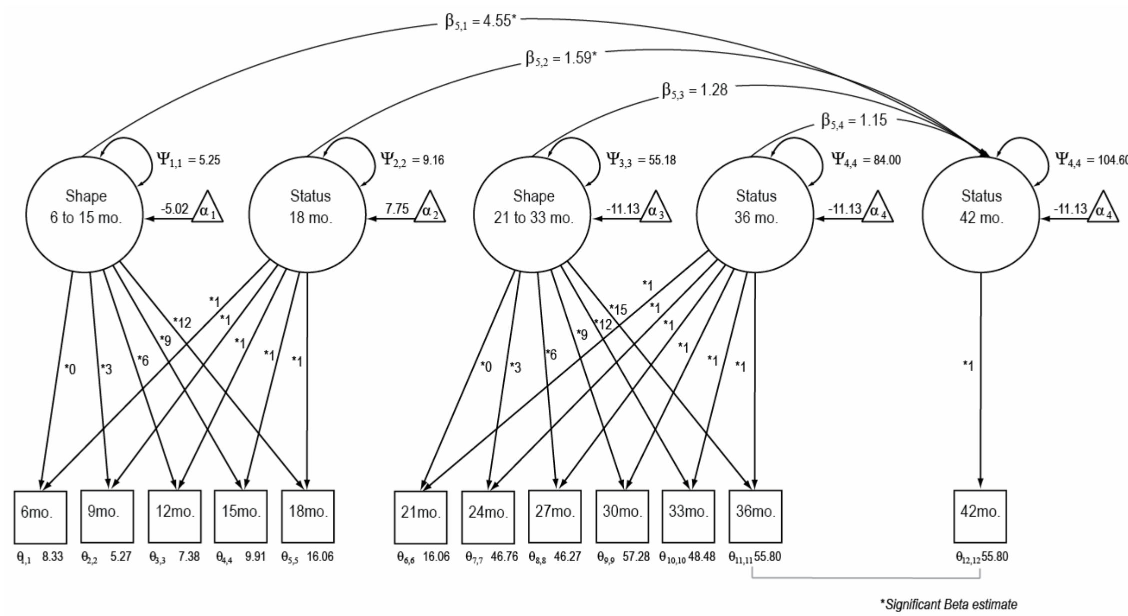


*Figure 5.* Growth Curve Model for Total Communication



# Appendix A:

# ECI Administration Tools

**Table of Contents**

## ECI Administration Checklist

Trainee________________________ Date:____________________ Tape: ______________

This checklist may be used to score the administration tapes for the ECI. To be certified to administer the ECI, the adult play partner should complete the administration steps to at least an 81% (13 out of 16) criterion level.

Setting up the ECI Administration Situation: Materials & Positioning

1. Adult play partner sets up the House or Barn prior to session.
2. The toys inside have been arranged to attract child's attention.
3. Barn or house is set up with sides open.
4. Adult and child are positioned so they can see and reach toys.
5. Adult Play partner and child can have eye contact.
6. Child is positioned appropriately for his/her developmental level (head, neck and feet supported as needed).
7. Session is timed

ECI Assessment Administration: Play Situation

8. Adult play partner follows child's lead in play situation.
9. Adult play partner comments about what child is doing.
10. Adult play partner describes what he/she is doing.
11. Adult play partner interacts in non-directive, friendly manner.
12. Adult play partner uses questions sparingly.

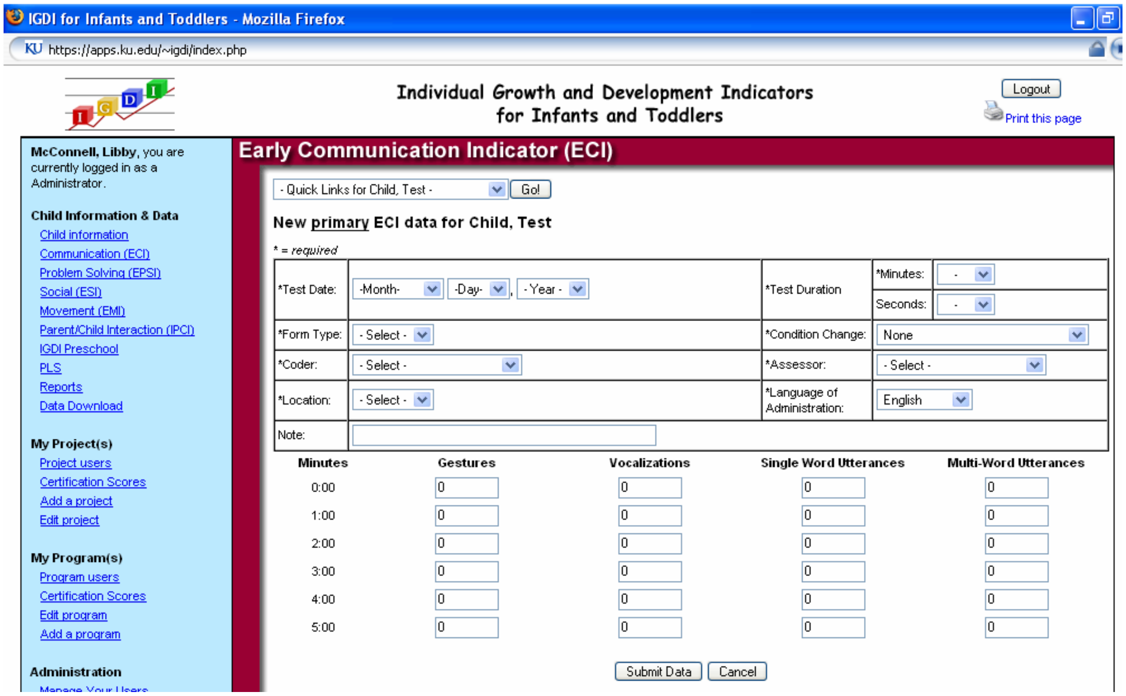
Ending ECI Session

13. Session ends exactly after 6 minutes have elapsed.
14. Adult play partner lets child know that it is time to stop.
15. Adult play partner thanks child for playing.
16. Adult play partner cleans toys (may be reported).

Administration Accuracy = [(Total Number of Steps Completed Correctly/16 Steps) x 100] = ________% (Need 81%)

| Item | Yes | No |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| | | |
| 7 | | |
| | | |
| 8 | | |
| 9 | | |
| 10 | | |
| 11 | | |
| 12 | | |
| | | |
| 13 | | |
| 14 | | |
| 15 | | |
| 16 | | |
| Total | Yes | No |

Online Data Entry Form



IGDI for Infants and Toddlers - Mozilla Firefox

https://apps.ku.edu/~igdi/index.php

Individual Growth and Development Indicators for Infants and Toddlers

Logout

Print this page

**McConnell, Libby**, you are currently logged in as a Administrator.

**Child Information & Data**

Child information
Communication (ECI)
Problem Solving (EPSI)
Social (ESI)
Movement (EMI)
Parent/Child Interaction (IPCI)
IGDI Preschool
PLS
Reports
Data Download

**My Project(s)**

Project users
Certification Scores
Add a project
Edit project

**My Program(s)**

Program users
Certification Scores
Edit program
Add a program

**Administration**

Manage Your Users

**Early Communication Indicator (ECI)**

- Quick Links for Child, Test - Go!

**New primary ECI data for Child, Test**

* = required

| | | | |
|---|---|---|---|
| *Test Date: | -Month- -Day- , - Year - | *Test Duration | *Minutes: - Seconds: - |
| *Form Type: | - Select - | *Condition Change: | None |
| *Coder: | - Select - | *Assessor: | - Select - |
| *Location: | - Select - | *Language of Administration: | English |
| Note: | | | |

| Minutes | Gestures | Vocalizations | Single Word Utterances | Multi-Word Utterances |
|---|---|---|---|---|
| 0:00 | 0 | 0 | 0 | 0 |
| 1:00 | 0 | 0 | 0 | 0 |
| 2:00 | 0 | 0 | 0 | 0 |
| 3:00 | 0 | 0 | 0 | 0 |
| 4:00 | 0 | 0 | 0 | 0 |
| 5:00 | 0 | 0 | 0 | 0 |

Submit Data Cancel

Appendix A-3