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Convergent Validity of Infant/Toddler Developmental Progress Monitoring Tools

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Abstract

Background

Using progress monitoring data to make effective and timely decisions in early intervention (EI) requires high quality assessment. Infant/toddler individual growth and development indicators (I/T IGDIs) have been developed to be brief, reliable and engaging progress monitoring tools that are sensitive to change over short time periods (Greenwood et al. in J Early Interv 33:254–267, 2011. https://doi.org/10.1177/1053815111428467).

Objective

The current study examined the convergent validity of IGDIs in three developmental areas: the early communication indicator, early problem solving indicator (EPSI), and the early movement indicator (EMI), with standardized criterion measures. In addition, growth patterns in the current study of children receiving EI services were examined.

Method

One hundred twenty-three children along with their service provider practitioners ($N = 50$) participated in the study. Practitioners administered IGDIs with children on their regular caseloads; data were examined for comparison with criterion measures and growth patterns.

Results

Significant relationships were found between I/T IGDIs and corresponding domains on the Battelle Developmental Inventory-2nd edition and the Vineland Adaptive Behavior Scales-2nd edition. Linear and quadratic growth trajectory patterns from the current study resembled those of comparable samples from prior studies, where available.

Conclusions

Results supported the convergent validity of these I/T IGDIs with established criterion measures. Growth trajectory patterns for key skills and total scores were similar to those in prior studies, where available, with a few exceptions. Growth trajectory patterns for the EPSI and EMI with children from EI programs were demonstrated for the first time and supported hypothesized patterns.

Keywords

Progress monitoring, Early intervention, Assessment, Home Visiting

Abstract

Background: Using progress monitoring data to make effective and timely decisions in Early Intervention (EI) requires high quality assessment. Infant/Toddler Individual Growth and Development Indicators (I/T IGDIs) have been developed to be brief, reliable and engaging progress monitoring tools that are sensitive to change over short time periods (Greenwood, Carta, & McConnell, 2011). Objective: The current study examined the convergent validity of IGDIs in three developmental areas: the Early Communication Indicator (ECI), Early Problem Solving Indicator (EPSI), and the Early Movement Indicator (EMI), with standardized criterion measures. In addition, growth patterns in the current study of children receiving EI services were examined. Methods: One hundred twenty-three children along with their service provider practitioners (N = 50) participated in the study. Practitioners administered IGDIs with children on their regular caseloads; data were examined for comparison with criterion measures and growth patterns. Results: Significant relationships were found between I/T IGDIs and corresponding domains on the Battelle Developmental Inventory-2nd edition (BDI-2) and the Vineland Adaptive Behavior Scales-2nd edition (VABS-II). Linear and quadratic growth trajectory patterns from the current study resembled those of comparable samples from prior studies, where available. Conclusions: Results supported the convergent validity of these I/T IGDIs with established criterion measures. Growth trajectory patterns for key skills and total scores were similar to those in prior studies, where available, with a few exceptions. Growth trajectory patterns for the EPSI and EMI with children from EI programs were demonstrated for the first time and supported hypothesized patterns.

Convergent Validity of Infant/Toddler Developmental Progress Monitoring Tools

Children make greater progress toward developmental goals when their growth or progress is monitored on a frequent basis (Gettinger & Stoiber, 2008; Landry, Anthony, Swank, & Monseque-Bailey, 2009; VanDerHeyden, Snyder, Broussard, & Ramsdell, 2008). Gathering and using progress monitoring data for decision making is an effective but frequently neglected component of early intervention (EI) with young children who have disabilities or who are at risk for developmental delays, largely due to a lack of valid and reliable progress monitoring assessments.

Moving away from highly structured norm-referenced measures that might not effectively capture functional skills, the field of early intervention has increased its attention to validate and use more naturalistic measures for assessing early developmental progression (Bagnato, 2005; Dunst, Trivette, & Cutspec, 2007). This move is related to the need to capture children's responsiveness to various intervention strategies, otherwise known as response to intervention (RTI: Buysee & Peisner-Feinberg, 2013; McConnell, Wackerle-Hollman, Roloff, & Rodriguez, 2015). Assessments used to monitor child progress and change are designed to be used frequently and to be sensitive to small changes in development that quickly inform practitioners when adjustments to intervention strategies are needed. In addition, information is generated that can be used to communicate children's developmental growth to the family and the rest of the intervention team (Greenwood, Carta, & McConnell, 2011). In order to be effective, these assessments need to measure the constructs they were designed to measure, do so reliably, and be effective for diverse groups of children and their varying service providers (Greenwood & McConnell, 2011). Infant/Toddler Individual Growth and Development

Indicators (I/T IGDIs) are a set of progress monitoring tools that are being used with more frequency.

Data captured by I/T IGDIs are used in early intervention to compare a child's skills to developmental expectations, and to monitor child progress in response to specific interventions or Individualized Family Service Plan (IFSP) outcomes. These data provide practitioners with information to identify and adjustment intervention strategies more speedily, thereby improving intervention effectiveness.

IGDIs for Infants and Toddlers

I/T IGDIs are play-based, naturalistic progress monitoring assessment tools for infants/toddlers (Carta, Greenwood, Walker, & Buzhardt, 2010). Using the approach of General Outcome Measurement (GOM: Deno, 1997; VanDerHeyden, 2005), I/T IGDIs provide data about socially valid key skills that are important to long-term academic and social functioning in children. I/T IGDIs are not tied to a specific curriculum or intervention model/process, thus the resulting data provides information for making decisions about a variety of intervention approaches. One of the main strengths of using I/T IGDIs is their focus on measuring growth or acceleration of skills rather than simply assessing current static levels of development. This is particularly relevant for children who have developmental delays or disabilities who may be making meaningful progress despite discrepant developmental status compared to typical peers. A strengths-based approach to intervention would argue that capitalizing on small amounts of progress motivates both children and parents in the intervention process. A consistent message that children are not meeting developmental milestones is discouraging. However, when parents can see their children make incremental progress over time, they are encouraged.

I/T IGDIs were designed specifically to be used with children six months through three years, to be brief (6 minutes each), easy to administer, and to be engaging for children so that they could be assessed frequently. Each IGDI assessment involves using typical play materials presented to the child and adult assessor (or play partner) who interacts with the child in a developmentally appropriate way. For example, the Early Communication Indicator (ECI) includes a pretend house or barn play set with a variety of pieces (people, animals, vehicles). The adult follows the child's lead in play and is responsive to the child, but *does not* use specific prompts for child communicate (e.g., "What's this?"). The materials and developmentally appropriate responses from the adult naturally facilitates child communication. Further details about administration requirements and materials can be found at www.igdi.ku.edu. Initial validation of I/T IGDIs has been documented for key developmental areas: communication skills with the Early Communication Indicator (ECI: Greenwood, Carta, Walker, Hughes, & Weathers, 2006; Greenwood, Ward, & Luze, 2003; Luze et al., 2001), cognitive skills with the Early Problem Solving Indicator (EPSI: Greenwood, Walker, Carta, & Higgins, 2006), and gross motor skills with the Early Movement Indicator (EMI: Greenwood, Luze, Cline, Kuntz, & Leitschuh, 2002). The purpose of the current study was to provide an external validation of I/T IGDIs separate from the primary development and enhance understanding about the convergent validity (also termed concurrent, criterion-related validity in related fields) and replication of I/T IGDI growth trajectories with additional samples of children.

I/T IGDIs are being used for progress monitoring in a variety of early childhood settings (Carta et al., 2010) and are cross-walked for Early Childhood Outcomes reporting (ECO; Early Childhood Technical Assistance Center [ECTA], 2016). Within the context of EI (birth to age

three) home visiting services, the ECI, EPSI and EMI can be implemented within routine service provision. The current study focused on I/T IGDIs within EI home visiting programs.

Convergent Validity and I/T IGDIs

Convergent validity of I/T IGDIs with established developmental assessment measures has been examined to varying degrees (depending on the developmental area), and primarily with Early Head Start (EHS) samples of children. A few studies have validated I/T IGDIs with children receiving EI and other intervention services (Greenwood, Carta et al., 2006; Greenwood, Walker, & Buzhardt, 2010). To date, the most studied developmental area has been communication. In one of the first psychometric studies of the ECI, 50 children were assessed monthly for 9-months. Statistically significant correlations between the IGDI tool and the Preschool Language Scale-3 (PLS-3; Zimmerman, Steiner, & Pond, 1992) and Caregiver Communication Measure (CCM; Walker, Hart, Linebarger, & Parsley, 1998) were found (r =.62 and .56, respectively) (Luze et al., 2001). To date, this has been the only published study of convergent validity using the ECI.

Similar small-scale psychometric studies were conducted for the EPSI and EMI. In order to examine the convergent validity of the EPSI, scores were correlated with the Bayley Scales of Infant Development, Second Edition (Bayley II; Bayley, 1993) and the Wechsler Preschool and Primary Scale of Intelligence-Revised (WPPSI-R; Wechsler, 1989) with a sample of 30 children. Key skill and composite scores were found to be statistically significantly related to the BDI-II Mental Development Index (with a range of r = .42 to r = .48) (Greenwood, Walker et al., 2006). Likewise, a study of repeated EMI assessments with 29 toddlers showed large, statistically significant correlations between EMI total scores and the Peabody Developmental Motor Scales-2 (Folio & Fewell, 2000) and the Caregiver Assessment of Movement Skills-Gross Motor

(Kuntz, 2001) at two years of age (Greenwood et al., 2002). One aim of the current study is to add to the limited research on convergent validity of I/T IGDIs by examining correlations between IGDIs scores to established measures of development in related domains thus advancing our knowledge about the validity of three I/T IGDI assessments, especially with the population for which the assessments were designed.

Replication of Growth Trajectories of I/T IGDIs

Since the original ECI study, several larger studies have been conducted providing support for construct validity across ages, samples, and time (Buzhardt, Greenwood, Walker, Anderson, Howard & Carta, 2011; Greenwood, Buzhardt, Walker, McCune, & Howard, 2013; Greenwood, Carta, et al., 2006; Greenwood, Walker, & Buzhardt, 2010). These studies reported similar ECI growth trajectories across samples of children with similar demographic characteristics, but different patterns of growth were found for children with and without special needs (Greenwood, Carta et al. 2006; Greenwood et al., 2010). In addition, these studies included practitioners from a variety of disciplines including EHS teachers and EI practitioners. However, studies replicating growth patterns for the specific key skills with additional samples of children and practitioners (assessors) have not been published for the EPSI and EMI. Based on theoretical and empirical evidence, children receiving EI tend to show lower overall scores and slower growth trajectories (Greenwood, Carta et al. 2006). Another aim of current study was to provide an incremental advancement of our knowledge about how I/T IGDIs work with various populations by examining whether the current sample of children showed similar or differing growth acceleration patterns from prior samples for specific key skills scores as well as total scores. We examined the following research hypotheses.

1. We hypothesized that I/T IGDIs would show significant correlations for related developmental domains with criterion measures (demonstrating convergent validity).
2. We hypothesized that acceleration growth patterns of children's I/T IGDI scores would reflect this EI population of children. Specifically, we expected:
    a. scores on the ECI would be similar to previous samples of children receiving EI services, and
    b. children in this sample would show slower acceleration growth patterns for EPSI and EMI scores compared to EHS samples from the original study since children in the current study had identified special needs. This prediction was based on results found in prior studies with the ECI and other studies of growth for children in EI.

Method

The current validation study used a quasi-experimental design to answer research questions related to the convergent validity and replication of I/T IGDI scores. Practitioners were recruited from agencies in Iowa who volunteered to be part of this professional development opportunity. Children who were under the age of two, and their families, were recruited from their service provider's caseloads. This translational research project was a feasibility study and therefore we did not have experimental control over several aspects of the study (including the number, types and timing of IGDIs administered to each child).

Participants

EI practitioners (N = 50) were recruited to administer I/T IGDIs in their routine practice. All practitioners had a least a bachelor's degree with 75% having a master's degree. Practitioner ages ranged from 25-60 years with an average age of 42 years. One practitioner was African-American; all others reported their ethnicity as White, and one person also identified as Hispanic.

Forty-eight practitioners identified as female and two identified as male. Practitioners were from a variety of professional disciplines including: 27 EI teachers/consultants, eight speech and language pathologists, six social workers, four physical therapists, two teachers for deaf/hard of hearing, one occupational therapist, one family support coordinator, and one service coordinator.

Following practitioner recruitment, children under the age of two (with parents) were randomly selected from their caseloads and were invited to participate. A total of 123 children were enrolled in the study. Numbers of children included in each of the analyses vary based on which IGDI assessments were conducted with each child. Fifty-six percent of children were male. The majority of children (80%) were White, Non-Hispanic, 11% were Hispanic, 3% were Black/African American, 1% were Asian, 3% were biracial, and1% were other ethnicity/race. English was the primary language for 91% of children. The nature of children's impairment/risk was identified by parents. Half of the children were identified as having a language impairment, and 41% having a developmental delay. Twenty-one percent were born with low birth weight. Forty-one percent of children had a form of physical impairment (i.e., vision/hearing, physical, health, traumatic brain injury). It should be noted that the identified categories of impairment/risk were not mutually exclusive. The vast majority of families had parents that were married and living with each other (81%), and had more than a high school education (86%). Overall, parents were more highly educated and were more likely married/living together than the Iowa EI population as a whole (Feinberg, Silverstein, Donahue, & Bliss, 2011).

Initially, children were randomly selected from de-identified caseloads with the only criteria being they were under two years of age in order for participation over the course of at least one year. During the recruitment phase, we found many children were included on caseloads as "monitoring only" and did not have specific IFSP goals. The recruitment strategy

was revised to randomly select children from caseloads omitting children who were "monitoring only" because the primary goal of the study was to understand I/T IGDIs with children who had identified individualized family service plan (IFSP) outcomes.

Procedures

All participants, including practitioners and parents, were informed about the elements of the study and voluntarily signed informed consent prior to any research activities. Participating EI practitioners received individual or group training and coaching (based on their preferences) to implement the assessments. Participating parents completed an interview about their child's needs, services received, and family demographics. Participating children completed I/T IGDI assessments with practitioners, and completed criterion assessments with researchers during an additional research home visit. Practitioners administered all IGDI assessments with children. Parents were present, and occasionally assisted with the video equipment, but did not participate in the administration of IGDIs with their children.

Practitioners conducted all IGDI assessments after being trained to meet reliability criteria for both administering and scoring the IGDIs. They received continued coaching support to maintain overall inter-rater agreement with project research staff (at 85% or higher), and to integrate IGDI assessments into their practice. Seventeen percent of I/T IGDI assessments were video recorded for reliability scoring by research staff. Average scoring reliabilities by practitioner were 88%, 90% and 89% for the ECI, EPSI and EMI, respectively.

Measures

Family and child characteristics. Child and family demographic information was collected by research staff via interview during an initial research home visit. Parents were also

asked to identify their child's area of developmental delay or risk (reason for receiving services), services received, and participation in developing the IFSP.

I/T IGDI data. I/T IGDI data were gathered by practitioners during the course of ongoing assessment and service provision to the child and family. Practitioners used IGDI assessments related to child IFSP outcome goals. The ECI was the most utilized IGDI, followed by the EPSI and the EMI. Table 1 shows the number of I/T IGDI assessments by age group. Table 2 shows the number of I/T IGDI assessments across children. For example, 10 children had 1 ECI and 17 children had 2. The average number of I/T IGDI assessments per child were 4.81 (SD = 4.14), 4.04 (SD = 3.40), and 3.62 (SD = 3.22) for the ECI, EPSI and EMI, respectively.

Each IGDI assessment uses materials familiar to children (and that are commercially available) that naturally elicit the behaviors being assessed. For example, the EMI consists of large foam blocks and balls of various sizes or a nylon pop-up structure (e.g., school bus) and balls. As children play with the materials, they naturally engage in the movements being assessed (e.g., crawling, walking, kneeling, throwing, and catching). The materials are set out to be ready for children to play as they wish. The adult assessor does not prompt or direct a child to do any specific behavior, but simply plays in a developmentally appropriate way. Each assessment is designed to be six minutes, which is long enough to get a reliable sample of behavior, but not so long as to tire even the youngest children. Key skills are assessed using a frequency count. Scores can be reported for each key skill, total score summed across key skills, or a relevant combination of skills. Summed scores can be reported across the entire six-minute assessment or as a rate per minute. We reported scores to match the original studies as closely as possible.

The ECI includes four key skills: Gestures, Vocalizations, Single Words and Multiple Words. Practitioners counted the frequency the child engages in each key skill over the course of the 6-minute assessment. Single Words and Multiple Words scores were weighted as per the I/T IGDI manual (Single Words x 2, Multiple Words x 3; Carta et al., 2010) and a total score was calculated by summing Gestures, Vocalizations, weighted Single Words, and weighted Multiple Words. Rate per minute scores for each key skill and for the total were calculated by dividing the scores by the duration of the assessment in minutes.

For the current study, key skills for the EPSI included: Explores, Functions and Solutions. The original EPSI includes Looks as a key skill (looking at a toy). Our pilot work indicated difficulty for practitioners to maintain reliability on Looks. As the original study (Greenwood, Walker, et al., 2006) did not show growth over time for this skill, a decision was made to omit Looks in the current study. Explores, Functions and Solutions were summed for a total score, and a Functions + Solutions score was calculated for making comparison to prior work. Rate per minute was calculated for all scores.

The EMI included five key skills: Transitional Movements, Grounded Locomotion, Vertical Locomotion, Throwing/Rolling, and Catching/Trapping. The total summed score and the rate per minute were calculated for all skills. Table 2 gives the descriptive information for all key skills and total scores for all three I/T IGDIs.

Criterion measures for convergent validity. Two standardized criterion measures (one direct assessment and one caregiver report) were used to examine convergent validity of the I/T IGDIs. The Battelle Developmental Inventory-2nd edition (BDI-2; Newborg, 2004) provided direct assessment of developmental skills while the Vineland Adaptive Behavior Scales, Survey Form, 2nd edition (VABS-II; Sparrow, Balla, & Cicchetti, 2005) provided caregiver reported

information. These particular measures were selected because they have proven technical adequacy and cover the areas of development that match the areas assessed by the IGDIs.

The BDI-2 (Newborg, 2004) is a standardized norm referenced assessment. The BDI-2 can be used with children ages birth through 7 years and 11 months for screening, diagnosis, and evaluation of child development; it covers developmental domains of adaptive, personal-social, communication, motor, and cognitive. The normative sample included more than 2,500 children, closely matched to the 2000 U.S. Census. Reliability of the BDI-2 was reported to be .90 for overall development score; domain scores had lower reliabilities. Convergent validity of the BDI-2 was established with other measures of development. Moderate correlations with the Preschool Language Scale, 4th edition (r = .57), Bayley Scales of Infant Development (r = .61) (Bayley, 1992) and Wechsler Preschool and Primary Scale of Intelligence, 3rd edition respectively (r = .72) (Weschler, 1989) were found (Zimmerman et al., 1992).

The VABS-II (Sparrow et al., 2005) is a general assessment of adaptive behavior in the domains of communication, daily living skills, socialization, and motor skills. The VABS-II is appropriate from birth to 90 years. The Survey Form includes 297 items. Using a semi-structured interview, a trained interviewer asks caregivers questions about the child's skills in these domain areas. The VABS-II has domain and composite standardized scores. The VABS-II was normed on national standardized sample of 3,695 individuals (which included some people with disabilities). Internal consistency reliability was reported to be between .77 and .93 for domain scores, and .93 to .97 for the adaptive behavior composite score. Test-retest reliability was reported .76 to .92 for domain scores, and .88 for the composite score. Convergent validity was examined with a number of different types of instruments, including other measures of adaptive behavior and intelligence tests. Correlations between the VABS-II and the Adaptive

Behavior Inventory for Children (ABIC) were reported to be .58. Correlations between the VABS-II and the AAMD Adaptive Behavior Scale were reported to be between .40 and .70. The VABS-II does not assess cognitive skills.

Analytic Approach

Convergent validity. Since I/T IGDIs were conducted monthly and criterion measures conducted yearly, we aggregated the IGDI scores from the month prior, month of, and month after the criterion assessment visit. This allowed us to have a point-by-point comparison of a static IGDI score for comparing with the criterion scores. Following the work of the original I/T IGDI developers, we correlated both the total scores and specific key skill score composites with the corresponding criterion subscales. ECI weighted Single Words (X1) and Multiple Words (X2) were summed for the composite key skill score since Gestures have a relatively flat growth pattern and Vocalizations have a quadratic pattern (Luze et al., 2001). For the EPSI, Functions and Solutions were summed for the composite key skills score (Greenwood, Walker et al., 2006) and for the EMI, only the total score (Greenwood et al., 2002) was used. Table 3 shows the means, standard deviations and ranges for the aggregated IGDI data along with the corresponding BDI-2 and VABS-II subscales.

Growth trajectories. Two-level Growth Curve Modeling (GCM) was used to examine patterns of growth trajectories over time for all key IGDI developmental skills. Two-level GCM accounted for the nested structure of the data: Time (Level 1) is nested within children (Level 2). There was no conceptual reason to assume nesting within practitioner as they were all trained to criterion on administering and scoring IGDIs. In this study, the Level-1 model estimated children's longitudinal growth trajectories from approximately 6 months to 36 months for each IGDI. The Level-2 model estimated the variation in IGDI growth trajectories across children.

Child age (in months when each assessment was administrated) was used as time indicators, and one-unit change in "child age" indicates IGDI growth over approximately one month. We compared the growth trajectories by examining linear and quadratic patterns in our study (centered at 24 months) and comparing our findings to those from prior studies (whether or not they were best described by a linear or quadratic pattern) by Greenwood and colleagues. If a quadratic pattern was found to be insignificant, we concluded a linear pattern was the most appropriate fit. Missing child assessment date were not imputed separately because the GCM approach utilizes all data from children who have at least one-time point data (Kwok et al., 2008).

Results

Convergent Validity

Aggregated IGDI scores were compared to the BDI-2 and VABS-II subscale raw scores to test for convergent validity. Table 4 includes descriptive statistics for all measures. Correlations between the EMI and the BDI-2 and VABS-II were calculated using the Spearman *rho* rather than Pearson *r*. With the small number of children who had EMI and criterion assessment scores (n = 16), we did not want to make assumptions about the distribution of the data, so selected the more conservative non-parametric correlation measure. Correlational results, shown in Table 5, indicate statistically significant, moderate to large positive relationships between all IGDI scores and related subscales on the BDI-2 and/or VABS-II with all p values below .01 and coefficients ranging from .44 to .66 (see bolded coefficients in Table 5).

Growth Trajectories

Growth trajectories for each IGDI are presented in tabular form followed by figures for total scores and then figures for all key skill elements.

ECI. As shown in Table 6, statistically significant linear growth patterns were found for the ECI total score (b = .37; p < .001), Single Words (b = .14; p < .001) and Multiple Words (b = .15; p < .001). These results indicate that, for each month, children gained an average .37 points for the ECI total score, .14 points for Single Words, and .15 points for Multiple Words. For Vocalizations, positive linear (b =.35; p < .001) and a negative quadratic growth patterns (b = -.01; p < .001) were found to be significant, indicating slower rates of positive growth in these skills until 25-30 month of age and then faster deceleration after 30 months. Gestures developed significantly over time with small magnitude (b = <.01; p > .05). Figures 1 and 2 are visual representations of the total score and key skills respectively.

EPSI. Table 7 shows growth patterns for the EPSI total score, Functions + Solutions score, and three key skill scores. Linear growth patterns were found for total score (b = .55; p < .001), Functions + Solutions (b = .49; p < .001), Functions (b = .43; p < .001), and Solutions (b = .06; p < .001). These results indicate that for each month, children gained .55 points for EPSI total score, .49 points for Functions + Solutions, .43 points for Functions, and .06 points for Solutions. For Explores, a positive linear (b = .47; p < .001) and a negative quadratic pattern were found to be significant (b = -.01; p < .001), indicating slower rates of positive growth in these skills until 25 month of age and then faster deceleration after 30 months. Visual representations of these growth patterns are available in Figure 3 for total scores along with Functions + Solutions, and in Figure 4 for the key skills.

EMI. Table 8 presents growth patterns for EMI total score and the key skill scores. Statistically significant positive linear and negative quadratic growth patterns were found for total scores (b = 1.18; $p < .01$ for linear growth; b = -.02; $p < .05$ for quadratic growth), Transitional Movements (b = .49; $p < .01$ for linear growth; b = -.01; $p < .05$ for quadratic growth), and Vertical Locomotion (b = .46; $p < .01$ for linear growth; b = -.01; $p < .05$ for quadratic growth), thus indicating slower rates of positive growth in these skills until 25-30 month of age and then faster deceleration after 30 months. A linear growth pattern was found for Throwing/Rolling (b = .07; $p < .001$), indicating .07 points growth for every month. Grounded Locomotion (b = .02; $p > .05$), and Catching/Trapping (b = .01; $p > .05$) did not show significant growth over time. Figures 5 and 6 are visual representations of total score and key skills respectively.

Discussion

Using psychometrically sound and feasible measures for monitoring children's developmental progress is critical if services are going to lead to improvements in child outcomes. Until now, there have been very few measures that directly assessed infant and toddler skills in key developmental areas, and even fewer measures that could be used to monitor progress frequently in response to intervention. Although advances are being made in the field of measurement for this age group, more information about both the constructs being measured and the replicability of results from assessments is warranted. The current study provides important information about both of these aspects related to I/T IGDIs. Support for convergent validity improves our confidence that IGDIs are measuring important aspects of development that have been captured by other established measures, thus advancing our knowledge about the integrity of the constructs being measured with I/T IGDIs. Replication of results from previous

studies that examined children's developmental growth trajectories improves our understanding of the nature of the data that practitioners can obtain with a variety of children. Specifically, similar data across similar population samples of children add to the validity of results. Likewise, differences in data between samples known to differ (in this case a sample of children with identified special needs compared to children from more representative samples) adds to our confidence that these measures are capturing important individual differences that are both theoretically and empirically supported in EI.

Convergent Validity

To our knowledge, the current study is the first convergent validity study of I/T IGDIs beyond the initial validation studies. Results support the validity of the ECI, EPSI and EMI as they relate to the established BDI-2 and VABS-II measures of related developmental domains. The current study sample of children receiving early intervention is different from the original validation studies that included children both with and without special needs from community child care programs. Demonstrating convergent validity with an exclusively EI sample provides additional evidence for construct validity. Practitioners can have increased confidence using I/T IGDIs for frequent measurement and progress monitoring. Thus, they can decrease use of more time-consuming measures that are not designed to capture small increments of change. Taken together with validation studies to date, the ECI has now been related to communication scores on the PLS-3, CCM (Luze et al., 2001), BDI-2, and VABS-II. The EPSI is related to relevant scores on the Bayley II, WPPSI-R (Greenwood, Walker et al., 2006), and BDI-2; and the EMI is related to scores on the PDMS-2, CAMS-GM (Greenwood et al., 2002), BDI-2, and VABS-II. This growing body of support for the concurrent criterion-related validity of the I/T IGDIs is compelling.

Growth Trajectories

We examined the growth trajectories of children in the current study (linear vs. quadratic patterns) and compared our results to patterns found in prior studies. Centering on growth trajectories for 24-month-olds (since that was a consistent age of data collection across studies), we visually compared the growth of our sample to specific prior study samples. For each IGDI, the relative linear and quadratic patterns (where available) is discussed followed by the comparison of key skill growth.

The growth trajectories for the ECI show similar patterns to those reported in Greenwood et al. (2010) study, which included multiple samples of children with and without IFSPs. For the total weighted communication score, the Greenwood et al.'s study found significant quadratic growth patterns, with small acceleration in growth of .01 words per month (Greenwood et al., 2010). Our results showed a linear pattern only. The current study is likely to be underpowered for detecting this small quadratic effect due to the limited number of assessments with children older than 30 months of age.

The original validation study of the EPSI (Greenwood, Walker et al., 2006) showed linear patterns for Functions, Solutions, and Functions + Solutions and did not examine quadratic patterns. We examined both linear and quadratic patterns and found linear patterns for Functions, Solutions, and Functions + Solutions (our total score did not include the "Looks" key skill in the EPSI). We found a quadratic pattern for Explores; the scores peaked around 23 months. This may be because once children "figure out" the toy, they no longer needed to explore it.

Growth trajectory patterns for the EMI total score for both the current and the initial study (Greenwood et al., 2002) were quadratic. Total scores in our EI sample peaked at

approximately 27 months and then declined, whereas in the Greenwood sample (29 children from child care centers), EMI total scores peaked at about 40 months and leveled off. These differences may be because the current EI sample of children may have motor difficulties. We found quadratic growth patterns for Transitional Movements and Vertical Locomotion, with both peaking at approximately 27 months. Linear growth patterns for Throwing/Rolling were found and no statistically significant growth was found for Grounded Locomotion or Catching/Trapping. This may be due to the early transition from crawling to walking and the greater difficulty of catching and trapping compared to throwing and rolling. Based on data from the original study, we see similar patterns in growth for Transitional Movements and Vertical Locomotion until approximately 24 months, and then their scores leveling off or slightly decreasing. Increasing growth in Throwing/Rolling was found in both studies, and very small gains in Grounded Locomotion and Catching/Trapping were seen in both studies, although the growth in Grounded Locomotion and Catching/Trapping were not statistically significant in the current study. Overall growth trajectories for the ECI, EPSI and EMI show consistencies between the current sample and samples from other published studies.

The current study provides overall support for consistency of data (growth trajectories and scores) across studies for these three IGDIs. These studies were conducted with different samples of children (those with and without special needs), in different states, with different types of assessors (researchers versus practitioners). These results provide additional evidence confirming the technical adequacy of I/T IGDIs.

Limitations and Implications

Several study limitations should be noted. The sample size in the current study was limited, especially for the EMI. Children in the current study were largely White (80%); thus

generalization of results to other ethnic populations should be done with caution. We had limited information about the severity or complexity of children's developmental needs. Additionally, children had varying numbers of assessments at different ages across the IGDIs. Growth estimation at ages with more data was more reliable. We were unable to perform direct statistical tests between growth trajectories found in the current study and those in prior work because we lacked information about specific data sets. The relatively small percentage of inter-observer comparisons (17%) may have influenced our reliability estimates.

Additional research needs to be conducted looking at the influence of specific child needs to their scores and growth with I/T IGDIs. Data gathered from a variety of contexts including homes, centers, and clinics should be examined more thoroughly. Continued examination of growth trajectories for all IGDIs across multiple samples of children and in a variety of settings will enhance confidence in the use of these tools in daily practice.

Despite the limitations, this study adds to the growing empirical base supporting the validity of I/T IGDIs related to the constructs measured (congruency with established measures) and reliability of results across populations of children.

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Conflict of interest. The authors report no conflicts of interest.

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Table 1

I/T IGDI Observation Frequencies

Age at test (months)	ECI	EPSI	EMI
6-8	7	4	1
9-11	10	7	5
12-14	12	16	9
15-17	26	17	16
18-20	42	27	15
21-23	50	22	12
24-26	62	34	13
27-29	83	41	13
30-32	73	37	15
33-35	42	25	9
Total Observations	407	230	108

Note: Outliers not included: 2 ECI (child under 6 months of age), 1 ECI (assessment under 5 minutes), 1 EMI (child under 6 months of age), 1 EPSI (assessment under 5 minutes).

Table 2

Number of Participants by Number of Observations

Number of Observations	ECI	EPSI	EMI
1	10	14	7
2	17	7	8
3	14	8	3
4	12	13	5
5~16	-	-	7
5~17	-	15	-
5~21	31	-	-
Total	84	57	30

Table 3

IGDI Key Skills and Total Scores (Rate per Minute)

	M	***SD***	**Min**	**Max**
ECI Total Score*(*N*=409)	6.98	6.29	.00	32.83
Single Words + Multiple Words*	3.10	5.49	.00	29.17
Gestures	.96	.95	.00	7.50
Vocalizations	2.92	2.54	.00	16.83
Single Words*	1.93	3.08	.00	16.33
Multiple Words*	1.18	3.08	.00	25.00
EPSI Total Score (*N*=230)	13.42	6.51	.00	32.50
Functions + Solutions	6.71	5.57	.00	23.83
Explore	6.71	3.16	.00	19.83
Functions	6.07	4.84	.00	20.00
Solutions	.64	.88	.00	5.50
EMI Total Score (*N*=108)	8.91	4.98	.50	27.17
Transitional Movements	4.11	2.23	.00	10.00
Grounded Locomotion	.84	.87	.00	3.17
Vertical Locomotion	2.03	2.32	.00	10.33
Throwing/Rolling	1.70	1.25	.00	5.83
Catching/Trapping	.23	.51	.00	3.33

*Scores are weighted. Single Words X2, Multiple Words X3.

Table 4

Means and Standard Deviations for IGDIs and Related Subscales on Battelle and Vineland

Measure	***M***	***SD***	**Min**	**Max**
ECI Total Score (*N*=51)	38.64	35.90	1.50	164.00
ECI Single Words + Multiple Words	16.46	30.45	.00	130.00
BDI-2 Communication Raw Score	40.12	13.58	5.00	72.00
VABS-II Communication Raw Score	45.25	15.77	12.00	80.00
EPSI Total Score (*N*=36)	76.00	37.38	3.67	195.00
EPSI Functions + Solutions	31.89	26.67	.33	100.00
BDI-2 Raw Score	39.58	12.63	14.00	74.00
EMI Total Score (*N*=16)	54.98	34.02	14.50	163.00
BDI-2 Motor Raw Score	73.56	23.27	34.00	106.00
VABS-II Motor Raw Score	56.56	23.74	12.00	102.00

Note: Descriptive data are presented based on the samples of children who had both an average IGDI score for the three-month window and related Battelle and Vineland subscale scores.

Table 5

Concurrent, Criterion-Related Correlations

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1. ECI Total Score	1									
2. ECI Single & Multiple Words	.92**	1								
3. BDI-2 Communication	**.44****	**.45****	1							
4. VABS-II Communication	**.61****	**.61****	.78**	1						
5. EPSI Total Score	.67**	.54**	.48**	.62**	1					
6. EPSI Functions & Solutions	.79**	.70**	.56**	.71**	.88**	1				
7. BDI-2 Cognitive	.36**	.33*	.82**	.66**	**.59***	**.60****	1			
8. EMI Total Score[a]	.38	.29	.35	.55*	-.15	.33	.27	1		
9. BDI-2 Motor[a]	.25*	.25	.78**	.60**	.30	.38*	.83**	**.66****	1	
10. VABS-II Motor[a]	.44**	.40**	.58**	.71**	.55**	.62**	.58**	**.64****	.70**	1

Note: Sample sizes for ECI and criterion measures BDI-2 and VABS-II were 51 and 53 respectively. Sample size for EPSI with BDI-2 was 36. [a]Spearman's *rho* coefficient used with EMI Total Score due to small sample size (N=16). BDI-2=Battelle Developmental Inventory-2nd Edition. VABS-II=Vineland Adaptive Behavior Scale, Second Edition.
*$p<.05$, **$p<.01$

Table 6

ECI Growth Trajectory Estimates

	Total		Gestures		Vocalizations		Single words		Multiple words	
	b	*p*	*b*	*p*	*b*	*p*	*b*	*p*	*b*	*p*
Linear growth	.37	***	< .01		.35	***	.14	***	.15	***
Quadratic growth	-		-		-.01	***	-		-	
Intercept	-1.82		.91	***	-1.78		-1.26	*	-2.42	***
Random Effect	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
var(_cons)	27.35	4.89	.35	.09	3.96	.75	6.58	1.18	5.58	1.10
var(Residual)	13.24	1.04	.63	.05	2.90	.23	3.35	.26	4.56	.36

Table 7

EPSI Growth Trajectory Estimates

	Total		Functions + Solutions		Explore		Functions		Solutions	
	b	*p*	*b*	*p*	*b*	*p*	*b*	*p*	*b*	*p*
Linear growth	.55	***	.49	***	.47	**	.43	***	.06	***
Quadratic growth	-		-		-.01	**	-		-	
Intercept	.58		-5.07		1.59		-4.24	***	-.82	***
Random Effect	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
var(_cons)	15.28	3.89	10.83	2.81	5.81	1.54	8.22	2.12	.30	.08
var(Residual)	14.16	1.52	10.35	1.11	5.12	.56	7.63	.82	.36	.04

Table 8

EMI Growth Trajectory Estimates

	Total		Transition Movements		Grounded locomotion		Vertical locomotion		Throwing rolling		Catching trapping	
	b	*p*	*b*	*p*	*b*	*p*	*b*	*p*	*b*	*p*	*b*	*p*
Linear growth	1.18	**	.49	**	.02		.46	**	.07	***	.01	
Quadratic growth	-.02	*	-.01	*	-		-.01	*	-		-	
Intercept	-6.44		-2.19		.32		-3.53		.17		.05	
Random Effect	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
var(_cons)	12.59	4.75	2.87	1.00	.22	.13	2.48	.99	.52	.26	.11	.05
var(Residual)	10.48	1.82	2.05	.33	.56	.09	2.41	.40	.95	.16	.16	.03