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Stability of serial assessments of motor and communication abilities in typically developing infants—implications for screening

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Abstract

Background: Neuromaturational theory and dynamic systems theory make different assumptions about the rate of development of motor and communication skills. *Aims*: The stability of fine motor, gross motor, and communication scores of infants was evaluated to test these assumptions. *Study design*: This longitudinal descriptive study evaluated infants in their homes at 9, 11, 13, 16, and 21 months of age. *Participants*: One hundred and two Canadian children of English-speaking parents classified as typically developing at 23 months of age using the Diagnostic Inventory for Screening Children Preschool Screen were included. *Outcome measures*: The Peabody Developmental Motor Scales and the Communication Symbolic Behavior Scales—Developmental Profile were used to assess development at each time. Scores were stable if the 95% confidence intervals around the scores overlapped across all assessments. Correlations evaluated the relationship of scores in a domain over time (normative stability) as well as the relationship of scores between domains (ipsative stability). *Results*: There was large variability in scores within an infant, among infants and across developmental domains. Typical development is nonlinear rather than occurring at a constant rate. Fine motor, gross motor, and communication skills appear to develop independently. *Conclusions*: These results have implications both for developmental screening policies and for early intervention programs. Screening should include

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multiple domains and multiple time points before referrals are made to early intervention programs.

Keywords: Infant development; Test results

1. Introduction

Programs for early screening and intervention for infants with developmental problems are widely available in Canada and mandated by law in the United States [1]. Screening for developmental delay is based on the assumption that early delays in development predict later delays. This assumption is derived from the neuromaturational model of development first described by Gesell [2]. Using tenets derived from this theory, changes in developmental domains are explained primarily by maturation of the central nervous system (CNS). The rate of emergence of skills in a developmental domain is assumed to be constant. For instance, if an infant's score is at the 75th percentile (± standard error of measurement) at 4 months of age, her abilities will remain within this range at later testing times. Remaining in essentially the same place within a group of children over time [3] is defined as normative stability [4]. Another assumption from the neuromaturational model is that different domains develop at a similar rate within a child [5]. The concept of ipsative stability [6] assumes that children demonstrate similar abilities (as reflected in their test scores) across different developmental domains. The expectation of linear development "is used by clinicians to predict long-term outcomes based on children's rate of acquisition of specific developmental milestones in early infancy [7,p,11]."

Recently, tenets of the dynamic systems theory have been used to explain fine motor [8], gross motor [9], and communication development [10]. Dynamic systems theory states that changes in development are not dependent solely on the maturation of the CNS, but rather on the interaction of multiple subsystems within the child, the environment, and the demands of the task [11]. The theory does not support the concept of a constant rate of emergence of developmental skills, as small but critical changes in one subsystem can result in a large change in developmental abilities [12]. The emphasis on the interaction of many subsystems, including the environment, suggests that a specific developmental domain may not demonstrate stability of scores over time, and that different developmental domains may follow different developmental trajectories.

In contrast to research on infant cognitive development, little empirical evidence exists regarding either the stability of individual infant's scores in fine motor, gross motor, and communication abilities, or the relationships among the domains in the first 2 years of life. Recent longitudinal studies in infant motor and communication development are scarce, and the results are not conclusive. Rome-Flanders and Cronk [13] reported stability over time for typically developing infants at 9, 12, 15, and 18 months on a parent-report measure of expressive and receptive language abilities, while Fenson et al. [14] found individual differences in the language development of children 18–30 months of age. It has been reported that gross motor abilities mediate other areas of development [15], and that motor and speech abilities develop in parallel and are interdependent [16]. Conversely, other investigators have reported no relationship between language and motor abilities [17,18].

Because fine motor, gross motor, and communication are usually assessed during the first 2 years of life, evaluation is needed to clarify the stability of each domain in typically developing infants and the relationship among the three domains. A recent longitudinal evaluation of gross motor abilities in the first year of life [19] found normative instability for typically developing infants up to age 15 months.

Currently, the screening process assumes that early delay predicts later delay, and referral decisions are often based on one assessment. If typically developing infants do not demonstrate normative stability, developmental surveillance [20] is supported instead of one-point screening. In addition, if the ipsative relationships among fine motor, gross motor, and communication abilities are not stable, differences in performance across domains should not be considered atypical. The false-positive rate for identifying developmental delay may decrease with a better understanding of patterns of typical development. By evaluating which theoretical framework of motor development is supported, more effective intervention strategies could be developed based on a strong theoretical rationale. The development of specific intervention strategies that could be tested empirically supports Guralnick's [21] concept of 'second generation' research in early intervention.

This longitudinal study examined the stability of fine motor, gross motor, and communication development in typically developing infants. By examination of percentile rank scores obtained by infants over time on standardized tests, the intraindividual stability of scores was examined. Two questions were addressed:

(1) Do typically developing infants maintain the same percentile rank in performance within a specific developmental domain (normative stability) on standardized measurements at 9, 11, 13, 16, and 21 months of age?
(2) What is the relationship of individual infants' rankings across the domains of fine motor, gross motor, and communication development (ipsative stability)?

2. Methods

2.1. Sample

A volunteer sample of 120 full-term infants (37 weeks gestation or greater) was recruited. Because of the requirements of some of the standardized measures used, only families who reported speaking English to their infant, and could read English at a grade 8 level were recruited. Babies were recruited primarily from Moms and Babies groups at public health centers and the ages at recruitment ranged from 4 weeks to 8 months. At the time of recruitment and screening, no parents had concerns about their infants' development. The study was approved by the Health Research Ethics Board and parents agreed to participate.

2.2. Procedures

Twelve motor therapists (MT) (occupational and physical therapists) and 10 speech-language pathologists (SLP) collected data in the infants' homes. The assessments occurred when each infant was 9, 11, 13, 16, and 21 months old. These ages represented the midpoint of the normative age groupings on the measure of motor development (e.g., 13 months is midpoint of norms for ages 12–14 months). It was important that assessments occurred at the same point in each age grouping to eliminate changes in scores based on test construction. If two assessments occurred within the same normative age grouping, the percentile rank might increase at the second age merely because the infant, being older, had more skills than most children in the age grouping. A MT and a SLP assessed each infant individually, and followed the same children for the duration of the study. Each assessment took approximately 1 h. All therapists allowed time for the child to 'warm-up' to them and, if an infant was ill or upset, as judged by the parent, the assessment was rescheduled. However, because therapists completed the assessments in the infants' home, most babies were happy and comfortable during the assessment.

All therapists were trained on the measures used and obtained 80% item-by-item agreement with all other therapists before the project began. Interrater reliability, assessed at regular intervals, averaged 0.99 for MTs and 0.89 for SLPs. On average, at every 10th assessment, a therapist's score was compared to that of another therapist, either by observing the same child (MTs) or by a videotaped assessment scored by two therapists (SLPs). These reliability checks were done to ensure consistency of scoring among the therapists. In addition, at each age, therapists discussed the scoring of relevant items and observed an infant with all therapists together if possible. To reduce the possibility of therapists remembering an infant's performance from previous assessments, only the project coordinator added up the items and calculated the total scores and percentile ranks, not the therapists.

At the initial visit, information on income, parent education, and other demographic data was obtained. At every visit, parents completed a short questionnaire documenting any illness or other circumstances since the previous visit that may have influenced their infant's current performance. At 23 months of age, each infant was evaluated using the Diagnostic Inventory for Screening Children Preschool Screen (DISC Preschool Screen) [22]. Infants receiving a score on the DISC Preschool Screen below the recommended cutoff to indicate a 'suspicious' classification ($<7/12$) were further assessed using the full Diagnostic Inventory for Screening Children (DISC) to more clearly determine their developmental skills [23]. To avoid confounding patterns of abnormal development with typical patterns of development, the data of any child receiving a 'suspicious' developmental classification on the full DISC were removed from the analyses.

2.3. Measures

MTs used the Peabody Developmental Motor Scales (PDMS) [24] to evaluate fine and gross motor abilities as it was the only version available when the study began. It is designed for clinical use to identify children whose motor abilities are delayed relative to a normative group ($N=617$). The gross motor subscale has 170 items, and the fine motor subscale has 112 items. Scoring is on a three-point ordinal scale. Raw scores are converted to a percentile rank. Interrater reliability correlation coefficients are 0.97 for the gross motor subscale and 0.94 for the fine motor subscale.

SLPs used the Communication Symbolic Behavior Scales—Developmental Profile (CSBS-DP) to assess communication abilities [25]. It was designed to identify children at risk for impairment and to establish a profile of communicative, social-affective and symbolic functioning for monitoring changes over time and directing intervention. A standard protocol uses communication temptations and toy objects (e.g., bubbles, play dishes) to assess social communication, sound and word use, and symbolic behaviors. A caregiver participates in the assessment, which is videotaped for reference in coding and scoring behaviors. There are seven cluster scores that are summed to provide a total score. Norms for the current version were generated using 337 infants aged 12–24 months. Cronbach's alpha is 0.93. Behavior sample composite scores (percentiles) are reported and referred to as the communication scores.

The DISC Preschool Screen identifies children who need further screening using items tapping receptive and expressive language, auditory attentional memory, and gross and fine motor abilities. Split-half reliability is 0.77. Sensitivity is 0.91 with a specificity of 0.76. The DISC, the longer version of the test, is currently used to identify infants who are eligible for early intervention programs and to monitor their development. It assesses fine motor, gross motor, receptive language, expressive language, auditory attention and memory, receptive attention and memory, social, and self-help. The DISC was normed on 571 Canadian children. In comparison to the Denver Developmental Screening Test [26] and Stanford–Binet [27], the DISC identified more children with delay. Thus, our exit criterion for typical development was very stringent.

The PDMS and the CSBS-DP are used clinically both to identify children with developmental delay and to evaluate changes in children over time.

2.4. Data analyses

Visual analyses of graphs of individual infant's data and correlational analyses were used to answer the two study questions. To evaluate normative stability, three analyses were performed. First, percentile rank plots for each infant at each assessment age were generated with a 95% confidence intervals (CI) plotted around each score. The standard error of measurement (S.E.M.) reported in the manual was used to calculate confidence intervals for the CSBS-DP. For the PDMS, the S.E.M. was calculated because only the standard error of the mean was presented in the manual, and this error measurement is inappropriate to use with individual scores. Normative instability was indicated when an infant had at least one score with a CI that did not overlap with any of the other assessment points. Second, the proportion of typically developing infants who received 'at-risk' scores (< 16th percentile or 1 S.D. below the mean) was determined. Finally, correlation matrices were generated within each domain across assessment ages by calculating Pearson product-moment correlation coefficients. To examine ipsative stability (the relationship of scores across domains), two analyses were used. First, individual scores on fine motor, gross motor, and communication were plotted with 95% CI. Instability was identified at each assessment age by nonoverlapping CI across the three domains. Visual examination of the stability of individual infant's percentile rank changes over time provides descriptive information that is very clinically relevant. Second, intercorrelations of scores across domains at each assessment age were examined using Pearson correlation coefficients.

The CSBS-DP is a new test and normative data were being analyzed during our study. When normative data became available, the youngest age category reported was 12–14 months. Thus, stability of communication and cross-domain analyses can only be reported for 13, 16, and 21 months.

3. Results

3.1. Participants' characteristics

Data from 102 of the 120 children were used in the final analyses. One family moved, 11 children did not receive assessments by a SLP, and 4 children had missing data for one assessment. Two children received suspicious scores on the full DISC and were removed from the analyses. Of the 102 children, 49 were girls (48%) and all but 15% were White (2% Chinese, 2% South Asian, 11% mixed ethnicity). In two families, one parent was Black. The median yearly income was \$50,000–\$59,000 Canadian (range: < \$20,000 to >\$80,000) similar to the average household income of Alberta families [28]: 13% of the families were under the low-income cutoff. For education, 66% of the fathers and 68% of the mothers had completed college or university. Twenty-three infants (23%) were hospitalized at least once during the study.

3.2. Normative stability

Group data for the infants over time were normally distributed, confirming the appropriate use of percentile ranks and confidence intervals to examine stability of scores. Visual inspection revealed that the majority of infants (99% for fine motor, 94% for gross motor) demonstrated unstable patterns over the five assessments. Fig. 1 illustrates

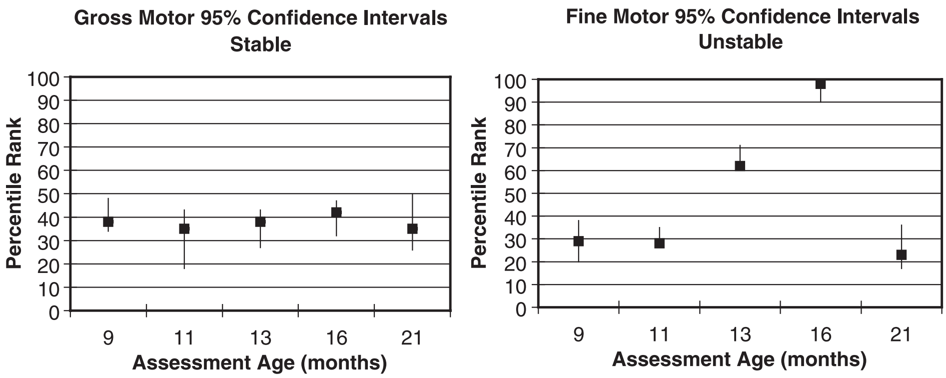

Fig. 1. Examples of stable and unstable motor development by confidence intervals.

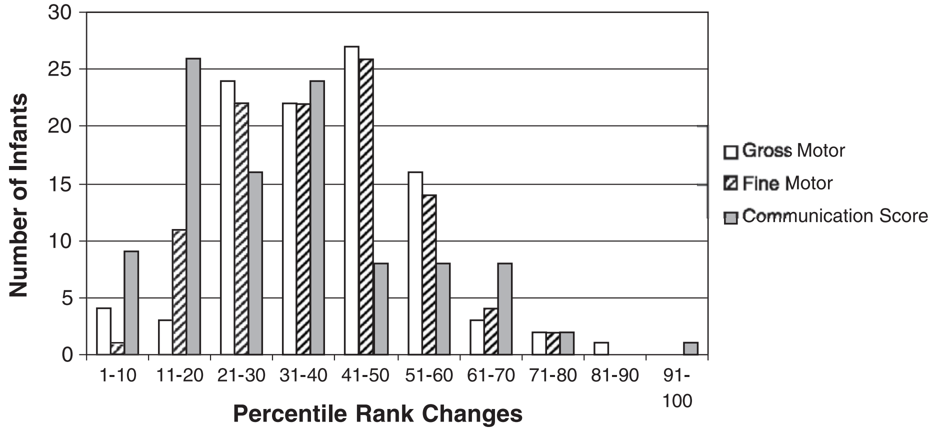

Fig. 2. Distribution of infants' percentile rank changes: Maximum gross motor and fine motor changes for 9, 11, 13, 16, and 21 month assessments; communication scores for 13, 16, and 21 months.

examples of stable and unstable developmental profiles. No common pattern could be identified among the infants. Their scores did not increase or decrease at the same ages in any domain.

Forty-one infants (40%) demonstrated unstable communication scores at 13, 16, and 21 months. Because of having fewer norm-referenced communication assessment times, patterns of stable/unstable motor scores were reexamined for the same three assessment ages. Eighty-seven (85%) infants had an unstable pattern for fine motor development and 77 (76%) had instability in gross motor scores.

Fig. 2 depicts the distribution of infants' maximum percentile change over the total assessment periods. This intraindividual variability in the scores of typically developing infants is larger than the band width of variability typically assumed by clinicians in rehabilitation. Sixty-two infants (61%) had at least one score below the 16th percentile over the five assessment ages. Table 1 shows the number of infants scoring below the 16th percentile at each assessment in each domain; some infants scored below the cutoff in more than one domain. In the gross motor scale, more infants scored below the 16th percentile at the early assessments, while in fine motor, more infants received scores below the cutoff at older ages. Most infants falling below the 16th percentile did so only once.

Table 1
Number of infants with a score of < 16th percentile at each age in each domain[a]

Domain	Age of assessment (months)				
	9	11	13	16	21
Gross motor	26 (25%)	17 (17%)	16 (16%)	8 (8%)	9 (9%)
Fine motor	11 (11%)	8 (8%)	10 (10%)	18 (18%)	21 (21%)
Communication	n/a	n/a	5 (5%)	4 (4%)	0 (0%)

[a] Normative data for 9 and 11 months for Communication are not available.

Table 2
Infants with scores < 16th percentile—number of occurrences[a,b]

Domain	Frequency of scores < 16th percentile				
	One time	Two times	Three times	Four times	Five times
Gross motor	16	8	7	2	3
Fine motor	21	11	7	1	0
Communication	7	1	0	n/a	n/a

[a] Normative data for 9 and 11 months for Communication are not available.
[b] Children may score below the 16th percentile in more than one domain.

However, three infants deemed typically developing at 23 months had scores below the 16th percentile on all five occasions in the gross motor domain (Table 2). When infants scoring below the 16th percentile were compared to those who did not, there were no significant differences between groups for number of illnesses, hospitalizations, family income, or parent educational level.

Stability of scores in each domain was examined using correlation coefficients (Table 3). The highest correlations were between the first three gross motor assessments and the lowest correlations were in fine motor scores. Fine motor scores at 9 months of age had little relationship to scores at 16 months. As expected, scores for adjacent ages were more highly correlated than for ages that were not adjacent.

Table 3
Within-domain correlation coefficient matrix[a]

Domain	Assessment age (months)			
	11	13	16	21
9 months				
GM	0.72	0.74	0.38	0.50
FM	0.57	0.42	0.15	0.27
11 months				
GM		0.76	0.37	0.48
FM		0.48	0.42	0.33
13 months				
GM			0.44	0.52
FM			0.46	0.32
CS			0.55	0.46
16 months				
GM				0.56
FM				0.44
CS				0.50

GM = Gross motor; FM = Fine motor; CS = Communication Scores.
[a] Normative data for 9 and 11 months for the Communication Scores (CSBS-DP) are not available.

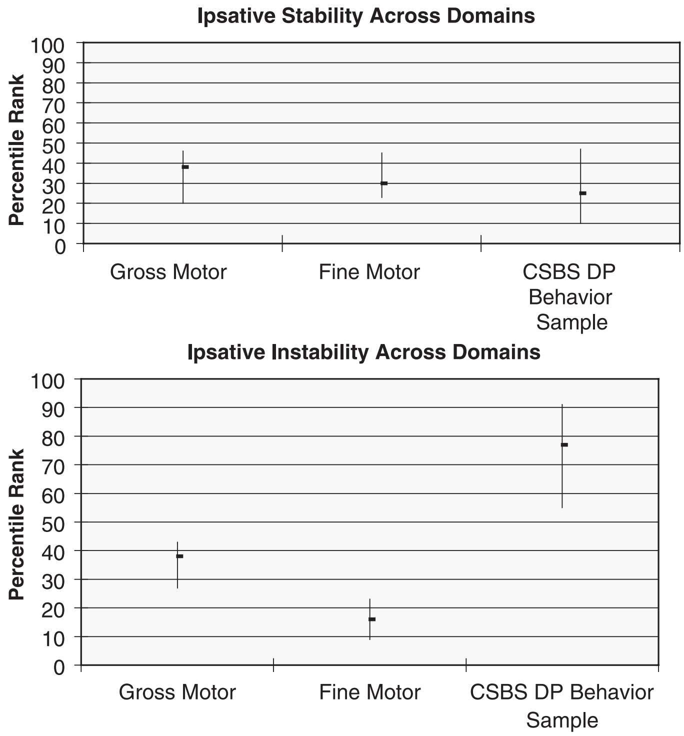

Fig. 3. Examples of ipsative stability and instability at 13-month assessment.

3.3. Ipsative stability

At 9 months, 68% of infants had nonoverlapping CI between fine motor and gross motor percentile ranks, while at 11 months, only 41% of infants demonstrated ipsative instability. Examining ages 13, 16, and 21 months when communication data were available, the proportion of infants demonstrating instability increased to 83% at 13 months, 84% at 16 months, and 92% at 21 months. This increase is not surprising considering that three domains were compared instead of two. Fig. 3 illustrates examples

Table 4
Correlation coefficients across pairs of domains[a]

Assessment age (months)	GM × FM	GM × CS	FM × CS
9	0.15	n/a	n/a
11	0.25	n/a	n/a
13	0.36	0.01	0.04
16	0.38	− 0.13	0.17
21	0.32	0.09	0.18

GM = Gross motor; FM = Fine motor; CS = Communication Scores.
[a] Normative data are not available for 9 and 11 months.

of ipsative stability and instability at the 13-month assessment. The correlation coefficients between fine motor, gross motor, and communication scores (Table 4) are lower than those obtained within each domain over time, indicating a weak relationship among scores in the three domains at any one assessment age. There is virtually no relationship between gross motor and communication scores while gross motor and fine motor scores appear to have a weak relationship at older ages.

4. Discussion

The results did not support the assumptions of either normative or ipsative stability in fine motor, gross motor, and communication abilities for typically developing infants between 9 and 21 months of age. Wide variability both within a child (intraindividual) and across children (interindividual) was observed in all three domains. Infants showed variable developmental trajectories. These results support the dynamic systems theory tenet of nonlinearity more than the constant rate of emergence of developmental skills suggested by tenets of the neuromaturational theory.

4.1. Intraindividual variability

Examination of individual trajectories of development over time provides richer information about intraindividual patterns of development than merely examining the rank order of infants' percentile ranks over time [29]. A clinical appreciation that intraindividual variability can be very large may improve the accuracy of screening in the three domains examined. Morrison [30] suggested that errors in screening, both false-positive and false-negative identification, occur for one of two reasons, characteristics of the test itself or the interpretation of the test results. Over the last 20 years, the emphasis in improving developmental screening has been on test characteristics and developing standardized measures with strong psychometric properties. Professionals assumed that using improved measures would decrease the rate of false-positive referrals. While the adoption of standardized measures has contributed to the accuracy of developmental screening, the large intraindividual variability demonstrated by the infants in this study, despite the use of psychometrically sound measures, suggests that screening results are influenced by the very nature of development. This reasoning challenges traditional interpretations of test results. Fluctuations in an individual infant's scores over time may not always indicate deviance or the need for intervention. Rather, maturation can occur in 'leaps and bounds' as well as in steady increments.

Typically developing children can score below the 16th percentile. In addition, a child who scores above the 90th percentile is not necessarily 'advanced' compared to a child who scores at the 40th percentile on the same measure at the same age because they may switch rankings at another assessment time. Rate of development should be viewed as fluctuating rather than constant. This view supports developmental surveillance [20], or the process of assessing a child's development serially over time, and seeking the impressions of caregivers as well as using the results of standardized measures. Meisels and Atkins-Burnett [31] caution that test results should only guide parents, teachers, and specialists to identify the best possible decisions for each child. The results of standardized testing must be placed in an appropriate context when used for screening purposes.

Intraindividual variability also has implications for the evaluation of intervention programs. It raises the possibility that a significant ‘improvement’ in the score of a child involved in early intervention may not represent a treatment effect, but may also be due to normal variations. This makes it more difficult to tease out the effects of early intervention from the effects of typical maturation.

4.2. Interindividual variability

Interindividual variability of scores among the infants was also evident. Some infants received higher percentile rank scores at younger ages and then scores steadily declined. Some had low scores to begin with and attained higher scores as they got older while many had scores that went up and down. This interindividual variability suggests that the variability observed is not due solely to a weakness of the tests. If test structure was the primary reason for the variability, then the infants’ scores would increase or decrease at the same ages. The low correlations across infants’ rankings over time also confirmed that infants’ scores did not increase or decrease in unison at particular ages. Rater error is also an unlikely reason for the observed variability as the interrater reliability was high, suggesting consistency of scoring conventions among therapists. In addition, the use of confidence intervals around the percentile ranks to determine stability/instability was used to account for measurement error.

What are the clinical implications of interindividual variability in development? For intellectual development, Moffit et al. [32] reported that in long-term serial assessments, children with labile (unstable) development had no difference in intellectual ability at 13 years of age compared to children who demonstrated stable intellectual development. The effect of different developmental profiles has not been studied for fine motor, gross motor, and communication skills. Perhaps children with a specific profile over time have a greater probability of showing long-term developmental problems. This ‘at-risk’ profile may not be one of consistently below average scores. The present cohort of infants will be followed to determine if children with developmental problems at 7 years of age have any commonalities in their scoring profiles during infancy and early childhood. Examination of developmental profiles, in addition to absolute scores, may improve screening predictions. More evaluation of developmental patterns is necessary. For the present, an awareness of the range of development in typically developing infants serves as a reminder to clinicians that there is no ‘gold standard’ of typical development.

4.3. Across-domain variability

The concept of ipsative stability across fine motor, gross motor, and communication developmental domains was not supported. The strongest relationship ($r = 0.38$) among any pair of domains was between gross and fine motor scores at the 16-month assessment. At 21 months of age, 92% of infants had nonoverlapping CI for fine motor, gross motor, and communication scores. These results suggest that development is asynchronous in the three areas. A typical infant may score high in one domain but low in another. It suggests that all areas of development should be encouraged simultaneously and that there should be no expectation that scores across developmental domains should show a strong relationship. Many of the infants in this study had higher scores in communication than fine and gross motor skills. This result may be influenced by the higher socioeconomic status (SES) of the families, reflected in the median income and the high number of years of education for the mothers. Schuele [33] reported that a disproportionately higher number of children with lower SES are represented within the lower regions of the normal distributions on standardized measures of language performance.

Our study was descriptive and exploratory in nature. As with all developmental research, it is extremely difficult to disentangle environmental influences from genetic influences to explain the infants' scoring patterns. No attempt was made in this study to identify or evaluate factors that contribute to the variability observed such as parenting styles, maternal depression, or environmental constraints. Future research needs to use a variety of methodologies such as regression modelling and cluster analysis to identify possible mediating variables and to tease out subgroups that are susceptible to increased variability. In addition, infants in the analyses were classified as typically developing at 23 months of age from their exit scores on the DISC Preschool Screen. Some of these children may demonstrate developmental concerns as they become older. Glascoe [34] suggested that children in the false-positive category of screening (i.e., those children that scored below a cutoff, but were deemed typically developing on further testing) constitute an 'at-risk' group that may need intervention services. Following our study group to age 7 will provide valuable information regarding the outcome of this interesting subgroup of children.

5. Conclusions

Our results challenge rehabilitation professionals involved in screening infants for developmental problems to reflect on the assumptions used to interpret scores on standardized assessments. Scores are an important component of the screening process, but it is imperative to use the results in conjunction with other important information such as parents' and professionals' general perceptions of an infant's abilities. In this study, infant development in the domains of fine motor, gross motor, and communication was characterized by variability rather than stability. This variability was identified within infants, across infants, and across different skill areas. Infant development is a wondrous journey, and its nuances may not be fully captured in current models of development. We need to learn from the infants.

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