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Neurobehavioral and developmental profile of very low birthweight preterm infants in early infancy

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Aim: To describe the neurobehavioral and developmental profile of very low birthweight (VLBW) preterm infants in early infancy. *Methods*: Twenty VLBW infants and 10 term control infants were assessed at term, 3 and 6 mo of age. Neurobehavioral assessments included the Neonatal Behavioral Assessment Scale (NBAS) at term; the Infant Behavioral Assessment at term, 3 and 6 mo of age and the Behavioral Rating Scale of the Bayley Scales of Infant Development—II (BSID-II) at 3 and 6 mo of age. Development was evaluated with the Bayley Motor and Mental Scale at 3 and 6 mo. *Results*: At term age VLBW infants differed from term infants on all the clusters and supplementary items of the NBAS. VLBW infants also showed more stress and less approach behavior at term and 6 mo of age and more problems with self-regulation in all subsystems at 6 mo of age. Moreover, VLBW infants performed lower on the Bayley Motor, Mental and Behavioral Rating Scale: 12 VLBW infants scored questionable or non-optimal on the Psychomotor Development Index and 18 questionable or non-optimal on the Behavioral Rating Scale. These results support the need for neurobehavioral intervention of VLBW infants in the first 6 mo of life.

Conclusion: Almost all VLBW infants showed non-optimal motor quality behavior at 6 mo and encountered far more problems with self-regulation compared with term infants.

Key words: *Bayley Behavioral Rating Scale, infant behavioral assessment, motor quality, preterm infants, self-regulation*

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Advances in perinatal and neonatal care lead to higher survival rates in preterm infants. The increased survival rate, however, has been accompanied by an increase in morbidity (1). Although severe developmental problems are encountered in only a minority of preterm infants, more than half of these infants suffer from minor deficits such as visual–motor integration problems, attention deficit disorders, hyperactivity, speech and language delay, behavioral problems, learning disabilities and motor impairment (2–4). Numerous studies reveal that these minor deficits become increasingly apparent with age, but may develop soon after birth (5–7). Minor deficits are often not identified early in life because measurements are not sensitive enough to detect behavioral and motor quality problems.

Very low birthweight (VLBW) preterm infants are born during a period in which the organization of the central nervous system is at a particularly vulnerable stage (8). Organizational processes during this period, also referred to as the “wiring” of the brain, are important for the development of autonomic stability, motor maturity, state organization, attention, interaction and self-regulation. Alterations can result in hypersensitivity and poorly modulated behaviors, and unexpected and frustrating patterns for the first 3–6 mo (9). Preterm infants risk poor developmental outcomes owing to both the child’s own immature and inadequate organizational system and the child’s early extrauterine environment (10).

The development of the child can be evaluated with respect to both its capability and rate. The developmental milestones have been the predominant metric for child assessments in most outcome studies in preterm infants. However, neurobehavioral assessments such as the Neonatal Behavioral Assessment Scale (NBAS) (11) the Infant Behavioral Assessment (IBA) (12) and the Behavioral Rating Scale of the Bayley Scale of Infant Development—II (BSID-II) (13) provide evaluation of atypical behaviors, e.g. problems in self-regulation, that may signal developmental complications susceptible to early intervention. Achievement of typical capabilities at certain times (milestones) may be important and informative, but atypical content and quality of development rather than milestone attainment may be of greater concern.

The purpose of this study was to describe the neurobehavioral and developmental profile of VLBW premature infants at term, and 3 and 6 mo of corrected age, and to compare their profile with healthy, term infants. The research question was whether neurobehavioral and developmental measurements would be able to detect neurobehavioral and developmental deficits in the first 6 mo of life, in order to investigate subsequently the effect of an individualized infant- and parent-focused neurobehavioral intervention program (14) in the near future.

Patients and methods

Study subjects

From January 1999 to July 1999, 20 VLBW preterm (11M, 9F) infants, who were born with a gestational age of <32 wk and admitted to the neonatal intensive care unit (NICU) of the Academic Medical Center (AMC) in Amsterdam, the Netherlands, were consecutively enrolled in the study. Only babies whose parents were living in Amsterdam were recruited. There were no rejections or missing cases. Gestational age was determined by the maternal history and ultrasound examination in early pregnancy and was confirmed postnatally by examination with the Dubowitz score (15). Infants were excluded if they had a congenital malformation or an intraventricular hemorrhage grade III/IV (16), or if their mothers had a history of drug use. A volunteer sample of 10 healthy term infants (3M, 7F), who were recruited from the antenatal clinic at the AMC and born in the same period, served as a control group. All term babies had an uncomplicated delivery and Apgar scores of >8 at 5 min. They had no detectable sensory or motor problems and their mother had used no drugs during pregnancy.

Preterm and term infants had a birthweight of 1198 ± 397 and 3293 ± 406 g (mean $\pm$ SD), respectively. Mean gestational ages for the preterm and term neonates were 29 ± 1.6 and 40 ± 0.6 wk, respectively. Eleven preterm infants (55%) had been ventilated (mean duration of mechanical ventilation 4.35 ± 5.9 d, range 1–19 d). None of the preterm infants suffered from a significant neurological problem in the early neonatal period; in 2 infants a small subependymal hemorrhage was found on cranial ultrasonography, 5 infants had chronic lung disease, 3 infants had ROP (two grade 1 and one grade 2) and 11 infants were firstborn.

Preterm infants were assessed at term (mean post-term age of assessment 9.7 ± 1.9 d), and 3 and 6 mo of corrected age. Term babies were assessed within 14 d after delivery (mean post-term age of assessment 9.1 ± 2.0 d). After discharge, all infants were followed by means of home visits. Moreover, information on socioeconomic status of the family, type of household, maternal and parental education, occupation and marital status was obtained.

Characteristics of the parents

Parents were from a mixed variety of ethnic backgrounds and 60% belonged to "ethnic minorities" from Turkey, Morocco, Africa and Asia; this proportion is representative of the total population of Amsterdam. Mean maternal and paternal age in the preterm group was 33 and 37 y, respectively, and in the term group 34 and 39 y, respectively. No significant differences were found in marital status, composition of the household, ethnicity, maternal and paternal years of education or employment status between the preterm and term groups.

The study was approved by the medical ethics committee of the AMC in Amsterdam and written informed consent was obtained from all parents during admission of their child to the hospital.

Methods

Measures were administered at term, 3 and 6 mo of corrected age at home by trained examiners in the presence of each infant's mother and/or father. Assessments were videotaped and included the NBAS (11) and the IBA (12) at term (corrected) age, and the IBA and the BSID-II (13) at 3 and 6 mo of (corrected) age.

Neonatal Behavioral Assessment Scale

The NBAS was performed by two certified pediatric physical therapists (MJW, KK). Both examiners achieved competence in administration at greater than 90% inter-rater reliability in scoring of the NBAS.

The NBAS evaluates the infants' status in four dimensions of functioning: autonomic stability, motor organization, state organization and attention/interactive capacities. Each of the behaviors is scored on a nine-point scale (17). The scoring of the NBAS includes seven supplementary items, but the item "Emotional response of the examiner" item was omitted in this study. These supplementary items are used to assess the behavioral quality of high-risk newborns. The conceptually and empirically based seven-cluster scoring method, developed by Lester, was used for data reduction. It reduced the behavioral items into seven clusters. The clusters were derived from previous factor-analysis studies (18) and included: 1, habituation: response decrement to repeated stimuli; 2, orientation: responses to animate and inanimate stimuli and overall alertness; 3, motor processes: integrated motor acts and overall muscle tonus; 4, range of state: rapidity, peak and lability of state changes; 5, regulation of state: efforts to modulate the infant's own state; 6, autonomic stability: signs of physiological stress (tremors, startles and color changes); and 7, reflex items. A higher score on the clusters indicates a more optimal behavior.

The predictive validity of the NBAS has only been described in short-term follow-up studies. Long-term follow-up studies suggest that the predictive validity of the NBAS depends on the use of repeated assessments over the first month of life (11).

Infant Behavioral Assessment (IBA)

The IBA was developed by Hedlund and Tatarka (12) for infants between 0 and 6 mo of age. The IBA was designed to sensitize parents and health professionals to the behavioral state and the organizational abilities of the infant by appropriate identification and interpretation of the infants' "communicative" behaviors. The IBA measures the capacity of the infant's level of self-regulatory strategies as a means to stabilize his or her neurophysiological functioning during assessment, care-giving routines and social interactions with adults. The assessment provides information that is necessary for the caregiver or health professional in mediating the infants' interactions with the environment and is in this way a prerequisite for a sound neurobehavioral intervention strategy.

The IBA is a 2 min observation of the infant's behavioral responses that can be easily incorporated within the administration of a "hands-on" instrument or during an observation of the parent and child in a caregiving, social interaction or the presentation of a toy. It provides a window into the infant's behavioral repertoire and measures the neurobehavioral integrity of the infant. In total, 115 behaviors have been defined, based on the work of Als (19). Drawing on Als' conceptualization of the Synactive Model, Hedlund and Tatarka (12) have further articulated this theoretical construct, resulting in the identification of four subsystems: autonomic, motor, state and attention/interaction. These four subsystems are defined as follows. The autonomic system is expressed in the pattern of respiration, color changes and visceral signals; the motor system is expressed by changes in tone, posture and movement; the state organizational system is expressed by the range of states available to the infant (i.e. deep sleep, light sleep, drowsy, alert, active alert, hyperalert and crying); and the attention/interaction system is used by the infant during an alert state to process cognitive and social information from the environment.

Hedlund and Tatarka identified three categories of behavioral expression: approach, coping (self-regulatory) behavior and stress. These three categories of behavioral cues reflect both the infant's responses to sensory input and the integrity of the four subsystems. Approach behavior may be interpreted to indicate that the sensory input that is being received by the infant matches his readiness to process and to make sense of the information. The infant uses coping (self-regulatory) behavior to help him to concentrate, process and learn from the stimuli that are offered to him, to "hold on" to maintain himself in response to incoming stimuli, or to console himself if pushed beyond his input threshold in attempt to regain a state of neurophysiological balance. Stress behavior indicates that the sensory input that the child is receiving is too much, too long, too frequent or too complex (12).

The IBA was administered and scored according to the directions in the manual (12). Both observers (MJW, KK) had achieved at least a 90% item-by-item agreement during training and certification. The occurrence of approach, self-regulatory (coping) and stress behaviors was counted within each subsystem, and the mean and median for each subsystem were calculated. A higher score of approach behaviors is more optimal and a higher score of stress behaviors is less optimal.

The infant needed to be in an alert state during all IBA observations. At term age the IBA was observed during the NBAS administration. For purposes of standardizing, test material from the NBAS was chosen. To obtain a precise interval or window, within which to observe the child's behavioral repertoire, an observation period of 2 min was specified by the examiner by using the visual orientation item (red ball) of the NBAS, because this task is simple and easy to replicate across examinations. All observations were videotaped and consisted an interaction using the visual tracking of the red ball, when the baby was supported on the examiner's lap at a 45° angle and the ball was held about 25–30 cm from the baby's eyes at midline. Subsequently, the ball was moved slowly and smoothly to the left and to the right. At 3 mo of age the IBA was observed, while the BSID-II Mental Scale was assessed during the administration of the item "glancing from bell to rattle". The examiner held the bell in one hand and the rattle in the other, keeping them about 20 cm apart and approximately 25–30 cm above the child's eyes but within visual field. This observation also lasted for 2 min when the child's eyes moved from one object to the other in response to the sounds. At 6 mo of age the IBA was observed before the administration of the BSID-II Mental Scale. This time, a bell was held in front of the child and the observation comprised the first 2 min in which the child looked at, reached for or manipulated the bell (from the BSID-II kit).

Because standardization was important, the interactor maintained a neutral face without speaking, as this posture will minimize the variability and intensity of social input. The tasks, comprising visual tracking in the neonatal period and looking for a rattle (3 mo of age) and reaching/grasping for a standard toy (6 mo of age), are easy to replicate across observations. Infants were always placed in a supine position, which allows for easy observation of the infant's face and extremities (12). All the observations of the IBA during the NBAS and BSID assessments offered enough opportunities to observe the infant under conditions that may be considered stressful (e.g. looking at a moving red ball, at toys with different sounds or at a silver-colored bell).

Bayley Scales of Infant Development—II

The BSID-II, including the Mental Scale, Motor Scale and Behavioral Rating Scale, was administered by the same experienced examiners (MJW, KK).

The BSID-II yields scores for mental and psychomotor development with a standardization mean of 100 and SD of 15 points. A score of <70 is 2 SD below the mean. Development was considered significantly delayed if the score was below 70, mildly delayed if the score was between 70 and 84, and within normal limits if the score was between 85 and 114. A score of 115 and above was considered as an accelerated performance. Scores from the Behavioral Rating Scale were interpreted at two levels: total score and factor scale scores. The total score represents the examiner's overall impression regarding the qualitative aspects of the child's behavior. It reflects neurobehavioral integrity and falls into one of three descriptions: within normal limits (score ranking at or above the 26th percentile for age), questionable (score ranking from the 11th to 25th percentiles for age) or non-optimal (score ranking at or below the 10th percentile for age). Scores in the non-optimal range signal that the infant is demonstrating delayed or impaired behaviors in one or more areas, while scores in the questionable range suggest possible impairment. At the age of 3 mo, two factor scores are measured: the attention/arousal factor and the motor quality factor. The attention/arousal factor refers to the infant's level of arousal, alertness and attention. At the age of 6 mo three factor scores are measured: the orientation/engagement factor, the emotional regulation factor and the motor quality factor. The factor scores fall into the same descriptions as the total score.

The content, construct and criterion validity of the BSID-II appears comprehensive and appropriate, while the predictive validity becomes more accurate from 2 y of age (13). Because there is no standardization for children in the Netherlands, US standardized norms were used.

Statistical analyses

Data were analysed using the SPSS 10.0 program (SPSS, Chicago, IL, USA). On the IBA a frequency measure was created by counting the occurrence of approach, self-regulatory and stress behaviors within each subsection, and calculating the mean and median for each subsection and subsystem. This particular derived measure was chosen because of its relevance to neurobehavioral interventions. Group differences on continuous measures were analysed using the Mann–Whitney *U*-test (two-sided). Differences on categorical measures (socioeconomic status, occupation, marital status and ethnicity) between the two groups were analysed with χ^2-tests. *p*-Values of <0.05 were considered to be significant

Results

Neonatal Behavioral Assessment Scale

The habituation cluster was omitted because the optimal state for the administration of the habituation cluster is a sleep state and most of the infants were in a drowsy or an awake state. In the remaining clusters, preterm infants showed lower scores, i.e. worse performance on the orientation, motor, range of state, regulation of state and autonomic stability cluster, but there was no difference between the preterm and term infants on the reflex scores (not shown). With the supplementary items, preterm infants also showed less quality of responsiveness (quality of alertness) over the course of the examination. There was also a significant difference in the attention item (Table 1). This item attempts to capture the cost of the attention by measuring the extent to which the motor and physiological systems are stressed. For the preterm infants it was much more difficult to maintain a state of attention and the stress of attending to an orientation item, measured by observing the demands on physiological or motor systems, was very high. The amount of help necessary from the examiner to facilitate the infants' optimal performance was also higher in the preterm group. Moreover, preterm infants showed more general irritability, which reflects their response to the mildly and moderate adverse stimulus situations encountered during the examination, and they had more difficulty with the state regulation system, which was reflected in less clear, organized states. Finally, preterm infants had limited "energy" resources (robustness of endurance)

Table 1. Neonatal Behavioral Assessment Scale: cluster scores and supplementary items in term and preterm infants at term age.

	Term		Preterm		
	($n = 10$)		($n = 20$)		p^a
Cluster scores					
Orientation	7.8	(5.5; 8.5)	4.5	(2.9; 5.9)	0.000
Motor system	5.8	(5.4; 6.6)	4.1	(2.7; 4.7)	0.000
Range of state	4.0	(3.6; 4.5)	3.1	(2.1; 3.7)	0.009
Regulation of state	6.5	(5.7; 7.1)	3.5	(2.8; 4.7)	0.000
Autonomic stability	6.0	(5.0; 7.2)	4.7	(3.1; 6.8)	0.049
Supplementary items					
Quality of alertness	8.0	(6.5; 9.0)	3.0	(2.2; 4.7)	0.000
Cost of attention	7.5	(7.0; 8.0)	5.0	(4.2; 6.0)	0.000
Examiner's facilitation	7.0	(5.7; 9.0)	4.0	(2.2; 5.7)	0.001
General irritability	6.0	(5.0; 8.0)	4.0	(2.0; 7.2)	0.035
State regulation	8.5	(6.7; 9.0)	6.0	(4.2; 7.0)	0.001
Robustness/ endurance	8.0	(6.7; 9.0)	4.0	(2.0; 5.7)	0.000

Data are median (P_{25}; P_{75}) values.
[a] Mann–Whitney *U*-test (two-tailed).

Table 2. Infant Behavioral Assessment: autonomic, motor, state and attention/interaction cluster scores in term and preterm infants at term age.

	Term		Preterm		
	($n = 10$)		($n = 20$)		p[a]
Autonomic cluster scores					
Approach	3.0	(2.7; 4.0)	1.0	(1.0; 2.0)	0.000
Coping	2.0	(0.0; 2.0)	2.0	(1.2; 2.0)	ns
Stress	0.5	(0.0; 1.2)	3.5	(2.2; 4.7)	0.000
Motor cluster scores					
Approach	6.5	(4.0; 8.0)	3.5	(2.0; 5.0)	0.002
Coping	5.0	(3.5; 7.0)	5.5	(4.0; 7.0)	ns
Stress	2.0	(0.7; 2.2)	5.0	(3.2; 7.0)	0.002
State cluster scores					
Approach	1.0	(1.0; 1.0)	1.0	(1.0; 1.0)	ns
Coping	1.0	(1.0; 2.0)	2.0	(1.0; 2.0)	ns
Stress	0.0	(0.0; 0.0)	0.5	(0.0; 1.0)	0.03
Attention/interaction cluster scores					
Approach	3.0	(2.0; 3.2)	2.0	(1.0; 2.7)	0.012
Coping	4.0	(1.7; 6.5)	6.5	(5.0; 8.0)	ns
Stress	0.5	(0.0; 1.2)	2.0	(1.0; 4.0)	0.007

Data are median (P_{25}; P_{75}) values.
[a] Mann–Whitney *U*-test (two-tailed). ns: not significant.

Table 4. Infant Behavioral Assessment: autonomic, motor, state and attention/interaction cluster scores in term and preterm infants at 6 mo.

	Term		Preterm		
	($n = 10$)		($n = 20$)		p[a]
Autonomic cluster scores					
Approach	4.0	(3.7; 4.0)	3.0	(2.0; 3.0)	0.009
Coping	0.0	(0.0; 0.2)	1.0	(1.0; 2.0)	0.004
Stress	0.0	(0.0; 0.0)	0.0	(0.0; 1.0)	0.014
Motor cluster scores					
Approach	10.0	(9.0; 10.0)	7.5	(6.0; 8.0)	0.002
Coping	6.0	(5.7; 6.2)	8.0	(7.0; 8.0)	0.003
Stress	0.5	(0.0; 1.0)	4.0	(2.0; 4.7)	0.000
State cluster scores					
Approach	1.0	(1.0; 1.0)	1.0	(1.0; 1.0)	ns
Coping	1.0	(1.0; 1.0)	1.0	(1.0; 1.0)	ns
Stress	0.0	(0.0; 0.0)	0.0	(0.0; 1.0)	ns
Attention/interaction cluster scores					
Approach	4.5	(3.0; 5.2)	3.0	(3.0; 4.0)	ns
Coping	3.0	(2.0; 5.0)	5.0	(4.0; 6.7)	0.010
Stress	0.0	(0.0; 0.0)	1.0	(1.0; 2.7)	0.014

Data are median (P_{25}; P_{75}) values.
[a] Mann–Whitney *U*-test (two-tailed). ns: not significant.

and needed more intermittent rest during the examination to reorganize themselves.

Infant Behavioral Assessment

State organizational subsystem cluster scores were not different between the groups at term, 3 mo and 6 mo of age (except for stress behavior at term age). Tables 2–4 show the results of the behavior counts by category (approach, coping and stress) in the autonomic, motor, state and attention/interaction subsystems at term, 3 mo and 6 mo of age, respectively. Differences between the two groups at term age were observed in approach behavior, which was decreased in the preterm group, and in stress behavior, which was increased in the preterm group. However, no differences in coping (self-regulatory) behavior were observed between the two groups (Table 2).

Table 3 shows the results of the behavioral counts by category in the two groups at 3 mo of (corrected) age. Differences were observed in approach and stress behavior in the motor cluster and in stress behavior in the attention/interaction cluster. Coping behavior was only increased in preterm infants in the autonomic system. Table 4 summarizes the results of the behavior counts by category at 6 mo (corrected) age. Differences in approach, coping and stress behavior between the two groups were observed in all systems, except that no difference in approach behavior was seen in the attention/interaction cluster.

Test results of the IBA proved to be fairly stable over time for each individual child, in both preterm and term infants (not shown).

Table 3. Infant Behavioral Assessment: autonomic, motor, state and attention/interaction cluster scores in term and preterm infants at 3 mo.

	Term		Preterm		
	($n = 10$)		($n = 20$)		p[a]
Autonomic cluster scores					
Approach	3.5	(2.0; 4.0)	2.5	(2.0; 3.0)	ns
Coping	0.0	(0.0; 1.2)	1.0	(1.0; 2.0)	0.049
Stress	0.0	(0.0; 0.2)	1.0	(0.0; 1.0)	ns
Motor cluster scores					
Approach	6.5	(6.0; 8.0)	4.5	(4.0; 6.7)	0.014
Coping	5.0	(3.7; 7.0)	5.0	(3.0; 7.0)	ns
Stress	1.0	(0.0; 1.2)	4.0	(2.2; 4.0)	0.000
State cluster scores					
Approach	1.0	(1.0; 1.0)	1.0	(1.0; 1.0)	ns
Coping	1.0	(0.7; 1.0)	1.0	(0.0; 1.0)	ns
Stress	0.0	(0.0; 0.0)	0.0	(0.0; 0.0)	ns
Attention/interaction cluster scores					
Approach	4.0	(2.7; 5.2)	3.0	(2.0; 5.2)	ns
Coping	2.0	(1.0; 3.2)	3.5	(2.2; 4.7)	ns
Stress	0.0	(0.0; 0.0)	0.0	(0.0; 1.0)	0.014

Data are median (P_{25}; P_{75}) values.
[a] Mann–Whitney *U*-test (two-tailed). ns: not significant.

Bayley Scales of Infant Development—II

Results for psychomotor developmental and mental index on the Bayley-II at 3 mo (corrected) age are shown in Table 5. At 3 mo of age only 1 preterm infant had a Bayley mental developmental index (MDI) <70 and 7 (35%) preterm infants had a Bayley MDI <85. One preterm infant had a Bayley psychomotor developmental index (PDI) <70 and 16 preterm infants (80%) had a Bayley PDI <85. None of the term infants

Table 5. Bayley Scales of Infant Development: motor and mental index scores and behavioral scores in preterm and term infants at 3 mo.

	Term		Preterm		
	(*n* = 10)		(*n* = 20)		p^a
BSID index scores					
Motor index scores	97	(89.5; 101)	79	(74.5; 82)	0.000
Mental index scores	104	(98.5; 107)	91	(80; 96.5)	0.001
Behavioral percentile scores					
Total percentile score	82	(52; 95)	16.5	(9.2; 29)	0.000
Attention/arousal	92	(79; 99)	56	(42; 88.5)	0.004
Motor quality	54.5	(37; 99)	11.5	(3.0; 15)	0.000

Data are median (P_{25}; P_{75}) values.
[a] Mann–Whitney *U*-test (two-tailed).

had a Bayley MDI <85. None of the term infants had a Bayley PDI <70, but one term infant had a Bayley PDI <85. On the Behavior Rating Scale (total percentile score), 6 (30%) preterm infants scored in the non-optimal and 8 (40%) in the questionable range. Nine (45%) preterm infants were in the questionable and 10 (50%) in the non-optimal range on the motor quality factor, whereas on the attention/arousal factor 17 (85%) preterm infants were in the normal range, 3 (15%) in the questionable and none in the non-optimal range. All term infants were in the normal range on both the Behavioral Rating Scale (total score) and the attention/arousal factor, but one term infant was in the questionable range on the motor quality factor (Table 5).

Results for psychomotor developmental and mental index on the Bayley-II at 6 mo (corrected) age are shown in Table 6. None of the preterm infants had a Bayley MDI <70 and 6 (30%) preterm infants had a Bayley MDI <85. Four (20%) preterm infants had a Bayley PDI <70 and 12 (60%) infants had a Bayley PDI <85. None of the term infants had a Bayley MDI <85 or a Bayley PDI <70, but two term infants had a Bayley PDI <85. On the Behavior Rating Scale (total percentile score) at 6 mo, 8 (40%) preterm infants were in the non-optimal and 10 (50%) in the questionable range. Seventeen (85%) preterm infants were in the non-optimal and one preterm infant was in the questionable range on the motor quality factor. All term infants were in the normal range of the Behavioral Rating Scale (total score), but one infant was in the questionable range on the motor quality factor. On the orientation/engagement factor, 3 (15%) preterm infants were in the non-optimal range and 7 (35%) in the questionable range. All term infants were in the normal range. On the emotional regulation factor, 7 (35%) preterm infants were in the questionable range and 3 (15%) in the non-optimal range. One term infant was in the non-optimal range and one term infant in the questionable range (Table 6).

Table 6. Bayley Scales of Infant Development: mental and motor index scores and behavioral scores in preterm and term infants at 6 mo.

	Term		Preterm		
	(*n* = 10)		(*n* = 20)		p^a
BSID index scores					
Motor index scores	91	(86.5; 101)	77.5	(70; 88)	0.004
Mental index scores	109	(102; 116.5)	88	(84; 101)	0.001
Behavioral percentile scores					
Total score	87.5	(73; 98)	14.5	(7.2; 24.2)	0.000
Orientation	98	(87; 99)	28	(21; 51)	0.000
Emotional/ regulation	87.5	(64; 97)	30.5	(16.5; 54)	0.006
Motor quality	74	(38.5; 99)	5.5	(3; 9.5)	0.000

Data are median (P_{25}; P_{75}) values.
[a] Mann–Whitney *U*-test (two-tailed).

Discussion

The main finding of this study was that VLBW preterm infants behaved different in early infancy compared with term infants, in terms of both neurobehavioral and developmental function. Moreover, the neurobehavioral functioning of the VLBW infants improved only slightly over time and these infants continued to remain vulnerable and poorly organized at 6 mo of (corrected) age.

The preterm infants in this study exhibited differences in all aspects of neurobehavioral function compared with term infants, and showed poorer performance not only on all neurobehavioral clusters but also on all supplementary items. Lester et al. (20) found similar results in the USA. Preterm infants were less well organized than term infants, who demonstrated a capacity to control their behavior to different levels of stimulation through an appropriate change of state. In the present study, the observed problems with state control, autonomic stability, lower level of alertness and higher level of irritability in preterm infants are all indicative of their difficulties in self-regulation. Although the follow-up period was short, this incapability to self-regulate, in particular as it improves only slightly over time, is of great concern because it may prelude developmental problems later in life, as recently shown in term infants (21). Although the value of assessing problems in self-regulation is increasingly recognized by researchers and practitioners in the interdisciplinary fields of early intervention (22, 23), many preterm infants with self-regulatory problems may not be under consideration for early intervention because their attainment of milestones may not be delayed. This is the result of assessment instruments that aim at quantifying the "skills" of the preterm infants rather than qualitative neurobehavioral measurements that provide indicators of the cost to the infant when interacting with the environment.

The IBA has been shown to be particularly valuable for use in early intervention programs because it measures the neurobehavioral integrity of the infant and facilitates the self-regulatory competence and developmental trajectory of the infant through the implementation of neurobehavioral strategies (developed as part of the Neurobehavioral Curriculum for Early Intervention) (14).

The preterm infants in the present study showed more stress and less approach behavior both at term and at 6 mo of age compared with term infants, although they improved slightly over time. At the age of 6 mo preterm infants also showed more coping behavior compared with term infants.

Coping or self-regulation can be used by the infant to process incoming information and may serve as a warning signal of impending disorganization. Preterm infants may, therefore, have used their coping, i.e. self-regulatory behaviors as strategies to lower the level of arousal, reduce stress and increase their interaction.

Preterm infants were, like term infants, able to maintain an alert (awake) state during the observation window. An alert (awake) state is a prerequisite for administering the IBA as the infants' behavioral repertoire is observed while they are interacting with the environment. It is likely that the preterm infants were able to remain in an alert state because of the very short observation period. However, if further demands had been placed on these infants by attempting to elicit longer attentional responses ("invested attention responses"), then coping strategies and stress signals might have become more predominant, as shown with the NBAS, which lasted much longer. Although preterm infants were able to stay in an alert state for a short period, it was evident that the alert state and attentional responsivity led to physiological and motor instability, accompanied by signs of disorganization and stress behavior. Preterm infants exhibited less smiling, greater fussiness, more irritability and gaze aversion during social interaction. They also showed more extension behavior such as grimacing and arching, which are considered as indicators of stress (19). These findings suggest that the accomplishment of a task increases the incidence of stress behavior as the preterm infant grows older. Stress behavior and disorganization in the autonomic system may potentially harm the growing, developing infant, and the combination of physiological instability and stress, even long after the NICU period, may be a potential risk factor for neurobehavioral and developmental dysfunction later in life (24).

Although behaviors in this study were elicited through a standardized sensory experience in both preterm and term infants, one should keep in mind that the results were obtained in a stressful situation, in that the examination involved an encounter with an unfamiliar adult and the assessment placed special demands on the infant.

However, in spite of the small sample size, considerable differences were found with the IBA between preterm and term infants, indicating that the IBA was an excellent observational instrument in infancy. However, further research is needed to examine its concurrent and predictive validity. Moreover, further standardization regarding the length of observation, activity during the observation and timing of the IBA observation is warranted.

The mean Bayley MDI score in preterm infants at 6 mo was 0.5 SD below the mean of the normative sample, but similar to the findings of the validity study of the BSID-II. The mean Bayley PDI score of preterm infants at 6 mo was approximately 1.5 SD below the mean of the normative sample and slightly lower compared with the USA preterm study group (13). This observation may be explained by the differences in gestational age of the respective preterm infants. The USA sample comprised older infants with a gestational age of >35 wk, while infants in the present study had a gestational age of <32 wk. Vohr et al. (25) reported, in a cohort of extremely low birthweight infants (ELBW), a mean Bayley PDI of 78.1 ± 18.3 at the age of 18 mo, which is similar to the results in the present preterm group at 6 mo. In their study, 57% of the infants had a Bayley PDI of 1 SD below the mean and 29% of the infants had a Bayley PDI of more than 2 SD below the mean. This was comparable with 60% and 20%, respectively, in the current study. The infants in Vohr's study, however, had a lower birthweight than the present infants. An explanation for the "relative" poor results therefore may be that more than half of the parents of these infants were from ethnic minorities and had a low socioeconomic status; factors that are associated with poor developmental outcome (25).

Other recent studies show similar results, with Bayley scores <70 in 20–26% of VLBW and ELBW infants (26, 27). These findings indicate that, even after correcting for prematurity, low-risk preterm infants perform less favorably on the BSID-II compared with their term peers and that the index scores do not improve over time. Preterm infants also scored lower on the Behavioral Rating Scale (total score) at 3 and 6 mo of age (28). At the age of 3 mo, however, none of the preterm infants fell into the non-optimal range. Similar results were encountered with the IBA at 3 mo of age, when no differences were found in approach and coping behavior between the preterm and term infants on the attention/interaction subsystem. The orientation/engagement factor of the Behavioral Rating Scale, which was measured at 6 mo of age, was lower in preterm infants as well. Scores in the non-optimal range indicate a low level of initiative and involvement with tasks, and a reluctance to engage socially (13). The emotional regulation factor rating scores were also lower in preterm infants; this factor indicates the infants' activity, adaptability, affect, cooperation and frustration tolerance. Scores in the non-optimal range indicate poor adaptability and irregular or unstable self-regulation. The fact that half of the preterm infants had problems in this domain was also reflected in the IBA at 6 mo, which revealed that preterm infants indeed had problems with self-regulation and showed much more stress and avoidance behavior compared with term infants in the autonomic, motor and attention/interaction subsystems.

Finally, the motor quality factor was markedly lower in preterm infants at 3 and 6 mo of age, and at 6 mo of age almost all preterm infants scored non-optimally. Motor quality assesses a variety of neuromotor functions, i.e. muscle tone, posture, fine and gross motor movements, bradykinesia and frenetic movements. "Subtle" problems, including delayed integration of postural reactions, delayed development of head and upper extremity control, poor visual motor coordination and motor clumsiness, in preterm infants have also been documented by others, and the assessment of the motor quality is considered to be a much better indicator of motor dysfunction and clinically more useful than milestone attainment (29, 30).

The outcome of the assessments in this study may have been influenced by the fact that giving birth to a preterm infant is a stressful event. Under these circumstances, the parents' ability to respond sensitively and to cooperate with the infant's behavior may be seriously compromised and may have influenced the behavioral state and interactional quality of the preterm infant and the outcome of the neurobehavioral tests.

In conclusion, although these infants were not very preterm by modern standards, the results of the NBAS, IBA and the Behavioral Rating Scale of the BSID-II showed that even in older preterm infants more problems with self-regulation were encountered when compared with term infants. As preterm infants grows older they show more approach behavior and less stress behavior in the absolute sense; however, compared with full-term infants they show still significantly more stress behavior and less approach behavior. Moreover, the PDI, MDI and behavioral scores, in particular the motor quality factor score of the BSID-II, were lower in preterm than in term infants, and this phenomenon did not improve over time.

The results of this study may contribute to the current body of research related to infants' approach, self-regulatory and stress behaviors, and this information can also be used to support further study on early neurobehavioral and developmental intervention in VLBW infants during early infancy.

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