History and Description of the Neonatal Intensive Care Unit Network Neurobehavioral Scale

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ABSTRACT. This article provides an introduction and background to the Neonatal Intensive Care Unit Network Neurobehavioral Scale (NNNS). First is a summary of the history of the field of infant assessment. This is followed by a description of the NNNS, including its basic features and how the NNNS differs from other examinations. We then describe the biobehavioral basis for the examination and review studies in which the NNNS has been used. Finally we discuss the developmental model on which the NNNS is based and consider the implications of using the examination. *Pediatrics 2004;113:634–640; assessment, at-risk infant, drug exposure, infant, low birth weight, neonatal, neurobehavioral, NNNS, prematurity.*

ABBREVIATIONS. NNNS, Neonatal Intensive Care Unit Network Neurobehavioral Scale; NBAS, Neonatal Behavioral Assessment Scale; APIB, Assessment of the Preterm Infant's Behavior; CNS, central nervous system; DTO, diluted tincture of opium; SDA, state-dependent administration.

HISTORY OF INFANT ASSESSMENT

The Neonatal Intensive Care Unit Network Neurobehavioral Scale (NNNS) was designed for the neurobehavioral assessment of drug-exposed and other high-risk infants, especially preterm infants. The NNNS evolved from a rich tradition of previous infant assessments.

Infant assessment, historically, has been strongly influenced by the current dominant theoretical view of the infant and of the mind or brain. Before the turn of the century, the infant was viewed as diffusely organized, unstructured, lacking in sensory capacities and motor abilities. No examinations existed because there was "nothing" to evaluate.

At the turn of the century, infant functioning was associated with the model of reflexes developed by Sherrington.[1] Much of this work was based on studies of the spinal frog and the view that the single neuron was the fundamental unit of the nervous system. This model was elaborated by learning theorists who viewed the reflex, like the neuron, as the building block of behavior. During this period,

Pieper[2] began his exploration of the newborn's reflexes, eventually publishing a standard neurologic text on newborn neurobehavior. Critical demonstrations of reflexes in anencephalic infants supported the idea that the infant operates only at the spinal level.

Reflex models became supplemented by models of more generalized motor functioning. André-Thomas[3] and Sainte-Anne Dargassies[4] developed an examination that focused on the motor tone of the infant in which tone involved passive and active components. They were influenced by models of the brain that were beginning to focus on mass action as enunciated by Lashley[5] in the United States and those that included inhibitory and excitatory centers, concepts that would not be fully incorporated into thinking about infants for another 25 years. Critically, this idea led to the view that the infant was able to modulate behavior, not just act in an all-or-none manner. Concepts of active and passive tone became part of the dominant view of infant assessment, and the model started to evolve into one of control or feedback systems, with the thermostat as the mechanical metaphor.

A major advance, by Prechtl and Beintema,[6] was the introduction of the concept of state. Descriptively, states were differentiated, structured organizations of the brain and associate physiology that affected how the infant responded to the same stimulus. The same stimulus resulted in different responses in different states, introducing a substantive change in the view of the infant's neurobehavioral functioning. The brain, not just the spinal cord, was involved in the infant's responses, and, more important, the infant's brain was active. When state was considered, the neurobehavioral organization of the infant became more apparent. State, the organization of its components and their sequential organization over time, became "assessable" features of the infant's neurologic status. An intact brain was capable of organizing states, whereas a damaged brain could not. This advance was derived from early work on sleep and electroencephalographic activity in which it was demonstrated that the brain is not simply quiescent when the organism is asleep but shows differentiated states with different electrical, physiologic, and behavioral concomitants. Thus, even when asleep, the brain was active. Prechtl's formulation of "state" decimated the reflex model of the infant.

Examination of the infant's neurologic status became a feature of standard care. These examinations

viewed the infant as active, as in part responsible for generating the responses, and as able to modulate performance. Research demonstrated that even asphyxiated infants and anencephalic infants generated variable reflexes that healthy infants modulated their responses and that modulation and state-dependent responsiveness were characteristics of the infant. Simple S-R reflex models were no longer tenable—there was a brain in the infant.

In the 1950s and exploding into the 1960s to 1990s, developmental researchers demonstrated highly complex functioning in the infant. Fantz et al[7] demonstrated preferential gaze, and much research followed showing that neonates were capable of complex, highly differentiated hand movements,[8] discrimination of sounds,[9–11] instrumental conditioning,[12] affective behaviors in response to stimuli,[13] detection of odors,[14] coordination of movement and speech,[15] and different cry patterns.[13,16] The infant also engaged in socially focused activities.[17]

As this competent infant arrived on the scene, it was also recognized that the infant had abilities to control (regulate) its own level of arousal and to habituate a rudimentary form of learning. The recognition of infant functional competence led to the development of assessments of these more complex forms of behavior. Rosenblith[18] developed a scale that incorporated qualities of infant orientation and habituation as well as tone and reflexes. Brazelton[19] developed the Neonatal Behavioral Assessment Scale (NBAS), which included items focused on the infant's capacity to self-regulate and to interact with animate and inanimate stimuli. Thus, for the first time, the infant's social competence was assessed, or at least the infant's competencies in a social context. With these advances and influences from formulation of the concept of temperament, the field of assessment moved beyond the evaluation of neurologic integrity and toward assessment of individual differences. The NBAS focused on assessing the infant in a social context and emphasized how the infant's individual differences affected caregiving and development.

Studies of normal infants raised questions about what might affect the expression of behavior of newborn infants. Brazelton and his colleagues pioneered studies of factors (eg, obstetric medication) of medical conditions (eg, low birth weight) that affected the infant's neurobehavioral organization. Thus, with its focus on individual differences and the factors that affect those differences, as well as its conceptualization that these differences affect the caregiver's behavior and infant long-term development, the NBAS became the dominant behavioral assessment in the field. This use of the NBAS confirmed the emerging view that infant development was determined by a complex interactionist perspective. It has been used in several hundred studies focusing on a variety of issues, including studies of normal development, at-risk infants, cross-cultural factors, and intervention. As such, the NBAS is the benchmark neurobehavioral examination, the "parent" of the NNNS and several other examinations such as the Assessment of the Preterm Infant's Behavior (APIB).[20]

DESCRIPTION OF THE NNNS

The NNNS was developed as an assessment for the at-risk infant, especially substance exposed, and was meant to have broad applicability. It is a comprehensive assessment of both neurologic integrity and behavioral functioning, including withdrawal and general signs of stress.

The NNNS was developed for the National Institutes of Health for the multisite "Maternal Lifestyle" longitudinal study[21–23] of prenatal drug exposure and child outcome in preterm and term infants. The demands of this project required an examination that evaluated risk status and toxic exposures in a wide range of infants of varying birth weights and that could be used reliably at multiple sites. The examination needed to assess broadly the infant at risk, not just a single group, such as preterm infants or only drug-exposed infants, for 2 major reasons. First, most drug-exposed infants are term, not preterm, infants. Second, prenatal drug exposure often occurs in the context of multiple risk factors. These factors may be biological, such as prematurity or intrauterine growth retardation, or social, such as poverty, poor nutrition, and lack of prenatal care, which also have biological consequences for the infant. Therefore, the examination needed to be sensitive to the many risk factors that affect infant neurobehavior and to assess a variety of domains of functional status. Moreover, there was a broader need for an examination that was standardized. The idea was to provide a comprehensive evaluation of the neurobehavioral performance of the high-risk and substance-exposed infant during the perinatal period: neurobehavioral organization, neurologic reflexes, motor development, active and passive tone, and signs of stress and withdrawal.

The NNNS draws on previous examinations in addition to the NBAS, including the Neurological Examination of the Full-Term Newborn Infant,[24] the Neurological Examination of the Maturity of Newborn Infants,[25] the Neurological Assessment of the Preterm Infant (NAPI),[26] and the APIB.[20] Signs of stress and withdrawal observed during a neurobehavioral examination were scored to the Neonatal Abstinence Score.[27] Use of the examination was not restricted to a particular type of infant (eg, drug-exposed) or to a limited age (eg, term or preterm), and it could be used for a variety of infants and for infants of varying gestational ages.

The NNNS assesses and scores the full range of infant neurobehavioral performance; assesses infant stress, abstinence and withdrawal, neurologic functioning, and some features of gestational age assessment; specifically and procedurally evaluates behavioral states; and frames the assessment of other behaviors within states. It can be used with low and extremely high-risk infants once they are stable and well into the postnatal period. It has a standardized administrative format that "removes" the examiner from the behavior assessed and evaluates the quality of the examination. The examination was designed to have internal validity and appropriate statistical properties and includes scores for the major domains

of neurobehavioral performance, as well as stress and withdrawal. Finally, the NNNS was designed to be sensitive to the effects of drugs and other risk conditions based on empirical literature.

There are important differences between the NNNS and the NBAS. First, the examinations were developed for different target populations. The NBAS was developed to describe the behavior of normal, term, healthy infants. The NNNS was developed to describe the behavior of infants at risk, with a focus on drug-exposed and preterm infants. This accommodation was achieved in the NNNS by expanding the scoring of NBAS items to include the behavior of at-risk infants, by adding new items, particularly as related to reflexes, tone, posture, motor activity, and by adding additional scoring for stress/abstinence signs. Second, the examinations are administered differently. The NBAS is more unstructured. The focus on eliciting optimal performance alters the order of administration of the items and the amount of time devoted to items (hence the overall examination length). It also results in the examination's being as much a product of the infant-examiner interaction as of the infant's behavior and makes it more difficult to conduct a standardized examination. The advantage of this approach is that it brings out the "best" behavior that the infant has to offer, which is useful for intervention with parents. The NNNS has a more standardized approach. The order of administration of items is specified, the items are skipped if the infant is in the wrong state, and there are scores to record deviations in the administration of the examination. There are guidelines for when and how to console the infant, there is less control over the infant's state, and procedures used to maintain the infant's state are coded. In short, the examination is more based in the infant than in the infant-examiner interaction, and the scores provide a better estimate of how the infant responds to a standardized set and sequence of events. This approach also shortens the time to administer the examination. Training is shorter and less complex because there is less need for the judgments and skills required to elicit optimal performance.

DESCRIPTION OF THE NNNS EXAMINATION

The complete NNNS examination should be performed only on medically stable infants in an open crib or isolette. It is probably not appropriate for infants <30 weeks' gestational age; the upper age limit may also vary, with a reasonable upper limit of 46 to 48 weeks (corrected or conceptional age, ie, weeks' gestational age at birth plus weeks since birth). Thus, the NNNS provides a useful bridge in assessment from the early gestation and newborn infant periods to 2 months' corrected age, when standardized infant assessments can be administered reliably.

Neurologic Status

Neurologic items were selected to provide a valid assessment of the neurologic integrity and maturity of the infant, based on their demonstrated clinical utility and empirical validation, as well as chosen to represent the various "schools," such as the French angles method[25] and the primitive reflexes method.[24] Many items were omitted because they were redundant with other items or because they have shown little utility in research studies. The number of neurologic items was limited to balance with the behavioral part of the examination so that it could be completed in <30 minutes and not unduly fatigue or stress the infant. Infant state is specified for each reflex. The NNNS identifies normal or best responses, if applicable, but a wide range of normal is recognized and the best response is meant only as a point of reference.

A crucial part of the neurologic assessment is the assessment of muscle tone, which is assessed under both active and passive conditions. Active tone is assessed while observing spontaneous motor activity, including efforts at self-righting. Passive tone can be assessed during the posture, scarf sign, popliteal angle, and forearm and leg recoil. Both may be influenced by infant state, position (prone, supine, or supported upright), or the effects of postural reflex activity. When assessing muscle tone, both the distribution (proximal versus distal) and the type of tone (extensor versus flexor) should be described because in the developing infant, proximal tone in the neck and the trunk may differ from distal tone in the extremities. For example, in the preterm infant, flexor tone develops first in the lower extremities, in contrast to the more mature term infant, who demonstrates uniform flexion.

Stress/Abstinence Scale

Most work documenting signs of stress in drug-exposed infants involves signs of abstinence or withdrawal, usually in infants of heroin-addicted or methadone-dependent mothers. Less potent opiates have been identified as precipitating a neonatal opiate abstinence syndrome, and some nonopiate central nervous system (CNS) depressants have also been implicated.

In work to date with cocaine-exposed infants, neonatal abstinence symptoms do not seem to be increased. However, abstinence may occur from the depressants and narcotics used concomitantly with cocaine. Cocaine-exposed infants may show additional signs of stress, such as lethargy, in which the infant is unable to maintain a quiet awake state or crying during social interaction. In addition, we have added other signs of stress that have been described in cocaine-exposed infants as well as signs of stress typical of other high-risk infants, including preterms.[20]

NNNS Procedure

In the NNNS, items are administered in packages, with each package beginning with a change in focus or position. The order of administration is relatively invariant. (See "The Neonatal Intensive Care Unit Network Neurobehavioral Scale Procedures" in this issue for details of the maneuvers or packages and their respective items in the preferred order of administration and Appendix 1, later in this issue, for the scoring form.)

During the preexamination observation, the infant is asleep, prone, and covered. Initial state is scored using the traditional 1 to 6 criteria described by Prechtl.[28] All other items include criteria for why an item is not administered in addition to criteria for scoring the behavioral response. The response decrement items are administered with infant in state 1 or 2 and coded on scales that include criteria for when the infant stops responding ("shutdown") and criteria for when the item is discontinued. During unwrap and supine, the infant's posture, skin color, and movement are observed and scored on scales that include, when appropriate, criteria for normal, hyporesponsivity, and hyperresponsivity. Skin texture is also scored for the presence of specific conditions. The 7 lower extremity reflexes, 9 upper extremity reflexes, 4 upright responses, and 3 prone responses are administered with the infant in states 3, 4, or 5 and include classic reflexes and measures of tone and angles, scored on scales that also include, when appropriate, criteria for normal, hyporesponsivity and hyperresponsivity. The infant, in state 4 or 5, is picked up and cuddled and scored separately for cuddle in arm and shoulder. The 6 orientation items are then administered with the infant still in state 4 or 5, on the examiner's lap. The types of handling procedures used to keep the infant in state 4 or 5 during the orientation package are scored along with the orientation responses. The infant is picked up for the spin items, returned to the crib for the final set of reflexes, and observed for the postexamination period.

Alternatives to this order may be required with some infants. For example, if the infant is not in an alert state or cannot be brought to an alert state when supine on the examiner's lap, then it may be necessary to administer the orientation items at a later point during the examination, when the infant is alert. For some infants, the examiner may need to rearrange the packages but can maintain the preferred sequence within the packages, whereas for others, the items must be administered without regard for the preferred order of either packages or items within packages. The extent of deviation from the standard order may provide critical information about the infant's functional status. Finally, although every effort should be made to start with a sleeping infant, this is not always possible and the response decrement items cannot be administered first.

The Stress/Abstinence Scale (items are listed in "The Neonatal Intensive Care Unit Network Neurobehavioral Scale Procedures" later in this issue) includes 51 items divided into the following systems: physiologic, autonomic, CNS, skin, visual, gastrointestinal, and state. Each item is scored as present/absent with definitions provided in the manual if the examiner observed the event during the examination.

Data Reduction and Scoring

Missing Data

Specific codes are used to identify reasons that an item cannot be scored. Each item contains only codes that are logical outcomes of the specific manipulation or observation. Codes may indicate that the item was started but discontinued because the infant's response lasted too long (eg, habituation items), that the item was not administered because the infant did not respond after gentle prodding (eg, habituation items), that the item was started but discontinued because the infant changed to an inappropriate state, that the item was not administered because the infant was in an inappropriate state, or that the item was inadvertently skipped by the examiner.

Asymmetric Reflex Scores.

For many reflexes, the left and the right sides are evaluated separately. The scoring system is designed to reveal systematic asymmetries across items.

Summary Scores

Summary scores were developed a priori and tested in the Maternal Lifestyle Study sample of 1388 infants. Half of the sample was randomly selected and used to test the internal consistency of the summary scores without any information about the characteristics of the infants (eg, exposure status, birth weight). Alpha coefficients were computed on the summary scores and found to be acceptable (shown in Table 1 of "Summary Statistics of the Neonatal Intensive Care Unit Network Neurobehavioral Scale Scores From the Maternal Lifestyle Study: A Quasinormative Sample" later in this issue). The summary scores were then computed for the entire sample and found to be stable. The summary scores include habituation, orientation, amount of handling, state, self-regulation, hypotonia, hypertonia, quality of movement, number of stress/abstinence signs (which can be also computed by organ system), and number of nonoptimal reflexes. Summary score definitions and calculations are shown in Appendix 2 (later in this issue).

BIOBEHAVIORAL BASIS OF THE NNNS

The term "neurobehavioral" is critical to understanding the NNNS. The term "neurobehavior" was developed to characterize older children and refers to an expanded neurologic examination that involves sophisticated observation of higher cortical function and motor output that is often combined with an assessment of the maturation of the CNS or a search for minor neurologic indicators. Here the term is used broadly to reflect the idea that all human experiences have psychosocial as well as biological or organic contexts. "Neurobehavioral" recognizes bidirectionality—that biological and behavioral systems dynamically influence each other and that the quality of behavioral and physiologic processes is dependent on neural feedback. Neurobehavior becomes the interface of behavior and physiology and includes neurophysiological mechanisms that mediate specific behaviors or psychological processes.

These processes are affected by multiple risk factors. Thus, the NNNS was designed to measure processes of biobehavioral organization determined by multiple risk factors. Because much of the biobehavioral organization of the infant is determined by the

combination of multiple biological and social risk factors, the examination must be sensitive to the broad range of behaviors that high-risk infants present.

Drug exposure is one such major biological factor and provides a good model for understanding multiple risk factors. Much is known about the mechanism of action of specific drugs, and there is concern that illegal (cocaine, opiates, and marijuana) and legal (alcohol and tobacco) drugs may act as behavioral teratogens, altering fetal brain development and subsequent function. Typically, the mechanisms of action are construed as individual agents such as cocaine on dopaminergic systems or alcohol on inhibitory amino acid systems. However, there is also evidence that, in addition to these specific effects, there is a mechanism of action common to all drugs of abuse that centers on activation of specific neural pathways that project from the pons and midbrain to more rostral forebrain regions, including the amygdala, medial prefrontal cortex, anterior cingulated cortex, ventral palladium, and nucleus accumbens.[29] Regardless of the site of initial binding of a drug in the brain, there may be a final common pathway for drug action that affects neurotransmitter systems. The behavioral expression of these effects is not known. This approach also supports the multiple risk model because it could suggest that polydrug exposure acts in a cumulative or synergistic manner on the same neurotransmitter systems. There is a cumulative effect of risk factors that place increased stress on the nervous system that in turn affects behavior, and these effects may be different from the effects of the individual risk factor.

Therefore, the NNNS was designed to be generically sensitive to the range of behaviors that at-risk infants display and also attend to the specific dimensions affected by multiple risk factors. Neurologic integrity, tone and posture, behavior and signs of stress, and withdrawal were included to assess a variety of functional domains and to be useful for the range of high-risk infants.

RELIABILITY AND VALIDITY

Training to reliability criteria, including separate criteria for the administration for scoring, was established for the Maternal Lifestyle Study. A training video and manual were developed. Twelve examiners at 4 sites were initially trained with reliability periodically rechecked during the 2-year period of data collection. Approximately 1400 1-month-old infants were given the NNNS, providing a database with a cross-section of infants who vary in birth weight, substance exposure, race/ethnicity, social class, and geographic location.

Test-retest reliability was established in 2 ongoing studies. In 2 studies, 1 in the United States, the other in India, preterm infants were tested at 34, 40, and 44 weeks' gestational age. In both studies, the NNNS summary scores showed statistically significant correlations ranging from 0.30 to 0.44 across the 3 tests.

Validity of the NNNS was first documented in a study of term newborns.[30] Infants with cocaine and alcohol exposure were compared with infants with alcohol exposure alone and those without prenatal drug exposure. Differences were found between the cocaine/alcohol and alcohol group as well as between these groups and the unexposed group showing the sensitivity of the NNNS to the effects of cocaine and alcohol.

Results from the Maternal Lifestyle Study, the study for which the NNNS was developed, in a sample of almost 1400 1-month-old infants showed that prenatal cocaine exposure was related to lower arousal, poorer quality of movement, self-regulation, higher excitability, more hypertonia, and more nonoptimal reflexes.[23] Most effects remained with adjustment for covariates, including other drugs (alcohol, marijuana, and tobacco), birth weight, and social class. There were also effects in this study for heavy cocaine exposure and separate effects for opiates, alcohol, marijuana, tobacco, and birth weight. These effects show that the NNNS is sensitive to level of exposure, to drugs other than cocaine, and to birth weight. Data from this study are also shown in "Summary Statistics of the Neonatal Intensive Care Unit Network Neurobehavioral Scale Scores From the Maternal Lifestyle Study: A Quasinormative Sample" later in this issue.

In a drug treatment study of infants with neonatal opiate withdrawal syndrome, infants treated with diluted tincture of opium (DTO) alone were compared with infants treated with DTO and phenobarbital (M. Coyle, MD, A. Ferguson, OTR/L, L. LaGasse, PhD, E. Liu, PhD, and B. Lester, PhD, unpublished data, 2000). On the NNNS, the infants in the DTO plus phenobarbital group were more alert and interactive with their environment, had smoother movements, were physically easier to handle, and were less stressed during the first 3 weeks. The improved neurobehavioral organization of these infants may indicate a more rapid recovery from opiate withdrawal. In a related study, the opioid-dependent pregnant women who were given buprenorphine showed little evidence of withdrawal on the NNNS, suggesting that buprenorphine might be more beneficial for the infant than methadone (M. Coyle, MD, A. Ferguson, OTR/L, L. LaGasse, PhD, E. Liu, PhD, and B. Lester, PhD, unpublished data, 2000).

The NNNS has also been used to study the effects of cigarette smoking during pregnancy and on NNNS scores in the newborn.[31] After adjustment for covariates, tobacco-exposed infants were more excitable, were hypertonic, required more handling, and showed more stress/abstinence signs. There were also dose-response relationships between level of maternal salivary cotinine (metabolite of nicotine) and the number of stress/abstinence signs and between the number of cigarettes per day that the mother smoked during pregnancy and the number of stress/abstinence signs. These findings indicate that the NNNS is sensitive to the neurotoxic effects of prenatal tobacco exposure and neonatal withdrawal from nicotine.

DEVELOPMENTAL MODEL

Our developmental model of the neonate has certainly come a long way since Sherrington's initial

"spinal frog" model and the early reflex models. However, although the NNNS embraces many of the constructs of the competent infant, we are equally impressed with the immaturity, poorly differentiated, and limited nature of the infant. The newborn can do only so much, and much of what it can do is affected by the very conditions under study (eg, level of prematurity, effects of pre- and perinatal conditions).

With the NNNS, we try to portray a comprehensive and integrated picture of the infant without weighting any specific functional domains. This holistic view assumes that an accurate assessment of the infant includes evaluation of classical reflexes, tone, posture, social and self-regulatory competencies, and signs of stress.

The high-risk infant is viewed as struggling to maintain a balance between competing demands. The preterm infant is trying to maintain physiologic homeostasis in the face of external stimulation. Internal demands such as maintaining respiratory and metabolic control are competing with external demands—stimulation that increases respiratory and metabolic demands. The drug-exposed infant may be experiencing withdrawal or disturbances in monoaminergic systems that can result in hyper- or hyporesponsivity. The assessment of these infants is complex—a simple assessment of reflexes or tone will miss higher order functioning, regulatory capacities, and coping strategies. Likewise, a focus on social interactive capacities will miss basic neurologic function that may determine current and future behavior. In addition, how information is gathered is critical. With the NNNS, some behaviors are observed (eg, state, posture, signs of stress), whereas others are elicited (eg, reflexes, motor responses, social interaction) and interpreted in the context of the infant's being challenged. Some responses require "scaffolding," ie, the examiner provides a certain amount of stage setting for the behavior to appear. How much scaffolding, or stage setting, is necessary to produce a behavior is as important as the actual behavior elicited. For example, an infant who is able to track a visual stimulus, does not need to be swaddled, and shows minimum respiratory instability and few signs of stress is clearly different from an infant who has the same visual tracking ability and requires substantial facilitation by the examiner and shows physiologic and behavioral signs of stress.

The concept of state-dependent administration (SDA) is an important principle of the NNNS. The NNNS requires that items be administered in specific states and that when they are elicited they are administered only a set number of times. This state dependence and the inherent variability of behavior in early infancy require flexibility of administration. However, when an examination is unstructured, a number of problems arise. The primary problem is that different examiners may do the examination differently and elicit different behavioral qualities in the infant. Thus, the scoring may reflect the examiner-infant interaction rather than the infant's performance when faced with a standard challenge.

The NNNS attempts to balance flexibility and structure in several ways. First, SDA is inherently structured and sensitive. Second, the NNNS has a relatively invariant sequence of item administration in that the specified sequence is one strongly preferred by experienced examiners because most infants can achieve it. Thus, individual differences in examiner style are minimized. The examination allows for modification, but the order of administration and deviations from the standard sequence are recorded. Third, SDA is facilitated by the use of "packages" of items that allow the examiner to maximize the number of items administered when the infant is in an appropriate state. Last, the NNNS contains codes to track the reason that an item was not administered. These reasons include examiner error but, more important, the failure of the infant to be in an appropriate state. This information is useful for explaining why the preferred order may have been varied. It also provides critical information on the performance of the infant.

SDA helps achieve several critical standardization goals. First, SDA ensures the comparability of how state affects performance. Second, SDA emphasizes the state-dependent features of infant responsiveness. At the same time, it does not fall into the trap of having to do items in a rigid order at all costs. Third, SDA maximizes that the performance observed is primarily self-generated by the infant, rather than the interaction of the examiner's skill and the infant's capacities brought out by optimizing procedures. Fourth, SDA facilitates the administration of the examination in the standard order. Last, SDA minimizes the time needed to administer the examination because handling procedures aimed at bringing out optimal performance are eliminated, especially the need for time-outs and soothing of the infant.

TRAINING REQUIREMENTS

Appropriate use of the NNNS requires certification, and certification procedures that require meeting specified criteria in areas of administration and scoring have been established. Training programs are available in the United States, Europe, South America, and Southeast Asia. There is also a Spanish version of the manual. In general, the recommended training process is for the trainee to practice the examination with intermittent feedback from either a trainer or an already trained examiner until such time as the trainee believes that he or she is ready for the certification test. Through telemedicine, videoconferencing is also being used from remote locations to provide introductory background and didactic material, observe a "live" examination that includes interaction between the examiner and observers in the remote sites, and give feedback to trainees as they examine infants in remote sites. The certification test can be arranged by contacting a trainer. Our experience is that the amount of practice that trainees need depends on previous experience and comfort in handling young infants and clinical acumen. A training kit that includes the necessary equipment (standard 8-inch flashlight, red ball, red rattle, bell, foot probe, and head supports) and scoring forms is available. Introductory and debriefing

scripts as well as scripts that are appropriate to specific items are provided in the procedures. The senior author may be contacted for information on training.

IMPLICATIONS

Information from the NNNS can be used for research and clinical practice. Clinical applications include developing a profile of the infant to write a management plan for the infant while in the hospital, evaluation of the infant close to discharge as part of the discharge plan, and transition to home that includes involving the caregivers in the examination. Postdischarge, the examination can be used to determine which infants qualify for early intervention services. The long-term goal is to provide standardized norms for the NNNS at selected gestational ages to be used for the evaluation of at-risk infants before and in the few months after hospital discharge. At Women and Infants' Hospital (Providence, RI), the NNNS is used for the evaluation and behavioral management of infants in the intensive care nursery and for drug-exposed infants.

It is a luxury to be able to choose from a variety of neonatal assessments, reflecting how far the field of neonatal assessment has progressed. The NNNS is appropriate for some uses and not appropriate for others. There are measures for very specific purposes, such as the Neurological Assessment of the Preterm Infant[26] for assessment of maturity and other procedures that measure aspects of neurologic function. Although the NNNS includes these domains, if this were the only interest, then there would be no reason to do a full NNNS examination. Similarly, for work with term, healthy infants, the NBAS should be used because many of the behaviors measured by the NNNS that would have to be scored will not occur; it would be "overkill." The NNNS is also not appropriate for highly detailed assessments of specific functions. For example, although the examination includes some classical reflexes, measures of tone and posture, preterm behavior, and stress/ abstinence, it does not provide the level of detail needed if the focus were on only 1 of these domains. For example, the examination includes items from the Finnegan scale[27] that are used to measure drug withdrawal but does not include all of the items or specific cut-offs. Therefore, it would be inappropriate to use the NNNS the way the Finnegan is used to determine drug treatment for addicted infants. Similarly, the NNNS does not provide the detail about preterm behavior that the APIB[20] provides. The NNNS is best suited for use with infants at risk, term or preterm, when the interest is in providing estimates of a broad range of neurobehavioral function.

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