Concept Clarification of Neonatal Neurobehavioural Organization

Aleeca F. Bell, PhD, RN, CNM
Doctoral Candidate
University of Illinois at Chicago,
College of Nursing,
845 South Damen, M/C 802,
Chicago, IL 60612,
abell2@uic.edu,
phone (312) 996-7936.

Ruth Lucas, BSN, RNC
Graduate Student
University of Illinois at Chicago,
College of Nursing,
845 South Damen, M/C 802,
Chicago, IL 60612,
rlucas4@uic.edu,
phone (312) 996-7936.

Rosemary C. White-Traut, PhD, RN, FAAN
Professor
University of Illinois at Chicago,
College of Nursing,
845 South Damen, M/C 802,
Chicago, IL 60612,
rwt@uic.edu,
phone (312) 996-7935.

Acknowledgement: This study was supported by scholarships from the University of Illinois at Chicago Board of Trustees and the Irving B. Harris Foundation.

Concept Clarification of Neonatal Neurobehavioural Organization

Abstract

Aim. This paper is a report of a concept analysis of neonatal neurobehavioural organization for healthy full-term infants.

Background. The neonatal period is an opportune time for researchers and clinicians to assess and intervene for optimal neurobehavioural organization. Yet there is inconsistency and lack of clarity in a scientifically grounded definition of neonatal neurobehavioural organization. Clarification of the concept will strengthen research findings that influence practice for optimal infant development.

Method. A concept analysis of the literature between 1939 and 2007 (n = 57) was conducted using Penrod and Hupcey's principle-based concept analysis and Morse's concept clarification.

Findings. The concept analysis within and across multiple disciplines revealed: 1) a view of the concept as a holistic phenomenon with multiple dimensions; 2) no agreement on the ideal instrument to operationally define the concept; 3) consistency in implied meaning, but great variability in terminology. Neonatal neurobehavioural organization was defined as the ability of the neonate to use goal-directed states of consciousness, in reciprocal interaction with the caregiving environment, to facilitate the emergence of differentiating, hierarchical, and coordinated neurobehavioural systems, with ever-increasing resiliency and capacity to learn from complex stimuli.

Conclusion. A clear conceptual definition will help the international community to communicate effectively within and between disciplines and to apply evidenced based

research findings. It will encourage the development of valid and reliable instruments to capture the concept's multiple dimensions and direct attention to the infant's experience, which sculpts early neurobehavioural organization.

Keywords: behaviour, concept analysis, development, infant, neonate, neonatal neurobehavioural organization, newborn, nursing

Summary Statement

What is already known about this topic

- In the neonatal period (the first 28 days after birth) there is a sensitive and dynamic unfolding of development unique to the neonate.
- This is therefore an opportune time to assess and intervene to promote optimal neurobehavioural organization.
- The policy and culture of many maternal-child units demand clinicians to be task- rather than synchrony-oriented and thus there are missed opportunities to enhance neonatal neurobehavioural organization.

What this paper adds

- Inconsistent terminology, lack of a gold standard measurement, limited understanding of the concept's interplay between environmental interaction and genetic expression, and limited evidence of the concept's predictive relationship between the neonatal period and later developmental trajectories were identified in the literature.

- Neonatal neurobehavioural organization is the ability of the neonate to use goal-directed states of consciousness, in reciprocal interaction with the caregiving environment, to facilitate the emergence of differentiating, hierarchical, and coordinated neurobehavioural systems.
- Maturation of neonatal neurobehavioural organization is evidenced by the neonate's ever-increasing resiliency and the capacity to learn from complex stimuli.

INTRODUCTION

In the neonatal period (the first 28 days after birth) there is a sensitive and dynamic unfolding of neurobehavioural organization (NBO) unique to the neonate (Blackburn, 2005). NBO is a mature multidimensional construct and includes an individual's ability to interact with the environment while maintaining internal stability. This internal stability is the foundation from which the neonate is able to socially interact and learn from the environment. The neonatal period offers an opportune time for researchers and clinicians to assess and intervene for optimal infant health. Yet, within and across disciplines, there is inconsistency and lack of clarity in a scientifically grounded definition of neonatal neurobehavioural organization. The aim of this paper is to analyze and clarify the concept of neonatal neurobehavioural organization (NNBO) for healthy full-term infants.

METHOD

Concept analysis method

Principle-based concept analysis by Penrod and Hupcey (2005) is a robust method for the advancement of a concept. Penrod and Hupcey emphasize two distinct elements within concept analysis. First, the existing state of science must be analyzed and clarified using a multidisciplinary approach. Second, advancement of the concept occurs through the synthesis of new insights. Principle-based concept analysis expands upon earlier work of Hupcey *et al.* (Hupcey *et al.* 2001, Morse *et al.* 1996). The analysis is guided by four principles: epistemological, pragmatic, linguistic, and logical. Penrod and Hupcey (2005) describe the epistemological principle as an exploration of what is known about the concept, and whether the concept is well-defined and differentiated from other concepts in the literature. They

describe the pragmatic principle as an evaluation of how well the concept has been operationalized, and whether it is applicable or useful for clinical practice and research. To address the linguistic principle, Penrod and Hupcey ask analysts to assess whether the concept has been used consistently and appropriately, and if the concept becomes more abstract or limited depending upon theoretical context. Finally, they describe the logical principle as an analysis of the integrity of the concept when positioned with similar concepts or elements within the concept. That is, they suggest asking whether the concept allows for multiple relationships without getting lost in translation.

Morse *et al.* (1996) suggested that concept analysis begins with assessing a concept's level of maturity. When a concept appears to be mature within a large body of literature, yet is associated with inconsistent and competing assumptions or variables, then quantitative and/or qualitative research may be used effectively in concept clarification. Clarifying a concept requires a thorough familiarization of the literature to recognize underlying values and assumptions common to the concept under review (Morse 1995). Based on these values and assumptions, attributes can then be identified and synthesized.

Data Sources

Selection of data sources for a concept analysis can be driven by an unconsciously assumed theoretical framework or by a consciously identified theoretical framework that is either implicitly or explicitly defined (Paley 1996). We identified an implicit theoretical framework, the infant's complex behavioural repertoire, to provide structure to the selection of the literature review. Recognition of the infant's complex behavioural repertoire was developed by experts across multiple disciplines over several decades, but can be first traced

to the 1930s with the publications of McGraw (1939b, 1943) and contemporaries (Gilmer 1933, Pratt 1935). Their views were in contrast to the prevailing theoretical perspective that the infant was a passive recipient of environmental stimuli. It was not until the 1970s that there was an acceptance of infants as active participants in sculpting their NBO. This paradigm shift integrated two approaches to infant assessment: neurological (Andre-Thomas & St.-Anne Dargassies 1960, Prechtl & Beintema 1964) and behavioural (Graham 1956, Rosenblith 1959). This integration in the literature of neurology and behaviour has created a more broad and holistic view of the infant's NBO.

The literature search was completed in two phases. Initially the search was conducted within the three most appropriate electronic databases (Ovid Medline, CINAHL, and PsycINFO) from 1970 to 2005. The search was limited to the English language and human studies. The keyword 'neonatal neurobehavioural organization' was initially used as the search term. This resulted in only a handful of articles; therefore the search was expanded to include various combinations of related keywords: neonatal, newborn, infant, behaviour, organization, neurobehaviour, behavioural response, behavioural competence, state regulation, central nervous system, and development. Papers were deleted if they were limited to a narrow dimension of the concept, such as habituation, or if the concept was used only as a measurement outcome without contributing depth and scope. Additionally, papers were rejected if limited to issues specific to preterm, compromised or pathologically developed infants since the focus was the normal NBO of the healthy, full-term neonate. It became apparent that certain authors were frequently cited for their contribution to

development of the concept of NNBO. Thus, a second literature search phase was refined to include the work of highly influential authors.

The final data set of the literature reviewed included 48 articles and 9 books from 1939 to 2007. Authors of the methodologies used for this concept analysis do not explicitly state a desirable data set size. Rather, Penrod and Hupcey direct that the 'literature selection must be conceptually driven, not statistically driven' to accurately represent the state of the science (2005, p. 407). Our literature selection represents a small data set owing to our commitment to include only researchers who contributed to the scope and depth of the concept.

RESULTS

Epistemological Principle

The epistemological principle was analyzed in three ways. First, we synthesized contributions from influential researchers in the fields of psychology, developmental psychology, medicine, and nursing (see Table 1). Second, we summarized the major contributions from each discipline. Exclusive contributions from within a single discipline were difficult to identify, as researchers concurrently and conjunctionally developed the concept. Finally, we extracted shared attributes from the literature using Morse's method of concept clarification (1995) to provide a clear definition of NNBO.

Summary of each discipline's contribution to defining the concept

Investigators in the field of psychology and developmental psychology established the foundation of our understanding of NNBO. They have recognized that infants are active participants in their own development. An infant's individual development is sculpted by

sensory experience and thus intrinsic to NNBO. NNBO unfolds in a hierarchical manner as the infant's capacity for stability increases in the midst of a constantly changing environment. An individual's NBO is based on the ability to self-regulate an internal locus of control and reciprocally interact with external environment stimuli.

In contrast to the holistic nature of NNBO found in the disciplines of psychology and developmental psychology, investigators in the field of medicine have emphasized the infant's neurological integrity as the basis of NNBO. The pediatrician, T. Berry Brazelton, was the first to articulate to the general public that NNBO was a multidimensional holistic phenomenon, and to encourage a multidisciplinary approach to research. Brazelton and colleagues led the paradigm shift towards recognizing the competent infant as a determinant in research and practice.

At the forefront of translational research, researchers in the field of nursing have investigated dimensions of NNBO as they apply to clinical practice. Not only have nursing researchers contributed to the understanding of how altered NBO in at-risk infants has immediate and long-term effects on developmental trajectories, but they have also designed interventions to support optimal NNBO. Interventions have included White-Traut's (White-Traut & Nelson 1988, White-Traut *et al.* 2002b) auditory, tactile, visual, and vestibular stimulation; Thoyre, Shaker, and Pridham's (Thoyre *et al.* 2005) developmental profile of feeding readiness; Pridham's (Pridham *et al.* 2005) guided participation on feeding competencies; Censullo's (1994, J. A. Horowitz *et al.* 2001) interaction coaching to promote mother-interaction; and Luddington-Hoe's (Ludington-Hoe *et al.* 1991, Ludington-Hoe *et al.* 2006) research on skin-to-skin contact (*i.e.* kangaroo care).

Attributes of the concept

Using Morse's method of concept clarification (1995), we found five attributes that were pervasive throughout the data set. The first attribute is the dynamic nature intrinsic to the concept. There is a reciprocal interchange of information between neonates and their caretaking environment. NNBO is characterized by rapid developmental change. With NNBO, there is never a finished product, but rather an ever-evolving fluid process.

Second, interaction with the environment is not random; therefore there is an attribute of selection and purpose. Neonates seek the stimuli they need to further their neuronal and behavioural development. Neonates influence their caretakers by communicating a wide variety of cues to elicit the behaviour they seek. When the neonate initiates a need and receives the attention desired, cues are sent to the caregiver that may induce a sense of satisfaction; therefore selective biobehavioural feedback loops serve to encourage continued reciprocity between neonate and caregiver.

The third attribute is that the neonate innately coordinates sensory, autonomic, motor, behavioural state regulation, and social interaction systems. Coordination of these systems develops in a hierarchical manner, with an open exchange of information that facilitates more and more complex organization. Social interaction is deemed the highest level of organization whereby the neonate is able to attend and interact with the caregiving environment.

Fourth, the neonate has the ability to recover from the physiological cost of positive and negative stimuli; therefore there is an attribute of resiliency. The neonate responds to

stimuli with states of consciousness that either encourage or discourage interaction. If a stimulus is overtaxing and the neonate's state discourages interaction, then the neonate must reorganize before a stimulus can be processed effectively. Challenging experiences with new stimuli encourages growth and differentiation of neurons and their synapses.

The fifth attribute, which builds upon the preceding four, is the recognition that the neonate has an ever-increasing capacity for stability through change. Living systems develop within an optimal range of external and internal conditions that are constantly changing. Thus, as the neonate's multilevel capacity for stability increases in the midst of changing conditions, developmental maturation is enhanced.

In summary, the shared patterns of attributes for NNBO include (a) a dynamic reciprocal process of neonatal interaction with the caretaking environment, (b) goal-directed behaviour that elicits environmental stimuli to fuel inner neuronal and behavioural development, (c) coordination of multi-systems that emerge in a hierarchical manner, (d) resiliency to recover from the physiologic cost of stimuli, and (e) a maturational capacity for stability through change.

Definition of the concept.

Synthesis of the shared attributes of NNBO may be clarified into one definitional sentence. Neonatal neurobehavioural organization is the ability of the neonate to use goal-directed states of consciousness, in reciprocal interaction with the caregiving environment, to facilitate the emergence of differentiating, hierarchical, and coordinated neurobehavioural systems. Maturation of NNBO is evidenced by the neonate's ever-increasing resiliency and the capacity to learn from complex stimuli.

Pragmatic Principle

NNBO has been operationally defined in a variety of ways. We found that there was lack of agreement in the literature within and across disciplines on the ideal operational definition. Factors that contribute to the difficulty in the measurement of NNBO include 1) the complexity of neonates as living systems, that interact bi-directionally with their environment, during a period characterized by rapid development; 2) multiple dimensions that are intrinsic to NNBO; 3) uncertain validity of an instrument's ability to predict meaningful developmental outcomes; 4) lack of a unified view of NNBO. In the past, researchers operationalized NNBO as either the neurologic status (Prechtl & Beintema 1964) or psychological function (Graham *et al.* 1956) of an infant. Today, many researchers appreciate that NNBO spans a broad behavioural repertoire which includes neurological integrity, learning, perception, and social interaction (Lipkin 2005). While past and current approaches of measuring NNBO are far too extensive to list, some salient approaches have included: 1) behavioural state regulation which serves as a critical antecedent and outcome of NNBO (Wolff 1987); 2) Brazelton's Neonatal Behavioural Assessment Scale - an excellent descriptor of a broad range of behavioural competencies but criticized for questionable predictive validity (Brazelton & Nugent 1995); and 3) nutritive sucking parameters that were first researched in the 1960s and recently resurfaced as a valid window into NNBO (Kron *et al.* 1963, Medoff-Cooper & Ratcliffe 2005). Additionally, we identified numerous multi-dimensional instruments specific for evaluating neurobehaviour in the fetus, preterm neonate, developmentally at-risk neonate, and older infant (Als *et al.* 2005, Amiel-Tison 2002, DiPietro *et al.* 2002, Einspieler & Prechtl 2005).

Currently, researchers in the fields of nursing, developmental neurology and physiology, physical and occupational therapy, pediatrics, and developmental psychology are contributing to our understanding of NNBO by measuring specific dimensions of this complex concept. Specific dimensions of NNBO include the measurement of sleep and alert states (Holditch-Davis & Thoman 1987, Salisbury *et al.* 2005, White-Traut *et al.* 2002a), breastfeeding behaviours (Radzyminski 2005), sucking parameters (Medoff-Cooper 2005) , movement patterns (Campbell *et al.* 2002, Einspieler & Prechtl 2005, Majnemer & Snider 2005), event-related potentials of auditory stimulated brain activity (deRegnier 2005), and heart rate variability (Porges 2007).

Linguistic Principle

The implied meaning of NNBO is consistent among the experts in nursing, developmental neurology and physiology, pediatrics, psychology and developmental psychology. Across disciplines, there was consistency regardless of the population, contextual setting, and independent and dependent variables used to examine the concept. However, as noted in the data source section, the terminology used for NNBO is quite variable within and across disciplines. While NNBO is conceptually bound to the neonatal period, and is the normative criterion for all infants at risk (*e.g.* preterm), there is coherent integration of dimensions within NBO between the preterm period and neonatal period.

Logical Principle

Researchers in nursing, developmental neurology and physiology, pediatrics, psychology and developmental psychology tend to view NNBO as a holistic phenomenon encompassing inter-related dimensions, although researchers in medicine are inconsistent in

their view of the integrity of the concept. Investigators in the field of medicine also have reduced NNBO to only physiological dimensions. Predominantly, researchers across disciplines have examined specific dimensions of NNBO that integrate and define the boundaries of the concept.

From this dimension-based analysis, NNBO was determined to be a mature yet inconsistently defined multidisciplinary concept. Through this concept analysis of NNBO we have clarified the common attributes, operational measurements, linguistic terminologies, and conceptual boundaries.

DISCUSSION

Limitations of this concept clarification were identified as inherent in the process of synthesizing a manageable data source. Early researchers, who pioneered the neurological integrity of infants, were not included because of their theoretical framework where infants were viewed as passive recipients of their environment. Animal literature on NBO was not included, as it is extensive and beyond the scope of this analysis. In spite of an effort to maintain scientific rigour in selecting a conceptual driven sample, we recognized that author bias is intrinsic to concept analysis.

Several important gaps in the current state of the science were identified: 1) the unclear influence of fetal exposure to maternal medication during labour on NNBO; 2) the need for stronger evidence of the predictive relationship between NNBO and individual infant developmental trajectories; 3) disagreement, within and across disciplines, on the ideal instrument to accurately measure NNBO; 4) limited understanding of the neurobehavioural

dimensions of NNBO and their interplay on multiple levels, from genetic expression to environmental interaction.

In the 20th century, researchers' perspectives changed from viewing the infant as passive objects of study to active participants in their own development. As a reflection of this paradigm shift, the opportunity has arisen to revisit the synchronous interplay between internal and external systems owing to a refined conceptual understanding of the dynamic forces that effect development. Additionally, experts have refined the ability to non-invasively capture multiple variables of NNBO, such as vagal tone, event-related potential, sucking parameters, mother-infant synchrony, and electroencephalogram characteristics of sleep-wake cycles. Recent technological advances in ultrasound have further contributed to understanding the continuity of development from fetus to neonate (Salisbury *et al.* 2005). The implications of the environment and the infant's unique neurobehaviour on the expression of the individual's genetic code should be considered in the advancement of this concept (Gottlieb 2001). For instance, Feldman and Eidelman model the advancement of this concept by exploring the dynamic relationship between biological dimensions of NBO and reciprocity of mother-infant interaction and the effect on future cognition (Feldman & Eidelman 2006). The development of effective interventions will be promoted by additional translational research.

Implications for advancement of the concept through clinical practice include the application of evidenced based research findings into everyday plan of care. Unfortunately, policy and culture of many institutional maternal-child units demand nurses to be task-oriented rather than synchrony-oriented (*i.e.* sleep-wake cycles, feeding readiness cues,

uninterrupted mother-infant skin-to-skin contact, attention-interaction). Clinicians' ability to augment NNBO by reducing infant stress, maintaining sleep-wake cycles, promoting social-interaction during alert periods, and modifying the environment to maintain social interaction will be strengthened by this concept clarification.

CONCLUSION

Neonatal neurobehavioural organization is a global phenomenon that captures the essence of healthy full-term neonatal function as resilient, individualized, complex, experiential, and holistic. A clear conceptual definition will aid the international community 1) to communicate effectively within and between disciplines, 2) to apply evidenced-based research findings, and 3) encourage the development of valid and reliable instruments to capture the multiple dimensions of NNBO. Clarification of NNBO directs attention to the infant's experience, which facilitates sculpting of early NNBO. Nursing and allied health professionals who influence neonates' initial unfolding of NNBO must be aware of the potential impact on their future developmental trajectories. Further analysis of NNBO with premature or medically-fragile infants would add to our understanding of compromised infants' ability to respond and recover from environmental stimuli. Thus development of the concept in this vulnerable population would advance clinical practice across disciplines.

Table 1 Contributions of influential researchers

Influential researchers and their disciplines	Epistemology	Pragmatic	Linguistic	Logistic
Psychology (Aitken & Trevarthen 1997, Trevarthen & Aitken 1994).	At birth, the neurobiology of the brain supports the intrinsic motivation to communicate and interact, which is a critical process for furthering human development.	Grounded observable behavioural literature to the brain's neurobiology.	Used a related concept, Intrinsic Motive Formation (neonate's motivation to communicate and promote self-development).	The concept of Intrinsic Motive Formation is a dimension of NNBO.
Psychology (Als 1982, 1991, Als *et al.* 2005).	Distinct subsystems of NNBO (autonomic, motor, state organizational, attentional-interactive, and self-regulatory) emerge in a hierarchical pattern through internal, dynamic, continuous interplay.	Developed the Synactive Model of Neonatal Behavioural Organization and Assessment of Preterm Infants Behaviour. Clinical significance is to modify the environment to stabilize the premature infant's initial emerging subsystems. Goal is to support the continued emergence of organization, culminating in social interaction.	Consistency in meaning and use of NNBO.	The concept holds its boundaries in preterm and neonatal periods.
Nursing (Anderson 1977, 1991, Gill *et al.* 1988).	Early work viewed sucking opportunities as facilitating neuromuscular coordination and behavioural state organization. Later work viewed skin-to-skin contact as supporting the coordination of physiological systems (i.e. autonomic system) and mother-infant reciprocity.	Translational application of NBO. Supporting mother-infant reciprocity facilitates breastfeeding in term and Kangaroo Care in preterm infant.	Implicit use of NNBO.	Coherent conceptual integration between mother-infant reciprocity and behavioural state organization.
Nursing (Barnard 1973, Barnard *et al.* 1984, Sumner *et*	Reinforced current knowledge base that premature infants have immature NBO. By	'Keys to Caregiving' is an educational intervention to improve behavioural state	Consistency in meaning and use that is maintained in varied contexts.	Coherent conceptual integration between the mother-infant contingency

al. 1999).	manipulating the environment, the term and preterm infant is better able to regulate states, which then improves contingency patterns of communication between mother and infant/child.	regulation and mother-infant interaction. Content consists of feeding interaction, state modulation, and infant state, behaviour and cues.		and NNBO. The concept holds its boundaries in the term and preterm neonatal periods.
Pediatric medicine (Brazelton 1978, 1979, Brazelton & Nugent 1995).	Pivotal in recognizing NNBO as a holistic phenomenon, with the neonate as an active and competent participant in shaping his/her NNBO. Integrated and translated prior work on the infant's neurological integrity, competency in state regulation, and reciprocal interaction with social and environmental stimuli.	Developed the Neonatal Behavioural Assessment Scale, which measures 7 clusters of neurobehaviour and is used world-wide in research: 1. Habituation 2. Orientation 3. Motor 4. Range of State 5. Regulation of State 6. Autonomic Stability 7. Reflexes.	Popularized the term NNBO. Consistent in use and meaning of NNBO.	Logical outcome of a holistic perspective on the neonate as an open evolving living system in dynamic reciprocal interaction with its internal and social environment.
Psychology (Feldman 2006, Feldman & Eidelman 2006, Feldman *et al.* 1999).	Disrupted periods of sensitive development in the preterm can be supported through positive mother-infant interaction. Aspects of NNBO (state organization, cardiac vagal tone, orientation, and arousal) are predictive of mother-infant synchrony.	Mother-infant synchrony is viewed as both an independent (modulator) and dependent outcome of NNBO.	Consistent in meaning and use of NNBO.	Coherent conceptual integration between the mother-infant synchrony and NNBO.
Nursing (Holditch-Davis 1990, Holditch-Davis *et al.* 2003, Holditch-Davis & Thoman 1987).	The preterm infant has attenuated NBO. Supporting sleep-wake cycles facilitates self-regulation and long-term development.	Researched the detailed organization of sleep-wake cycles of preterm infants as a predictor of neurobehavioural outcomes and to identify at-risk	Consistency in meaning and use of behavioural state as a variable of NBO.	Coherent conceptual integration between the preterm infant's sleep-wake organization and NNBO.

		infants for early intervention.		
Psychology (F. D. Horowitz 2000, F. D. Horowitz *et al.* 1983, F. D. Horowitz *et al.* 1978).	Sensory experience sculpts NBO.	Documented sophisticated capacities of the neonate.	Consistent in meaning and use of NNBO.	Intrinsic relationship between sensory experience and NNBO.
Pediatric psychology (Lester 1983, Salisbury *et al.* 2005).	Emphasized the developmental concept of integrity through continuous change. Infants demonstrate individual adaptive capacities. NBO originates in the fetal period.	Researched psychometrics of Brazelton's NBAS, NICU Network Neurobehavioural Scale, and pilot studies of Fetal Neurobehavioural Coding Scale.	Consistent in use and meaning of neurobehaviour as the interface between brain and physiology.	The concept holds its boundaries in the context of fetal, preterm and neonatal periods.
Developmental psychology (Dalton 1998, McGraw 1939a, 1943).	Emphasized motor and reflex development. An early researcher to view infants as having interconnected behavioural patterns that emerge through bi-directional interaction between structure and function. Systems continually reorganize into new configurations of stability for the emergence of maturing systems.	Limited in outcome measures. Pioneer of bi-directional relationship between brain and behaviour. Criticized for not including the environment.	Complex neurological terms.	Questioned assumptions of reflexology and maturationism.
Nursing (Medoff-Cooper 2005, Medoff-Cooper & Ratcliffe 2005, Medoff-Cooper & Ray 1995).	Described the longitudinal development of sucking organization in the preterm and full-term infant as a reflection of NBO.	Nutritive sucking organization (e.g. coordinated patterns of sucking pressure, number of sucks and bursts, suck duration, suck-burst ratio, and interburst width) is a valuable research outcome	Consistency in meaning and use of sucking organization as a variable of NBO.	Intrinsic relationship between sucking organization and NNBO.

		to measure NBO and predict developmental outcomes.		
Psychology (Fox & Porges 1985, Porges 1996, 2007).	Emphasizes the role of the primitive autonomic nervous system in self-regulation. Basic neurophysiological systems coordinate to culminate in self-regulation, which promotes social interaction.	Polyvagal theory: cardiac vagal tone predicts developmental outcome.	Implicit use of NNBO.	Intrinsic relationship between autonomic regulation and NNBO.
Medicine (Einspieler & Prechtl 2005, Prechtl, 1974).	Neurological integrity is the physiological basis of NBO.	Developed standardized neurological assessments. Used physiological outcome measures of respiration, eye movement, vocalization, and general movement.	Consistent in meaning of the neurological dimension of NBO.	Coherent conceptual integration between neurological integrity and NBO.
Psychology (Sameroff 1975a, 1975b, Sameroff & Mackenzie 2003).	Challenged the mechanistic view of human development. Introduced that development occurs within a continuous reciprocal interchange between the individual and environment.	Applied his Transactional Model of Development as a continuous transaction between infant/child, caretaker, and environment.	Consistency in meaning and use that is maintained in varied contexts.	The concept holds its boundaries beyond the neonatal period.
Developmental psychology (Thoman 1975, Thoman *et al.* 1987, Thoman & Whitney 1990).	Behavioural states reflect the competency of CNS, and are a window into NBO. States are an antecedent, mediator, modulator, and elicitor of environmental interaction.	Originally described 11 states, that were later synthesized into 6 states, which are frequently used by researchers: State I: Quiet sleep State II: Active sleep State III: Drowsy State IV: Quiet alert State V: Active alert State VI: Fussy-Crying.	Consistency in meaning and use of behavioural state, but did not use the term NNBO.	Clearly defined relationships between states and NBO.

Developmental psychology (Cohn & Tronick 1988, Tronick 1989)	Infants emotionally communicate within a reciprocal feedback system with the environment. They regulate their state in relation to internal goals (emotional and physiological homeostasis) and external goals (interaction with animate and inanimate environment).	Detailing the infant's emotional communication informs clinical practice	Self-directed and other-directed regulatory behaviours.	The concept holds its boundaries beyond the neonatal period.
Nursing (White-Traut & Hutchens-Pate 1987, White-Traut et al. 2002a, White-Traut *et al.* 2002b).	Early sensory experience modulates NBO. Preterm infants exhibit attenuated NBO, therefore early multisensory interventions strengthen the autonomic nervous system and facilitate the emergence of hierarchical neurobehavioural development.	Translational application of NBO. Auditory Tactile Visual Vestibular intervention was developed to improve NBO in preterm and at-risk infants. Improved NBO enhances mother-infant interaction and feeding.	Implicit use of NNBO.	Coherent conceptual integration between the preterm infant's NBO and NNBO.
Psychology (Wolff 1973, 1987, Wolff & Ferber 1979).	Identified distinguishable patterns of state behaviour in the neonatal period.	State I: Regular sleep State II: Irregular sleep State III: Drowsy (later redefined as descriptive state transitions vs. discrete states) State IV: Alert inactivity State V: Waking activity State VI: Crying Used outcome measures of sucking patterns, visual habituation, auditory responses, and social interaction.	Consistency in meaning and use of behavioural state, but has not used the term NNBO.	Evolved in his appreciation of the infant's complexity. A leader in creating the boundaries of NBO.

Note. NNBO = neonatal neurobehavioural organization, NBO = neurobehavioural organization.

References

Aitken, K. J., & Trevarthen, C. (1997). Self/other organization in human psychological development. *Development and Psychology, 9*, 653-677.

Als, H. (1982). Toward a synactive theory of development: Promise for the assessment and support of infant individuality. *Infant Mental Health Journal, 3*(4), 229-243.

Als, H. (1991). Neurobehavioural organization of the newborn: Opportunity for assessment and intervention. *NIDA Research Monograph, 114*, 106-116.

Als, H., Butler, S., Kosta, S., & McAnulty, G. (2005). The assessment of preterm infants' behaviour (apib): Furthering the understanding and measurement of neurodevelopmental competence in preterm and full-term infants. *Mental Retardation and Developmental Disabilities Research Reviews, 11*(1), 94-102.

Amiel-Tison, C. (2002). Update of the amiel-tison neurologic assessment for the term neonate or at 40 weeks corrected age. *Pediatric Neurology, 27*(3), 196-212.

Anderson, G. (1977). The mother and her newborn: Mutual caregivers. *Journal of Obstetric, Gynecologic, & Neonatal Nursing*, 50-57.

Anderson, G. (1991). Current knowledge about skin-to-skin (kangaroo) care for preterm infants. *Journal of Perinatology, 11*(3), 216-226.

Andre-Thomas, C., & St.-Anne Dargassies, S. (1960). *The neurological examination of the infant*. London: Medical Advisory Committee of the National Spastics Society.

Barnard, K. (1973). The effect of stimulation on the sleep behaviour of the premature infant. In M. B. Batey (Ed.), *Communicating nursing research* (Vol. 6). Colorado: WICHE.

Barnard, K., Bee, H. L., & Hammond, M. (1984). Developmental changes in maternal interactions with term and preterm infants. *Infant Behaviour & Development, 7*(1), 101-113.

Blackburn, S. (2005). *Maternal, fetal, & neonatal physiology* (2nd ed.). St. Louis, MO: Saunders.

Brazelton, T. B. (1978). Organization and stability of newborn behaviour: A commentary on the brazelton neonatal behaviour assessment scale. *Monographs of the Society for Research in Child Development, 43*(5/6), 1-13.

Brazelton, T. B. (1979). Behavioural competence of the newborn infants. *Seminars in Perinatology, 3*(1), 35-44.

Brazelton, T. B., & Nugent, J. K. (Eds.). (1995). *Neonatal behavioural assessment scale* (3 ed. Vol. 137). London: Mac Keith Press.

Campbell, S., Kolobe, T. H., Wright, B. D., & Linacre, J. M. (2002). Validity of the test of infant motor performance for prediction of 6-, 9- and 12-month scores on the alberta infant motor scale. *Developmental Medicine and Child Neurology, 44*(4), 263-272.

Censullo, M. (1994). Strategy for promoting greater responsiveness in adolescent parent/infant relationships: Report of a pilot study. *Journal Pediatric Nursing, 5*, 326-332.

Cohn, J., & Tronick, E. (1988). Mother infant face-to-face interaction: Influence is bidirectional and unrelated to periodic cycles in either partner's behaviour. *Developmental Psychology, 24*(3), 386-392.

Dalton, T. (1998). Myrtle mcgraw's neurobehavioural theory of development. *Developmental Review, 18*, 472-503.

deRegnier, R. A. (2005). Neurophysiologic evaluation of early cognitive development in high-risk infants and toddlers. *Mental Retardation and Developmental Disabilities Research Reviews, 11*(4), 317-324.

DiPietro, J. A., Bornstein, M. H., Costigan, K. A., Pressman, E. K., Hahn, C. S., & Painter, K., et al. (2002). What does fetal movement predict about behaviour during the first two years of life? *Developmental Psychobiology, 40*(4), 358-371.

Einspieler, C., & Prechtl, H. R. (2005). Prechtl's assessment of general movements: A diagnostic tool for the functional assessment of the young nervous system. *Mental Retardation and Developmental Disabilities Research Reviews, 11*(1), 61-67.

Feldman, R. (2006). From biological rhythms to social rhythms: Physiological precursors of mother-infant synchrony. *Developmental Psychobiology, 42*(1), 175-188.

Feldman, R., & Eidelman, A. I. (2006). Neonatal state organization, neuromaturation, mother-infant interaction, and cognitive development in small-for-gestational-age premature infants. *Pediatrics, 118*(3), 869-873.

Feldman, R., Greenbaum, C., & Yirmiya, N. (1999). Mother-infant affect synchrony as an antecedent of the emergence of self-control. *Developmental Psychobiology, 35*(1), 223-231.

Fox, N., & Porges, S. (1985). The relation between neonatal heart period patterns and developmental outcome. *Child Development, 56*(1), 28-37.

Gill, N., Behnke, M., Conlon, M., McNeely, J., & Anderson, G. (1988). Effect of nonnutritive sucking on behavioural state in preterm infants before feeding. *Nursing Research, 37*(6), 347-350.

Gilmer, B. V. H. (1933). An analysis of the spontaneous responses of the newborn infant. *J Gen Psych, 42*, 392-405.

Gottlieb, G. (2001). The relevance of developmental-psychobiological metatheory to developmental neuropsychology. *Developmental Neuropsychology, 19*(1), 1-19.

Graham, F. (1956). Behavioural differences between normal and traumatized newborns: I. The test procedures. *Psychological Monographs, 70*, 1-16.

Graham, F., Matarazzo, R., & Caldwell, B. (1956). Behavioural differences between normal and traumatized newborns ii: Standardization, reliability, and validity. *Psychological Monographs, 70*, 17-23.

Holditch-Davis, D. (1990). The development of sleep and waking states in high-risk preterm infants. *Infant Behaviour & Development, 13*, 513-531.

Holditch-Davis, D., Brandon, D., & Schwartz, T. (2003). Development of behaviours in preterm infants. *Nursing Research, 52*(5), 307-317.

Holditch-Davis, D., & Thoman, E. (1987). Behavioural states of premature infants: Implications for neural and behavioural development. *Developmental Psychobiology, 20*(1), 25-38.

Horowitz, F. D. (2000). Child development and the pits: Simple questions, complex answers, and developmental theory. *Child Development, 71*(1), 1.

Horowitz, F. D., Linn, P., & Johns Buddin, B. (1983). Neonatal assessment: Evaluating the potential for plasticity. In T. B. Brazelton & B. M. Lester (Eds.), *New approaches to*

developmental screening of infants (pp. 27-50). New York: Elsevier Science Publishing Co. Inc.

Horowitz, F. D., Sullivan, J., & Linn, P. (1978). Stability and instability in the new infant: The quest for elusive threads. *Monographs of the Society for Research in Child Development, 43*(5/6), 29-45.

Horowitz, J. A., Bell, M., Trybulski, J., Munro, B. H., Moser, D., Hartz, S. A., et al. (2001). Promoting responsiveness between mothers with depressive symptoms and their infants. *Journal of Nursing Scholarship, 33*(4), 323-329.

Hupcey, J., Penrod, J., Morse, J., & Mitcham, C. (2001). An exploration and advancement of the concept of trust. *Journal of Advanced Nursing, 36*, 282-293.

Kron, R. E., Stein, M., & Goddard, K. E. (1963). A method of measuring sucking behaviour of newborns. *Psychosomatic Medicine, 25*(2), 181-191.

Lester, B. M. (1983). Change and stability in neonatal behaviour. In T. B. Brazelton & B. M. Lester (Eds.), *New approaches to developmental screening of infants* (pp. 51-75). New York: Elsevier Science Publishing Co. Inc.

Lipkin, P. H. (2005). Towards creation of a unified view of the neurodevelopment of the infant. *Mental Retardation and Developmental Disabilities Research Reviews, 11*(1), 103-106.

Ludington-Hoe, S. M., Hadeed, A. J., & Anderson, G. C. (1991). Physiologic responses to skin-to-skin contact in hospitalized premature infants. *Journal Perinatology, 11*(1), 19-24.

Ludington-Hoe, S. M., Johnson, M. W., Morgan, K., Lewis, T., Gutman, J., Wilson, P. D., et al. (2006). Neurophysiologic assessment of neonatal sleep organization: Preliminary results of a randomized, controlled trial of skin contact with preterm infants. *Pediatrics, 117* (5), e909-923.

Majnemer, A., & Snider, L. (2005). A comparison of developmental assessments of the newborn and young infant. *Mental Retardation and Developmental Disabilities Research Reviews, 11*(1), 68-73.

McGraw, M. (1939a). Later development of children specially trained during infancy. Johnny and jimmy at school age. *Child Development, 10*(1), 1-19.

McGraw, M. (1939b). Swimming behaviour of the human infant. *Journal of Pediatrics, 15*, 485-490.

McGraw, M. (1943). *The neuromuscular maturation of the human infant*. New York, NY: Columbia University Press.

Medoff-Cooper, B. (2005). Nutritive sucking research: From clinical questions to research answers. *Journal of Perinatal & Neonatal Nursing, 19*(3), 265-272.

Medoff-Cooper, B., & Ratcliffe, S. (2005). Development of preterm infants: Feeding behaviours and the brazelton neonatal behavioural assessment scale at 40 and 44 weeks' postconceptuional age. *Advances in Nursing Science, 28*(4), 356-363.

Medoff-Cooper, B., & Ray, W. (1995). Neonatal sucking behaviours. *Image: Journal of Nursing Scholarship, 27*(3), 195-200.

Morse, J. (1995). Exploring the theoretical basis of nursing using advanced techniques of concept analysis. *Advances in Nursing Science, 17*(3), 31-46.

Morse, J., Hupcey, J., Mitcham, C., & Lenz, E. (1996). Concept analysis in nursing research: A critical appraisal. *Scholarly Inquiry for Nursing Practice, 10*, 257-281.

Paley, J. (1996). How not to clarify concepts in nursing. *Journal of Advanced Nursing, 24*(3), 572-578.

Penrod, J., & Hupcey, J. (2005). Enhancing methodological clarity: Principle-based concept analysis. *Journal of Advanced Nursing, 50*(4), 403-409.

Porges, S. (1996). Physiological regulation in high-risk infants: A model for assessment and potential intervention. *Development and Psycholopathology, 8*, 43-58.

Porges, S. (2007). The polyvagal perspective. *Biological Psychology, 74*(2), 116-143.

Pratt, K. C. (1935). The organization of behaviour in the newborn infant. *Psych Bull, 32*, 692-693.

Prechtl, H. R. (1974). The behavioural states of the newborn infant. *Brain Research, 76*, 185-212.

Prechtl, H. R., & Beintema, D. (1964). *The neurological examination of the full term infant* (Vol. 12). Lavenham, England: Spastics International Medical Publication.

Pridham, K., Brown, R., Clark, R., Limbo, R. K., Schroeder, M., Henriques, J., et al. (2005). Effect of guided participation on feeding competencies of mothers and their premature infants. *Research Nursing Health, 28*(3), 252-267.

Radzyminski, S. (2005). Neurobehavioural functioning and breastfeeding behaviour in the newborn. *Journal of Obstetric, Gynecologic, and Neonatal Nursing, 34*(3), 335-341.

Rosenblith, J. (1959). Neonatal assessment. *Psychological Reports, 5*, 791.

Salisbury, A. L., Fallone, M. D., & Lester, B. (2005). Neurobehavioural assessment from fetus to infant: The nicu network neurobehavioural scale and the fetal neurobehaviour coding scale. *Mental Retardation and Developmental Disabilities Research Reviews, 11*(1), 14-20.

Sameroff, A. (1975a). Early influences on development: Fact or fancy? *Merrill-Palmer Quarterly, 21*(4), 267-294.

Sameroff, A. (1975b). Summary and conclusions: The future of newborn assessment. *Monographs of the Society for Research in Child Development, 43*(5/6), 102-117.

Sameroff, A., & Mackenzie, M. J. (2003). Research strategies for capturing transactional models of development: The limits of the possible. *Development & Psychopathology, 15*(3), 613.

Sumner, G., Barnard, K., Johnson-Crowley, N., & Spietz, A. L. (1999). *Keys to caregiving: Study guide*. Seattle: NCAST Publications.

Thoman, E. (1975). Sleep and wake behaviours in neonates: Consistencies and consequences. *Merrill-Palmer Quarterly, 21*(4), 295-314.

Thoman, E., Holditch-Davis, D., & Denenberg, V. (1987). The sleeping and waking states of infants: Correlations across time and person. *Physiology & Behaviour, 41*, 531-537.

Thoman, E., & Whitney, M. (1990). Behavioural states in infants: Individual differences and individual analyses. In J. Colombo & J. Fagan (Eds.), *Individual differences in infancy: Reliability, stability, prediction* (pp. 113-136). Hillsdale, New Jersey: Lawrence Erlbaum Associates, Inc.

Thoyre, S. M., Shaker, C. S., & Pridham, K. F. (2005). The early feeding skills assessment for preterm infants. *Neonatal Network, 24*(3), 7-16.

Trevarthen, C., & Aitken, K. J. (1994). Brain development, infant communication, and empathy disorders: Intrinsic factors in child mental health. *Development and Psychopathology, 6*, 579-633.

Tronick, E. Z. (1989). Emotions and emotional communication in infants. *American Psychologist, 44*(2), 112-119.

White-Traut, R. C., & Hutchens-Pate, C. (1987). Modulating infant state in premature infants. *Journal of Pediatric Nursing, 2*(2), 96-101.

White-Traut, R. C., & Nelson, M. N. (1988). Maternally administered tactile, auditory, visual, and vestibular stimulation: Relationship to later interactions between mothers and premature infants. *Research Nursing Health, 11*(1), 31-39.

White-Traut, R. C., Nelson, M. N., Silvestri, J. M., Vasan, U., Littau, S., & Meleedy-Rey, P. e. a. (2002a). Effect of auditory, tactile, visual, and vestibular intervention on length of stay, alertness, and feeding progression in preterm infants. *Developmental Medicine and Child Neurology, 44*(2), 91-97.

White-Traut, R. C., Nelson, M. N., Silvestri, J. M., Vasan, U., Patel, M., & Cardenas, L. (2002b). Feeding readiness behaviours and feeding efficiency in response to atvv intervention: Auditory, tactile, visual and vestibular. *Newborn and Infant Nursing Reviews, 2*(3), 166-173.

Wolff, P. (1973). Organization of behaviour in the first three months of life. *Research Publications-Association for Research in Nervous and Mental Disease, 51*, 132-153.

Wolff, P. (1987). *The development of behavioural states and the expression of emotions in early infancy: New proposals for investigation*. Chicago: The University of Chicago Press.

Wolff, P., & Ferber, R. (1979). The development of behaviour in human infants, premature and newborn. *Annual Reviews Neuroscience, 2*, 291-307.