UNIVERSITY OF ALBERTA

GENERATING BASIC KNOWLEDGE ABOUT NEONATAL DISTRESS BEHAVIOR ASSOCIATED WITH ACUTE PAIN
(Newborn Distress Related Pain Behavior)

by

Fay Fathalee Warnock ©

A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy

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Fay F. Warnock
1988 Matthews Ave.
Vancouver, British Columbia
V6J 2T7

Date: December 21-2001

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommended to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled *Generating Basic Knowledge About Neonatal Distress Behavior Associated with Acute Pain* submitted by *Fay F. Warnock* in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Dr. Phyllis Giovannetti, Supervisor

Dr. Margaret J. Harrison, Committee Member

Dr. Linda M. Fedigan, Committee Member

Dr. Linda D. Ogilvie, Committee Chair & Examiner

Dr. Kenneth Denton Craig, External Examiner

Date: ____________

Abstract

One of the most difficult challenges facing researchers and clinicians is assessing pain in the newborn infant. Twenty five years of investigation have furthered our understanding of many aspects of newborn pain, however, no uniform technique exists to reliably assess neonatal pain. Behaviors provide one of the most promising avenues for generating basic understanding of complex behavioral phenomenon and they are key to developing the kinds of descriptive knowledge required to further pain assessment and measurement efforts. In this research, basic descriptive knowledge about newborn pain behavior was generated using ethological methods.

In Phase One, the videotaped behaviors of ten newborn male infants were repeatedly observed as each underwent circumcision and non-noxious but distress-inducing events such as diaper change and restraint application. A reliable ethogram (an exhaustive listing) was developed that contained 235 molar and molecular behavioral items for describing variation in neonatal motor movement, body postures, responsiveness, self-comfort, respiration and vocalization. In Phase Two, precise duration and frequency measures of behaviors were obtained along with descriptions of the pain context from 67 minutes of videotaped data, involving four other male neonates who had undergone the same surgery. The same distress events were coded at 1-second intervals (4010 seconds total) using the ethogram from Phase One. Rank ordering of the duration scores led to the identification of: 40 distress behaviors as they occurred along the continuum of distress; 13 behaviors as they occurred specific to the acute noxious event; and 25 behaviors that occurred following the three distress events. Two neonates

exhibited increased sensitivity to otherwise neutral stimuli and increased frequency and prolonged durations of extreme distress following circumcision.

The thesis includes four manuscripts; two present the findings of the sequential phases of the research. One manuscript gives an overview of the research literature on neonatal pain responses and another discusses the utility of ethological methods for developing nursing knowledge about human behaviors. The document concludes with a summary chapter containing recommendations for further study.

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CHAPTER ONE

Overview of Dissertation

The topic of my dissertation research is newborn distress behavior associated with acute pain. This chapter serves as a summary and guide to material comprising this dissertation document. I have prepared my dissertation in paper format, one of the options recommended by the Faculty of Graduate Studies at the University of Alberta. This means that the chapters contained in this document represent a series of publishable manuscripts. Because each manuscript is targeted to a specific journal and a distinct audience, some of the same content (although articulated differently) appears in each of the four manuscripts. The entire dissertation consists of this overview, four manuscripts and a concluding discussion paper which relates the separate manuscripts to one another. The references cited in each chapter are placed at the end of the chapter in the style appropriate for the chosen journal. The appendix provides important information that could not be included in the manuscripts such as the table summarizing the studies reviewed for Manuscript Two of the dissertation.

Background

As Wall (1999) notes, we all experience pain and are puzzled by its subjective nature; however, we are especially puzzled by pain when it affects the newborn infant. Newborns cannot verbally inform us of their pain experiences, and their rapid developments confound pain management efforts (Andrews & Fitzgerald, 1997). In the past 25 years, researchers have attempted to forward the science and the clinical management of neonatal pain by measuring the physiological, biochemical and behavioral responses of the newborn to varying pain situations (Porter, 1989). However, despite attempts to express in units of measurement the pain experiences of neonates, neonatal pain remains poorly understood. No single valid and/or reliable technique exists to assess, measure and hence treat neonatal pain (Franck & Miaskowski, 1997).

As a nurse interested in neonatal pain research, I approached these issues with a belief shared by others (Craig & Grunau, 1995) that the behavioral repertoire of the neonate provides researchers one of the most useful and objective ways to understand (infer) the neonate's pain experience (however, not in isolation of the other responses neonates make when exposed to pain). That belief led me to ask how other disciplines concerned with complex phenomenon develop their behavioral knowledge. I learned that major insight into complex phenomenon affecting other non-verbal human and animal populations has come from ethology and other naturalistic sciences, such as ecology (Houck & Drickamer, 1996). In developing their knowledge, those scientific traditions hold in common the requirement for foundational basic description of the organism's behavior. To begin, they suggest inductive and unobtrusive approaches to generate basic description of the behaviors to support further behavioral inquiry and hence, increased understanding of the phenomenon. From those perspectives, basic description of the behavior precedes its assessment and both are seen as necessary precursors to measurement and deductive inquiry on the topic (Lehner, 1996). Ethologists argue that it is impossible to conceptually understand, assess or measure complex behavioral phenomena affecting organisms unless their behaviors are first comprehensively and contextually described (Hinde, 1982; Lehner, 1996).

Close examination of the research on neonatal pain behavior did not reveal a comprehensive body of pain behavior description. Although some researchers have developed pain knowledge in relation to newborn body movement (Craig et al, 1993) and infant state (Stevens, Johnston & Horton, 1994), the majority focus on measuring neonatal facial action and cry in response to short-term procedural pain. While I found some evidence to support lack of pain assessment knowledge compared to that of pain measurement, (McGrath & Unruh, 1987), I found little written about the limited number of behavioral descriptions of neonatal pain. These findings suggested that our current understanding of neonatal pain behavior is limited, especially in terms of our descriptive understanding of the possible breadth of the behaviors and the varying contexts in which newborns normally express those behaviors.

While little doubt exists as to the importance of existing research on neonatal pain facial expression and cry, the current body of knowledge on the topic is insufficient to adequately inform us of neonatal behavior, which is highly complex, integrated and interactive (Bremner, 1998). A major disadvantage of relying on facial expressions and or cry as salient indicators of neonatal pain is that it limits the possibility that other distinct behaviors and behavioral patterns can be identified that may broaden our understanding of different aspects of the complex phenomenon. In addition, measures of neonatal pain facial action and pain cry represent only an initial behavioral response to pain, especially because measures are usually collected using very brief time frames and they mainly involve short term types of pain. The extent to which these behaviors remain intact or change in response to prolonged but intense noxious stimulation, or non-noxious but intense distress provoking stimulation awaits continued study.

I believed that, in view of the limited behavioral descriptions of neonatal pain behavior, foundational descriptive knowledge on the topic was incomplete. In assessing the situation further, it became increasingly clear to me that deductive modes of inquiry and pain measurement efforts were being undertaken in the absence of preliminary inductive and basic description of the behaviors and in the absence of a foundational descriptive base to the body of knowledge on the topic. I questioned whether these fundamental knowledge gaps were contributing to current pain assessment and measurement difficulties in the field. Moreover, I observed that while neonatal pain researchers identified distress as a major confounder to distinguishing neonatal responses specific to pain, most researchers did not consider distress within the design of their studies. Distress as commonly defined in the pain literature refers to the affective and emotional aspects that accompany the sensory components of a pain response such as fear and anxiety (Franck, Greenberg & Stevens, 2000). On the basis of that information together with knowledge gained from studies conducted using stress as the context to describe newborn pain cry (Porter, Miller & Marshall, 1986) and infant organization (Als, Lester, Tronick & Brazelton, 1982), I believed that comprehensive descriptions of neonatal distress responses--including those provoked by pain and non-pain situations--could also be used to help distinguish responses specific to pain

In taking what I had learned from the ethological literature, I reasoned that in addition to existing descriptions of neonatal pain facial expression and cry, our understanding of neonatal pain could benefit from a more complete and detailed description of the behaviors. These lines of reasoning provided the basis for me to pursue an alternative but complementary approach to neonatal pain behavior research. I designed a two-phased basic observational study using ethological methods to generate inductively derived comprehensive description of the behaviors followed by precise and detailed measures of the behaviors in order to distinguish distress behaviors specific to acute pain stimulation.

I believed that basic inductive approaches, such as those used in the natural sciences, would help strengthen the body of pain behavior knowledge to further conceptual and empirical understanding of neonatal pain. Further, I believed the fine-grained basic description of the behaviors arising from the basic approaches, would supplement existing descriptions, such as pain facial action and pain cry, and that together these would provide the foundational basis for constructing sound neonatal pain assessment knowledge. Currently, the lack of valid and reliable pain assessment instruments poses a serious impediment to effective neonatal pain treatment (Anand & McGrath, 1995).

The theoretical underpinnings guiding my research are the gate control theory of pain and the theory of infant development. The beliefs and assumptions which underlie my research are as follows:

1. Pain is a multidimensional phenomenon that affects the totality of all humans and as such, it can only be fully comprehended by the individual experiencing it.

2. All humans experience pain, but the developmental uniqueness of newborn infants, and their inability to communicate verbally demand that researchers draw on their behaviors since behaviors are one of the main means neonates have of communicating their pain experience.

3. Systematic observation of normally occurring human behaviors provide valid and reliable means for researchers to develop basic understanding of complex behavioral phenomenon, such as neonatal pain. Unobtrusive observation and systematic approaches from the science of ethology (the biological study of animal and human behavior) provide unique but credible guidance for conducting a basic study to further descriptive knowledge on how neonates behave when they are exposed to varying forms of sensory stimuli, including those involving acute pain stimulation.

4. Basic and comprehensive descriptions of neonatal pain behavior underpin accurate pain assessment, and these are cornerstone to effective measurement and management of neonatal pain. The ability of clinicians to correctly identify the entire range of neonatal pain behavior is critical to accurate neonatal pain assessment and treatment.

5. Nurses provide front line pain care to neonates and other individuals who are non-verbal. As a practical science (an applied discipline), nursing must develop a body of knowledge on human behaviors capable of informing and guiding nursing practice. This means that, specific to the topic of neonatal pain, the basic behavioral knowledge developed must be made available to assist nurses (and other health care providers) to correctly identify the entire range of neonatal pain behavior so that they can respond effectively to them. The comprehensive descriptions developed through the application of basic approaches coupled with existing descriptions will contribute to this. This approach to the development of neonatal pain assessment knowledge ensures research based and theory driven nursing pain care.

Manuscripts

Manuscript One

Manuscript One, entitled "Ethological Methods to Develop Nursing Knowledge," (Chapter Two) informs nurse researchers and clinicians of the merits of utilizing ethological methods for developing basic descriptive level knowledge about human behaviors; it has been sent for review to *Research in Nursing and Health*, a leading nursing research journal. Nurses deal with complex behavioral phenomenon; they care for individuals who are non-verbal in many different nursing care situations. They also use observation in their everyday practice and in their research endeavors. Yet, minimal evidence exists in the nursing literature to suggest nurses employ inductive means to develop basic behavioral descriptive information about complex behavioral phenomenon concerning them (Morse, 1990). I argue ethological methods will enable nurse researchers to inductively develop the requisite types of basic information needed to initiate nursing's understanding of complex human behaviors. Further, I argue that in laying a strong foundation of descriptive level information, these kinds of basic endeavors will help support construction of a sound scientific body of behavioral knowledge for nursing science from which higher-level theoretical formulations can develop. Nurse scholars have long acknowledged the need for nursing to systematically develop its theoretical and practical understanding of diverse phenomena concerning it, including human behavior (Barnard, 1983, Morse). They also acknowledge the need to take an incremental approach to development of scientific knowledge, particularly when a discipline is young and has not developed its descriptive scientific base (Carper, 1978; Kourany, 1998).

In presenting arguments in favor of ethological methods for nursing, three benefits are discussed: the compatibility of the philosophical underpinnings of ethology and nursing science; the benefits of using the methods to help nursing achieve some of its aims; and the benefits in using inductive systematic observation to guide nursing care and research activities. Examples taken from the nursing literature are used to illustrate how nurse researchers and clinicians have used ethological approaches to further knowledge about complex behavioral phenomenon and how they used that basic knowledge to further theoretically grounded clinical care. The exemplar of neonatal pain is used to illustrate how ethological methods may be used to develop descriptive level knowledge and a midrange nursing theory on neonatal pain assessment.

Manuscript Two

Manuscript Two, entitled "Neonatal Pain: An Overview of the Research Literature," (Chapter Three) offers an overview of the research on the physiological, biochemical and behavioral pain responses of the newborn infant; it has been formatted for submission to *The Clinical Journal of Pain*. Because observation of behaviors represents the most direct and objective way researchers have of generating meaningful knowledge about neonates and their pain (Craig, 1995), the focus of the overview is on neonatal pain behavior research.

Currently, researchers utilize deductive approaches to measure the neonate's multiple responses to pain. In many instances, however, researchers have been unsuccessful in consistently and reliably measuring the responses (Franck & Miaskowski, 1997). Moreover, clinicians experience difficulties in assessing neonatal pain despite having pain assessment tools available to them (Jones, 1989). Researchers have recommended the following to help address these persistent difficulties: controlling for the confounding effects of the neonate's development (Andrews & Fitzgerald, 1997), employment of developmental frameworks (Stevens et al., 1994) and development of standardized data collection protocols (Grunau, Holsti, Whitfield & Ling, 2000). While each of these recommendations is highly relevant, I suggest underlying conceptual and methodological problems associated with the research may be delaying our basic understanding of neonatal pain and hampering our ability to assess and measure it.

Imperfections in the research include (a) the inability to measure neonatal pain perceptions, (b) the difficulty of applying measurements to the multidimensional nature of neonatal pain using uni-dimensional approaches, (c) the limited observation of a few pain behaviors even though neonates display a wide range of behaviors, (d) the tendency to ignore potential confounding factors when measuring neonatal pain behavior, (e) the tendency to rely almost exclusively on short term pain associated with clinical procedures to measure neonatal pain, and (f) the tendency to conduct applied kinds of neonatal pain research while little basic description exists.

A discussion of the research literature on neonatal pain responses and a discussion of some of the shortcomings arising from the research imperfections lead to the identification of several gaps in basic descriptive understanding of neonatal pain.

Ethological methods are proposed as potential approaches to help address some of the gaps, particularly those arising from the behavioral research because of its potential to broaden understanding of the complex phenomenon. I argue, as others have, that description precedes assessment and measurement (Hinde, 1982, Lehner, 1996, Martin & Bateson, 1998), and that, for understanding neonatal behavior, description is best acquired inductively. My emphasis is placed on the benefits of using the two-phased ethological approach to help shorten gaps in basic descriptive understanding of neonatal pain. I explain how inductive approaches can help initiate development of a reliable ethogram (an exhaustive listing) of the behaviors and how researchers can then use the ethogram to generate detailed and precise description of the behaviors. The paper concludes with a discussion of the benefits of ethological methods for developing a strong foundation of basic pain behavior knowledge particularly as it relates to furthering neonatal pain assessment.

Manuscript Three

Manuscript Three, entitled "An Ethogram of Neonatal Distress Behavior to Acute Pain," (Chapter Four) offers the original research conducted for my dissertation; it has been formatted for submission to *Animal Behavior*, a major ethological journal. The manuscript is a report of Phase One of the original research. Because pain behavior in neonates is not well described and because this has implications for furthering neonatal pain assessment and pain measurement knowledge, rationale is given in this manuscript as to why inductive systematic approaches were selected to augment existing approaches and why I focused on distress to comprehensively describe newborn behavior specific to pain. Detailed information is also provided on how the inductive phase of the study was conducted using ethological observational approaches and secondary videotaped data to create a reliable ethogram on neonatal distress behaviors in response to acute pain.

The manuscript contains an example of the completed ethogram. The paper also contains a discussion of how the study differs from the only other basic study done on the topic (Cote, Morse & James, 1991) and of how each study adds unique descriptive insight into newborn distress and pain. Because this study serves as the basis for further investigation, I also explain how the ethogram could function as a reliable source of descriptive level information about the distress behaviors and how its continued development will help ensure it contains reliable and representative descriptions of the behaviors. The manuscript concludes with a brief discussion of the benefits and limitations of using secondary videotaped data and with some recommendations to improve the study.

Manuscript Four

Manuscript Four, entitled "Describing Newborn Distress Behavior To Acute Pain" (Chapter Five) offers a report of Phase Two of the original research; specifically it offers discussion on how the reliable ethogram developed in Phase One of the study and ethological methods (systematic observation and continuous time sampling) were utilized to describe the behaviors in further detail and to distinguish behaviors specific to acute pain. The purpose of Phase Two was to generate precise frequency and duration measures of neonatal distress behavior in response to seven noxious and non-noxious events associated with acute newborn surgical pain. The events were baseline, diaper change, post diaper change, restraint application, post restraint application, circumcision and post circumcision. Detailed information is given as to how the study was conducted. Steps taken to generate precise descriptive level measures of neonatal distress are offered, as are the processes used to descriptively distinguish behavior related to distress from behavior related to distress caused by pain. The benefits of generating frequency and duration data are discussed.

Findings include descriptions of the 40 neonatal distress behaviors. Of those 40, descriptions are provided of the 27 behaviors as they occurred across three distress events and 13 extreme descriptions of distress as they occurred only during circumcision. Also included are descriptions of the 25 behaviors that occurred following the three distress events. Other findings include the heightened sensitivity and prolonged duration and frequency of extreme distress (acute pain) following circumcision. The manuscript concludes with a brief discussion on how further basic investigation using ethological methods may augment existing pain behavior descriptions and on how such investigations may assist in furthering knowledge in important areas that remain particularly challenging for the neonatal pain field such as those concerning neonatal pain assessment and recovery from pain.

Additional Information

Not all information pertaining to this original basic research could be contained in the four manuscripts. Because the dissertation is comprised of manuscripts tailored for publication, some material is included as appendices, such as a table containing articles reviewed for Manuscript Two (Appendix A).

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CHAPTER TWO

Ethological Methods to Develop Nursing Knowledge

Gaps exist in nursing's theoretical and practical understanding of human behavior in many nursing care situations (Barnard, 1983). Such gaps are particularly evident when they concern pre and non-verbal individuals, and where behavior provides nursing the main means for understanding complex phenomenon. (Anand, 1998; Cook, Niven & Downs, 1999). A research technique that may hold promise for enhancing development of this needed knowledge is ethology.

To determine the suitability of ethological methods for developing basic descriptive nursing knowledge, we explore three matters in this paper:

1. the congruence of philosophical assumptions for ethology and nursing,
2. the value of ethological methods for developing sound and credible knowledge about human behaviors, that informs and guides safe and effective nursing practice, and
3. the limitations of observational methods currently used in nursing to determine if ethological methods are able to overcome these limitations.

Before addressing these matters, the methods of ethology will be outlined.

What is Ethology?

Ethology is the study of human and non-human behavior in the natural environment (Hinde, 1982). Its aim is to systematically describe behavior in all of its detail and to correlate it with varying exogenous and endogenous stimuli that naturally evoke it (Carthy, 1966). To help organize their thinking about the ongoing stream of behavior and to establish a biological base to their behavioral investigations, ethologists pose four distinct but interrelated questions (Hinde, 1982; Martin & Bateson, 1998):

- What are the immediate underlying physiological and environmental causes of this behaviour? (immediate causation)

- How did the behavior develop? (development or ontogeny)
- How does the behavior help the individual to survive or adapt? (function)
- How did the behavior evolve in the species? (evolution)

Ethology involves a two-part analytic process consisting of an inductive phase followed by a deductive phase. Systematic observation and description of behavior take place during the inductive phase. The end result is an ethogram; a concise, objective, and representative listing of an organism's behavior. Its purpose is to inform researchers about the complete range of contextually situated behaviors of that organism. Ethograms provide a legitimate and sound basis for initiating understanding of particular behavioral phenomenon (Sackett, 1978). In the deductive phase, precise measures of the behavior and hypothesis testing occur.

With the ethogram as the essential starting point for all research and a pre-requisite to the deductive phase, ethology differs from experimental and other forms of behavioral investigation (Lehner, 1996; Martin & Bateson, 1998). Ethologists argue that description precedes measurement, and that one cannot hope to accurately measure a behavior unless one understands the behavior contextually and comprehensively (Martin & Bateson, 1998).

Researchers have used the two-phased ethological approach in a variety of situations. The approach, or forms of it have been used to describe sophisticated tool use (Goodall, 1964), and facial expressions (van Hoof, 1967) in non-human primates; and imprinting in birds (Lorenz, 1981). In humans, the approach has facilitated description of simple behavior and complex social interactions (Blurton Jones, 1974). Its application has also led to comprehensive descriptions of cross-cultural human behavior (Eibl-Eibesfeldt, 1989), infant neurobehavioral organization (Prechtl & Beintema, 1964), infant-maternal interaction (Thoman, Becker & Freese, 1978), and autistic behavior in children (Tinbergen, 1974).

The Philosophical Underpinnings of Ethology.

While little explicit information exists about the philosophic underpinnings of ethology, Eibl-Eibesfeldt (1989) described them as *critical realism.* Critical realism refers to a theory of knowledge, which is *realistic* in that existence of an objective world independent of one's mind is accepted, and *critical* in that claims about reality are scrutinized (Mohan & Wilke, 1980).

The main assumptions of critical realism were formulated in the early 1900's, a time influenced by industrialism, political uprising (Marxism) and social change (Mohan & Wilke, 1980). During this time, philosophers questioned some of the conventional claims underlying naïve conceptions of natural science (positivism) This questioning led to rejection of several tenets of naïve realism. The notions of theory-free observation language and absolute infallible truths were rejected. Instead, the idea of non-material phenomenon was accepted. Philosophers began to distinguish between the object known and the mental state through which it is known. They acknowledged great variations in what we term truth or external reality. They recognized that human perception is imperfect due to the temporal nature of perception and individual differences in human mind states (Sellars, 1916). Their assertions signified a major departure from positivism, and set the stage for an epistemology that strove to unite scientific with humanistic concerns (Mohan & Wilke, 1980).

Critical realists, therefore, acknowledge the existence of a common external reality while asserting the fallibility of that knowledge and difficulties in obtaining scientific certainty about it (Cook & Campbell, 1979). Hence, they do not consider knowledge absolute; rather they consider truth in knowledge to be an approximate measure of how observation statements correspond. It is believed that persons can agree on the existence of common external objects despite observation language being theory laden (Mohan & Wilke, 1980).

According to Eibl-Eibesfeldt (1989), knowledge of the external world is based on sensory data processing mechanisms (including *a priori* knowledge inherited as phylogenetic adaptations) and individual experience. To further explain, our cognitive and perceptual capabilities are given to us before we have any experience. These phylogenetic endowments help us adapt to our environment much in the same way "a horse's hoof is suited for the plains before its birth" (p. 201, Lorenz, 1981).

While genetic endowments provide *a priori* perceptual knowledge, everyday experience influences the way an individual perceives and expresses objective truths. Personal physiology, environmental influences, genetic heritage, and cultural upbringing all play interactive roles in determining how individuals perceive reality, and how they express themselves in relation to their perceptions (Eibl-Eibesfeldt, 1989). Despite perceptual variations, common behavioral patterns are recognizable across individuals. It is these common patterns that ethologists seek to inductively describe, and deductively measure. While acknowledging variation in human perception (and thus affirming perceptual differences between observers), ethologists are confident they obtain representative and objective behavioral descriptions (Lehner, 1996). They are confident because they use rigorous procedures to establish the inter-rater reliability of the ethogram, test observer agreements, and reduce inevitable error.

As critical realists, ethologists, thus, obtain imperfect knowledge about common truths through rigorous inductive and deductive data collection and analysis procedures. They believe in the critical importance of a foundation for knowledge growth (though not a theory neutral foundation), where inductive inquiry precedes deductive inquiry. Theory derived from induction is essential to develop the foundation for knowledge. Scientific knowledge thus converges through a process of description, control of confounders to make rival hypotheses implausible, and correction of error (Cook & Campbell, 1979).

Ethology and Nursing Science: How Congruent Are Their Aims and Assumptions?

Nurses who espouse a critical realist view of nursing science advocate philosophic assumptions congruent with those underlying ethology. These assumptions include agreement of a common but non-absolute reality existing external to one's mind, acknowledgement of individual differences in human perception, and regard for objectivity (Gortner, 1993, Letourneau & Allen, 1999). The fit between ethology and nursing is also evident given the extent to which nurses engage in field and quasi-experimentation, and the interest some nurse scholars have in integrating inductive and deductive modes of inquiry (Gortner, 1993; Morse, 1991).

Not all would agree that ethology fits with some of the fundamental aims of nursing. Lincoln (cited in Maxwell & Lincoln, 1990) argues that a focus on objectivity is dehumanizing, and that epistemological incommensurability may result if inductive and deductive modes of inquiry are integrated. Although the end goal is to describe behaviour objectively, the process of inquiry in ethology is not dehumanizing since humans are not used as a means to an end. The subjective nature of humans and their environments are respected. Acquiring knowledge through rigorous and objective means does not negate the importance of first grounding inquiry in the everyday experiences of individuals. While inductive inquiry initiates understanding, deductive inquiry advances it. Both modes of inquiry are necessary and complementary. Together they inform us more completely about a phenomenon than when either approach is used alone. The benefit for nursing is comprehensive knowledge as a foundation for safe and effective practice.

Current Observational Methods Used in Nursing: Strengths and Limitations

To study human behaviour, nurses use observation in three ways. These include inductive use of systematic observation to develop an ethogram, deductive use of systematic observation to test hypotheses about already defined behavior, and non-systematic use of observation to simply describe behavior. It is in the use of systematic observation, and particularly its inductive use, that the benefits of ethology become evident and the disadvantages of proceeding deductively are recognized. Table 1 is a summary of inductive and non-inductive use of systematic observation.

Inductive use of systematic observation. A core group of nurse researchers have used systematic observation inductively to describe behavior. Their research describes neonatal postoperative pain responses (Cote, Morse & James, 1991), caregiver-infant interaction (Morse, Solberg & Edwards, 1993), types of attending and patterns of nurses' work (Bottorff & Morse, 1994), comforting behavior of caregivers toward distressed postoperative neonates (Solberg & Morse, 1991), and interactions between health care providers and patients (Bottorff & Varcoe, 1995). In this collection of studies, researchers used systematic observation to inductively develop two ethograms (Bottorff & Morse, 1994; Cote et al., 1991). In subsequent work, Bottorff and Varcoe (1995) used the ethogram developed by Bottoroff and Morse, to develop higher level theoretical formulations about nurses' work behavior. Together, these studies demonstrate the feasibility and utility of using ethological methods to generate foundational and higher level descriptive nursing knowledge about human behavior.

The use of systematic observation is also evident in nursing practice To assess neonatal stress, Als (1986) used systematic observation to inductively develop the behavioral coding component of the Neonatal Individualized Developmental Care and Assessment Program (NIDCAP). Since then, the coding scheme has evolved theoretically from its initial descriptive state, and it is now used to guide clinicians in the care of high-risk neonates. When applying the program clinically, caregivers make use of their ongoing, but reliably established observations of the neonate's behavior to guide their care-giving actions. The goal is to optimize a baby's development by reducing environmental stress through sharpening the everyday observation skills of clinicians.

That example illustrates how a program derived from ethological methods informs caregivers about important neonatal developmental factors, and how it guides them to use systematic observation in clinical practice. Caregiver interventions therefore become outcome-based, conceptually grounded, and theory-driven. This approach to care is important since theory driven research reduces trial and error. It links nursing research, theory and practice with distinct patient outcomes and it optimizes evidence-based decision-making (Chen & Rossi, 1989). Such an approach is congruent with nursing's social aims (Donaldson & Crowley, 1992).

Deductive (non-inductive) use of observation. Nurse researchers mostly use systematic observation deductively to test pre-developed concepts and theory about particular behavior. Their aim is not to develop new descriptive knowledge about a behavioral phenomenon. Rather, their aim is to test pre-existing information about behaviors that others have already described and or defined. Inter-rater procedures are used to test the reliability of the particular instrument containing the predefined behavioral descriptions.

Although it is advantageous and acceptable to use previously developed instruments (Streiner & Norman, 1998), researchers must continuously test their reliability and validity. Tesh and Holditch-Davis (1997) demonstrated this when they tested the concurrent validity of an inductively derived coding schema (ethogram) previously developed by Thoman et al. (1978). They used the ethogram to code mother-child interactions, comparing their findings to the HOME Inventory [Home Observation for Measurement of the Environment] and the NCATS [Nursing Child Assessment Teaching Scale]. Although all three instruments demonstrated concurrent validity, the systematic observation strategy used to test the validity of Thoman's et al. (1978) ethogram yielded a richer and broader range of child behavior than did the NCATS.

The findings of Tesh and Holditch-Davis (1997) provide important information because they suggest that the NCATS, while valid, may not contain the range of behavior items required to sufficiently describe behavior of children older than those for whom the NCATS was originally designed. This has implications for nurse researchers using the NCATS to deductively generate knowledge for groups of older children, and it has implications for use of that knowledge in nursing practice.

Researchers may assume that previously developed behavioral instruments have the capacity to yield comprehensive and representative data about behaviors of interest. They need however to address important methodological issues about the adequacy of construct validity (lack of specificity and sensitivity of the instrument). While deductive knowledge, generated from use of pre-existing behavioral instruments, provides some knowledge, it may be insufficient to enable comprehensive understanding of the phenomenon. This lack of comprehension is likely increased if the behavioural instrument was initially constructed using deductive, rather than inductive means. Before using a behavioral instrument, researchers need to investigate how it was developed. They may do this by asking 1) were behavioral items contained in the instrument based on inductive use of systematic observation, 2) when was the instrument developed, and 3) who developed the instrument? Formation of a sound foundation for subsequent knowledge development and, hence, understanding is optimized through the inductive use of systematic observation.

Use of non-systematic observation. Few nurse researchers incorporate inductive approaches to study human behavior and few clinicians use systematic observation to guide their practice. This is surprising since inductive inquiry is valued in nursing, and observation is a fundamental nursing practice and research skill (Nightingale, 1859 1946). According to Morse (1990), observation in nursing research has traditionally focused on describing human behavior in global (non-systematic) rather than distinct and reliable terms. That focus may have led to premature inferences and detracted from the use of systematic observation to develop basic scientific nursing knowledge.

If we are to counteract the limitations and inferences that have evolved in the premature use of deductive and non-systematic methods, we need to use ethological methods to facilitate development of credible and conceptually grounded descriptive level knowledge about human behaviors. Midrange theory resulting from such an approach will provide basic understanding to ultimately guide nursing practice.

Level of Theoretical Development Using Ethological Methods

Because ethological methods result in sound and relevant behavioral description, they hold promise for developing descriptive level, qualitatively derived theory about human behavior (Morse, 1997). The aim is to obtain an accurate portrayal of observed behavior in the context in which it occurs. At this level, data are not causal or interpretative, and the process does not produce formal theory (Morse, 1997). Descriptions arising from inductive inquiry (ethogram) are essential first steps to subsequent concept and theory development (Lehner, 1996; Morse, 1997). Descriptive level knowledge constitutes the first level in the incremental development of nursing scientific knowledge. Although alternative explanations exist about the development of scientific knowledge, it is appropriate to explain it as an incremental process when the discipline is young and lacks a developed descriptive base (Kourany, 1998).

One of the main reasons for developing descriptive level knowledge is that it provides a discipline with insight into the mechanisms and temporal ordering of complex real life events and behavior (Morse, 1997). Because inductively derived descriptive data are rooted in the everyday reality of the individuals under study, they are representative and complete. Unlike deductively derived instruments where behavioral descriptor items are limited, an ethogram contains the full complement of descriptor items for a particular behavior. The behavioral descriptors contained in an ethogram provide baseline data required for developing conceptually valid behavioral instruments. Moreover, these operationally defined descriptor items provide the basis for understanding complex behavioral phenomenon, and they serve as a scientifically solid foundation for further study and clinical improvement. It is in these ways that descriptive theoretical knowledge, in the form of an ethogram, lead to midrange theory for guiding nursing care. The following is an exemplar of ethological methods to develop an ethogram about human neonatal pain behavior and a middle range theory of neonatal pain assessment.

Development of Middle Range Theory Using Ethological Methods: An Exemplar

Much progress has been made to the science of newborn pain; however, assessing pain in the newborn remains a difficult challenge (Stevens, Johnston, Petryshen & Taddio, 1996). These challenges come from several interrelated problems. We experience difficulties in obtaining consistent measures of the physiological, biochemical and behavioral indices of neonatal pain (Franck & Miaskowski, 1997). The gate control theory of pain, which is used by researchers, is not sensitive to the developmental uniqueness of the infant, and their verbal inability to communicate (Anand & Craig, 1996). Furthermore, one persistent assumption that has delayed progress and effective pain treatment is that the human infant is unable to feel, or remember pain (Derbyshire, 1996).

While nurse researchers conduct studies to assess and measure behavioral and physiological indicators of newborn stress and pain, their aims are not to generate basic knowledge about the behavior. We found only one study where researchers (Cote et al., 1991) used systematic observation to inductively develop descriptive level knowledge about neonatal pain behavior. Despite its exhaustive listings, we did not utilize the ethogram developed by Cote et al (1991) because it did not contain behavioral descriptors representative of newborn responses to the actual pain of surgery. Rather, it contained items describing distress related pain states representative of pain responses 24 hours after surgery. Hence, little foundational knowledge has been developed in this important area of nursing practice. What is critically needed is a detailed description of neonatal acute pain behavior and descriptions of the pain context.

The major steps that nurse researchers can take to inductively develop an ethogram of acute pain related behavior in full term neonates are:

1. Preliminary observation to become familiar with neonates and their behaviors.
2. Repeated and non-obtrusive systematic observation of a defined number of neonates as they undergo a variety of acute pain events (either directly, or by using previously recorded videotapes of the neonates).
3. Describing the entire range of neonatal acute pain behavior in terms of their motor or functional (molar/molecular) and temporal (momentary/enduring) characteristics.
4. Preparing an exhaustive list of the behaviors, the subcategories of which are operationally defined (e.g., head movements, and general body position).
5. Organizing categories and subcategories into mutually exclusive lists.
6. Establishing the inter-rater reliability of the ethogram using Kappa (0.80).

Ongoing development of the ethogram will require that it be representative of the types of acute pain that full term neonates experience. Increased sampling can do this. Once researchers complete initial validity and reliability testing of the ethogram, they can use it to generate deductive knowledge about the pain behaviors. They can also use the ethogram to link precise measures of the behavior to other physiological pain responses like change in heart rate, thus promoting multidimensional neonatal pain descriptions.

Lastly, they may use the ethogram to develop clinically relevant neonatal pain assessment instruments. It is at this point of knowledge development, that clinicians can use and test the descriptive level theory in the practice setting.

Researchers may use the reliably established and developed ethogram to develop a middle range theory of neonatal pain assessment. They can do this by first generating detailed description of the characteristics of the pain behaviors. They may then integrate that descriptive knowledge with other types of related information. Examples may include integrating the behavioral descriptions with information like pain theory, neonatal neurodevelopment, principles of pharmacology, and nursing practice strategies for implementing and evaluating clinically based interventions. The midrange theory that subsequently develops has the potential to inform and guide clinicians in their daily pain care. The process is similar to the one Jacox (1974) described about developing a midrange theory of pain assessment.

Conclusion

The richness and complexity of the phenomena that concern nursing require diverse research methods to facilitate sound development of its scientific base (Carper, 1978). A critical examination of ethological methods demonstrates several convincing reasons why nursing ought to consider ethological methods to develop descriptive level knowledge about important behavioral phenomenon. These include shared philosophic assumptions between nursing science and ethology, and the benefits afforded to nursing in generating a sound body of basic descriptive level behavioral knowledge. Ethological methods offer nursing systematic and reliable approaches for generating credible behavioral knowledge. That type of complete and representative knowledge may shorten current gaps in our theoretical and practical understanding about complex phenomenon affecting non-verbal individuals, like pain in neonates.

While formal theory does not arise from the use of ethological methods, we demonstrated how a midrange theory about a behavioral phenomenon could develop from an ethogram and its prescribed use in clinical practice. In other words, the "know that" types of knowledge from the ethogram, combined with "know how" practice types of knowledge, provide the basis for guiding particular and general nursing action (Jacox, 1974; Wallace, 1983).

That approach to theory driven practice optimizes the delivery of credible, safe, effective, and ethical nursing interventions. These goals are important to the discipline as it strives to develop a sound scientific body of knowledge that can guide its theoretically based nursing practice. Sound development, however, is dependent upon a solid and supportive foundation. Clearly, ethological methods hold promise for development of this foundational support for nursing, particularly as it relates to the study of human behavior. It is for this compelling and important reason that we suggest ethological methods for developing nursing knowledge.

Table 1: Comparison of observational methods for developing nursing knowledge about human behavior: Ethology and experimental methods

Method	Types of Research Question(s)	Type of Study Design	Type of Observation	Type of inquiry	Outcome of type of observation
Ethology	What are the pain behaviors of full term neonates to acute pain?	NATURALISTIC Researcher exerts no control over variables that may influence naturally occurring behavior. Few study subjects compared to experimental, but behavior observed for longer periods of time, and in different situations.	INDUCTIVE USE OF SYSTEMATIC OBSERVATION Conducted using explicit rules - defining the observed behavior and using reliability agreement procedures. Descriptions arising from systematic observation are reliable and thus standardized.	INDUCTIVE (qualitative)	Development of a reliable ethogram (an exhaustive and complete listing of the organism's behavioral repertoire as it naturally occurs).
	What are the characteristics of the behaviors? How do they compare across pain and non-pain situations? What are the causes and functions of the behaviors?	NATURALISTIC As above but can also involve control if aim is to test hypothesis about the behavior.	NON-INDUCTIVE BUT SYSTEMATIC OBSERVATION: Still requires that ethogram withstand inter-rater reliability standards. Aim is to deductively test ethogram to generate higher-level theory about the behavior. Assumes inductive description through use of the ethogram.	DEDUCTIVE (quantitative)	Precise measurements of observed behavior. Because new descriptor items may still be added to the ethogram as result of its testing, the ethogram may still be considered as a work in progress.
Experimental	What is the child-parent interaction behavior in this particular context? This type of question would likely involve the use of previously developed tools such as the NCAST.	CONTROLLED Researcher exerts control over extraneous variables.	NON-INDUCTIVE BUT SYSTEMATIC OBSERVATION: Still requires instrument withstand inter-rater reliability standards. Emphasis is on testing theory/hypothesis. Use of pre-existing instrument assumes inductive description.	DEDUCTIVE (quantitative)	Precise measurements of observed behavior. Pre-existing instrument is not considered as a work in progress. Aim is not to add new descriptor items, but to test those contained in the instrument

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CHAPTER THREE

Neonatal Pain: An Overview of the Research Literature

In the past three decades, great strides have been made to further our understanding of how neonates experience (respond to) pain. However, to date, no biological measure of pain exists to unequivocally inform us that pain is being experienced; nor is the neonate able to verbalize perceptions of pain. When we observe tissue injury, we infer neonates must be experiencing pain and deduce that consequent events were likely caused by pain. Through this deductive process, researchers conclude that pain increases newborn mortality and morbidity [1] and it predisposes some neonates to developmental problems.[2]

In the absence of a biological pain measure, a wealth of research has developed as a result of measuring the physiological, biochemical and behavioral correlates of noxious events inflicted on the newborn.[3, 4, 5] However, certain methodological and conceptual issues arising from this research need to be taken into account to advance our knowledge. Because behavior is the main source of information about neonates,[6] the focus of this review is on the neonatal pain behavior research, its problems and its potential.

Four online databases, (Medline, CINHAL, EMBASE, and PSYLIT) were searched for studies on neonatal pain published between 1941 and 2001. Studies selected for inclusion were those that pertained to newborn infants. Although it is preferable to focus on a particular age, this review pertains to premature and full-term neonates because early studies did not distinguish gestational age or because researchers sampled varying age groups. Other inclusion criteria were that studies be published, that they involve noxious (causing tissue damage) stimulation and or care giving events that are not noxious, and that they pertain to assessment and or measurement of the physiological and/or biochemical and/or behavioral responses of the newborn to those events. For each of the 55 studies that were retained for review, we examined (as appropriate):

- design, purpose, and study findings

- model of pain tested
- period of time of data collection
- type of pain knowledge developed

The overview begins with a discussion of three research models each of which has guided the focus and direction of neonatal pain research. This is followed by a brief overview of the research on the three correlates of neonatal pain, with emphasis placed on identifying persistent challenges in progression of knowledge in each of the three areas. Next, conceptual and methodological problems associated with the research (particularly the behavioral research) are outlined. Lastly, ethological methods are suggested to help develop behavioral knowledge for furthering the field.

Models of Neonatal Pain Research

The three models of pain research that have been used to investigate the physiological, biochemical and behavioral correlates of neonatal pain include the basic experimental, the basic observational and the applied invasive models. The first two basic models yield foundational and theoretical description of the responses, while the applied model yields deductive knowledge relevant to clinical pain. Individual usage of the models has influenced evolvement of the research and shaped our understanding of neonates and their pain.

Four decades ago, researchers in the field of sensation employed a basic experimental model where they induced pain in otherwise healthy research subjects. They applied pressure, electric shock[7] and heat stimuli. Study findings furthered understanding of sensory pain and launched subsequent research on varying pain treatments. Children were occasionally included in these studies, but they rarely included neonates. More often, sensation studies involved the human fetus and they described the early emergence of contralateral and/or epislateral flexion reflexes.[8, 9]

Researchers were disinclined to use newborns in pain research, not because of ethical misgivings but because they perceived newborns as developmentally limited.[18]

Consequently, minimal sensory knowledge exists where pain was induced in children or neonates. What little has been published includes descriptions of flexor responses using Von Frey hairs[10, 11] and motor responses resulting from pin prick,[12, 13, 14] or the snapping of an elastic band on the sole of the foot.[15, 16, 17]

Historically, results showing non-specific neonatal motor responses to repeated heel snaps[12] profoundly strengthened the long-held belief that neonates were incapable of perceiving pain.[18] That belief curtailed further research on the topic for the next 20 years, which in turn delayed the development of neonatal pain assessment and treatment knowledge.[18] However, recent renewed interest in newborn pain sensation has led to significant developments. In using comparative animal models and neurobiological frameworks, Fitzgerald and her colleagues[11, 19] refocused attention on the newborn's capacity to respond to cutaneous stimulation. Results of those studies suggested that significant pain experienced early in human life may alter pain mechanism development at the cellular level[10] and that newborn infants may actually experience cutaneous pain longer and more acutely than older infants or adults.[11,19] In stressing development, these studies challenged old beliefs about neonates, and, in doing so, heightened our insight into the significance of constant neurodevelopment on newborn pain.[54, 83]

In contrast to the basic experimental model of inflicting sensory pain to document neonatal reflexive movement, research has also been conducted using the basic observational (or unobtrusive) model. Cote et al.[20] systematically observed ill neonates for up to 12 hours, starting 24 hours after cardiac surgery, to describe five behavioral newborn distress states. The researchers derived their inductive approaches from ethology, a science rooted in the biological study of animal and human behavior.[21] Researchers from the fields of infant psychology and infant development have used forms of the unobtrusive model to describe newborn interaction competencies;[23] yet, apart from Cote et al.,[20] this observational model has not been applied to the study of neonatal pain.

The most common approach to studying neonatal pain has been to conduct research in the context of short term pain.[1, 24, 25, 26, 27] Therefore, while it is experimental (deductive), the applied model is not laboratory based. This contemporary approach is premised on the view that it is unethical to induce pain in children and infants purely for the purpose of research. In contrast to the two preceding basic models, the applied model focuses on the deductive measurement of pre-defined neonatal pain responses rather than on their inductive description; its aim is to reduce clinical pain. With few exceptions such as infant state, most of the predefined responses are adult or infant based and presumed applicable to neonates.[3] Therefore, in using the applied model, researchers assume the predefined indicators adequately represent the phenomenon being measured.

Clinical neonatal pain arises from illness prevention procedures, such as immunization,[28, 29] screening for PKU[30] or administration of vitamin K.[31] It also arises from procedures to treat or to investigate newborn illnesses, such as those associated with congenital cardiac[1] and umbilical diaphragmatic hernias.[32] The measurement of pain is immediately preceded by an short term invasive procedure we hypothesize is capable of causing pain. The scenario allows researchers to deductively study many aspects of pain. Researchers typically use ten second time- frames to collect their pain response data before, during and following a noxious event. However, in some cases, researchers do not report measures of the baseline period even though they indicate having observed and or videotaped the neonate for all phases of data collection, including the baseline period. In some of those cases, measurement commenced at the start of invasive stimulation and for each 10-second interval. Physiological, biochemical and behavioral correlates of neonatal pain have been primarily identified through the applied research model.

Overview: Physiological, biochemical and behavioral correlates of neonatal pain

Physiological pain indicators.

Physiological measures of neonatal pain include involuntary cardiovascular and respiratory responses and changes in immune function. The measures are usually observed and or collected seconds before, during, and after the introduction of short-term noxious or non-noxious stimulation.

Change in heart rate is considered one of the main physiological indicators of neonatal pain as findings are generally consistent across studies. Researchers have utilized this indicator along with respiration to distinguish between types and phases of newborn pain. For example, Lander et al.[34] and McIntosh et al.[35] reported a significant increase in heart rate and a decrease in oxygenation ($tcP0_2$ and SaO_2) from baseline levels for different phases of circumcision and heel lancing respectively. Changes in heart rate and respiration, however, are not specific to the pain response. In examining factors related to the pain event, Cote et al. [20] and Evans et al.[36] reported that heart rate changes also occur in response to other simultaneous internal, external and non-painful stimuli, such as ambient sound and suctioning. Other researchers have questioned whether unexpected increases in $tcP0_2$ levels following newborn male circumcision were due to crying [37] and whether decreased $Pa0_2$ levels during the rubbing of the neonates heels occurred as a result of respiratory distress.[38]

Palmar sweat levels have been suggested as stable indicators of emotional state in full term neonates.[4] Palmar sweat is thought to reflect different levels of neonatal distress. Yet, in examining the development of emotional sweating, Harpin and Rutter[39] noted that palmar sweat levels vary across time for single subjects as well as across subjects by age. The usefulness of palmar sweat as a measure of neonatal pain is also questioned on the basis that no standardized protocol exists for measuring it.[40] Another issue is the delay in time between the moment the stimulus is received and the moment the indicator is collected. [40] Similar to heart rate and respiration, palmar sweat levels may not be specific to the noxious stimulus; they may instead represent other intervening events occurring during data collection.

Vagal tone is also regarded as a sensitive measure to discriminate stress from pain. As a form of parasympathetic activity, vagal tone functions to control (inhibit) heart and laryngeal musculature. In a series of studies Porter et al. [41, 56] found that decreased vagal tone results in neonates emitting high-pitched screeches during the most invasive (or stress inducing) phase of circumcision. As well, Gunner et al. [42] showed that neonates demonstrate significantly lower vagal tone during heel lance compared to baseline. Researchers who use longitudinal designs report, however, that measures of vagal tone change with age. [43] Still others report that the measure varies with the behavioral state[44] respiration and motor movement of the neonate.[45] Like the preceding physiological indicators, vagal tone is an imprecise measure of neonatal pain.

Biochemical indicators

Biochemical measures of neonatal pain include endocrine-metabolic indicators such as plasma and salivary cortisol, epinephrine and norepinephrine. They represent the neonate's stress response to nonpainful stimuli (routine physical care[46]), short term invasive procedures (heelstick [42]), and surgery (circumcision [47, 48] and heart repair [49]). In those pain contexts, the biochemical measures have been utilized to evaluate the efficacy of anesthetics and analgesic agents.[46, 47, 50]

In studying newborn response to heel lancing, Gunner et al. [51] reported a graded increase in plasma and salivary cortisol levels with increased intensity and repeated application heel lancing. However, during that study, the authors also observed that cortisol levels do not always predict the state of neonatal arousal, particularly for neonates who were quietly sleeping before they were exposed to a noxious stimulus. Gunner et al. [51] and others[57] found those neonates sometimes do not react in a robust manner as anticipated. As Gunner and Donzela [81] later explain, this may be because the increased rise in cortisol (as a result of the heel lancing) stimulates an increase in quiet sleep, which in turn reduces cortisol and other stress-sensitive systems. As well, because cortisol levels are usually taken during the most invasive phase of a noxious event, the levels may only measure a sequential segment of the neonate's overall stress response.[25] Cortisol levels have also been found to vary with neonatal cry, circadian rhythm and physical handling.[52] Similar to some of the physiological pain indicators, cortisol levels appear to be confounded by age and neonatal development,[53] and they are difficult to obtain in preterms who produce little saliva.

Clearly, stress (distress) may occur with pain, but not all pain is represented by stress, and not all stress responses are pain responses. Some researchers argue that, since it is difficult to ascertain whether the responses measured are specific to pain and not to other stimuli, we cannot correctly equate stress with pain.[54, 82] Despite this assertion, little is actually known about how neonates respond to noxious and distress evoking situations and to those situations that are non-noxious but distress evoking.

Behavioral indicators

Researchers describe and measure four categories of neonatal pain behavior: cry, facial action, body movements and complex social and self-regulative responses such as consolability. Cry has been used most frequently perhaps because it is relatively easy to quantify. Changes in facial action has also been used frequently in research following the emergence of coding scales. Body movements and complex social and self-regulative responses are less frequently used. As coding systems are developed to capture the rapid and co-occurring activities of the neonate, inclusion of complex behaviors, however, can be predicted.

Neonatal cry. Although it is the most frequently investigated newborn pain behavior, pain cry is difficult to distinguish in neonates because it is also stimulated by other factors such as cold and hunger, [43] and because some neonates fail to cry when exposed to pain.[55, 67] Insight into neonatal pain has arisen as a result of research on the various characteristics of newborn pain cry, [56] and on cry and other associated pain indicators such as neonatal pain facial actions, [55, 57] heart rate, [24] state,[58] body movements[14] and vagal tone.[41] The usual approach is to study cry following clinically based short term invasive procedures such as heel lance and venipuncture. It has also been assessed following routine care, circumcision and major surgery.

Progress in our knowledge of neonatal cry has largely come about through the efforts of pain researchers such as Johnston and her colleagues [24, 43, 55] who use spectral analysis to precisely distinguish between different types of pain cry and between various dimensions of same cry. Use of spectral analysis has enabled evaluation of neonatal pain related interventions such as oral sucrose, [59] and intra-operative fentanyl.[60] However, cry measures still vary, across studies, likely because no standardized protocol exists for selecting cries for spectral analysis. [55]

In addition to spectral analysis, Porter et al. [56] utilized human listeners to subjectively assess the qualitative features of newborn pain cry. Results of that study show high agreements between the qualitative and spectrogram descriptions of cry, particularly in response to acute surgical pain. Others report latency from noxious event to first cry and a systematic rise in cry duration with increased intensity of the stimulus in full-term and premature neonates.[29, 30, 41, 55, 56] In their study on newborn male circumcision, Lander et al. [34] reported that neonates who received a ring block anesthetic cried for shorter durations compared to neonates who received no anesthetic. In addition to noting high pitched screech sounds during the most intense phase of newborn male circumcision. Porter et al.[41] also reported that chronically stressed ill neonates produced cries that were generally higher and more variable in pitch than healthy full-term neonates.

In studying the developmental changes of pain in premature and full-term neonates Johnston et al. [29] observed that some premature neonates also produced high-pitched screeches following heel lance. It may be as Fitzgerald et al's comparative[19] findings suggest, the less developed neurological state of premature newborns may render them more sensitive to noxious forms of stimulation than healthy full-terms. Before accepting this conclusion, we must undertake two areas of study. As Johnston et al. [29] suggest, physiological factors must be eliminated as the cause of screech or hyper-phonated sound. The full range of cries (including lack of cry) made by premature neonates to both noxious and non-noxious (but distress inducing) stimuli must also be distinguished to rule out possible extraneous factors. Also, because research on neonatal pain cry mainly involves short-term pain, new research must broaden sampling to include ill neonates and varying pain, including those that are non-noxious but distress inducing.

Neonatal pain facial action. A change in facial action induced by aversive stimulation is the second most commonly employed behavioral indicator of neonatal pain. Although other neonatal facial scoring systems exist, researchers almost always use the Neonatal Facial Scoring System (NFCS) developed by Canadian researchers Grunau and Craig. [57,61] In using the NFCS, researchers use slow and stop-frame procedures on pre-recorded videotapes to score up to ten facial actions in 3- to 10-second time blocks before, during and following the introduction of a noxious stimulus (although in most cases, researchers commence scoring immediately after introduction of the pain stimulus). Increased NFSC scores indicate increased levels of pain.

Researches have utilized the NFCS to study many aspects of neonatal pain. The NFCS has been used to distinguish acute pain in full term and premature neonates. [28, 29,] and it has been used to distinguish [62] between varying pain situations, [29, 30] between pain and non-pain events [31, 55] and between varying routine care-giving procedures.[36] Ongoing testing has helped establish the validity of the NFCS for those pain events.

In using the NFCS, both Johnston et al.[63] and Ramenghi et al. [64] found that, following heel lancing, neonates who were rocked and given oral sucrose displayed less pain facial action than neonates who were not rocked and given sucrose. Similarly Barrier et al. [illegible] noted that neonates who were given pre-operative doses of fentanyl produced less facial action following minor surgery than did neonates who were given a placebo. In one study, authors reported NFCS scores to be lower for venipuncture than they were for heel lancing.[30] In other studies, pain related facial actions were found to increase with intensity of invasive [29, 30, 65] and non-invasive [31, 55] procedures. NFCS scores were also found to increase with gestational age [29, 62] and to diminish with increased numbers of invasive procedures, particularly in premature neonates.[66] Stevens et al.[58] recommends correcting for gestational age when using the NFCS to score for the less robust facial expression of premature neonates. However, before any definite conclusions can be made about facial action in premature neonates, a full description of their facial actions to varying pain situations must be documented. Full descriptions may reveal that premature neonates display a unique range of facial action to pain undetected by the NFCS. That issue may also be pertinent for assessing facial action in fullterm neonates who are exposed to varying types of pain. This is because the coding system on which the NFCS is based was initially developed for infants but modified for neonates, and because it has primarily been tested in response to short-term pain (heel lance). Similar to research on pain cry, the facial actions of neonates of a range of both gestational ages and states of illnesses need further testing, particularly in response to varying types and intensities of pain, including those that are chronic and or repetitive, and in response to varying non-noxious but distress inducing situations.

Generalized and specific motor movements. Little research has been undertaken to examine the neonate's motor response to pain in any great detail. Apart from studies conducted by Cote et al. [20] and Craig et al. [62] whose scoring systems contain a large number of pain related motor descriptions, most studies report on single motor responses such as reflexive ankle movements; movement of the hands, feet, arms, head, and or leg; and or body posture.

In using comparative animal models, Fitzgerald et al.[19] found that premature human neonates exhibit exaggerated reflexive limb movements to repeated tactile stimulation. Those authors also report that the initial reflexive motor responses of premature neonates to noxious stimulation are more delayed than are the reflexive motor responses of full term neonates.[19] With repeated stimulation, the reflexive motor responses of premature neonates were also found to become more exaggerated and prolonged. Along with body rigidity and startle responses, Franck [70] observed that some neonates withdraw from, and swipe at, sources of noxious stimulation. However, as Johnston et al.[67] note, some premature neonates fail to exhibit motor responses when exposed to repeated tactile stimulation--perhaps indicating restorative shutdown, hyper-vigilance (as described in the animal literature) [68] or post-traumatic stress reactions.[69]

Neonates are also observed to exhibit more motor activity than adults. As suggested by Fitzgerald, [19] greater variations of motor movements are likely to occur because newborns lack the ability to inhibit sensory inputs, as linked with their neurodevelopment. Perhaps because neonatal motor movements are so highly variable, researchers report opposing findings such as no purposeful motor responses, [12] to widespread reflexive withdrawal.[70] While documentation is made difficult by high variability and the concurrent and rapid nature of neonatal motor movements, these movements still deserve ongoing study: indeed, they represent the majority of the newborn's behavioral responses. In other fields of infant study, motor movements are regarded as main avenues for understanding how newborns self organize in response to varying stimuli.[84] We know very little about neonatal self-organization (recovery) in response to pain, especially from repeated and or prolonged exposure to pain and distress.

Complex social and motor related behavior. Several heterogeneous pain related behaviors are also described, although minimally. They include generalized body movements, infant state, excitability, consolability, sucking, sociability and/or agitations following either elective surgery or regular care giving procedures.[20, 36, 46, 60, 62, 71] Like neonatal motor movements, these complex behaviors are very important; they broaden the scope of pain behavior investigation. Because they include description of neonates in interaction with their environments, these movements may provide indirect descriptive insight into the pain context and into neonatal coping or adaptation to pain. Because they are composed of several simultaneously occurring behaviors, they may also permit an integrated and cohesive view of neonatal pain. Researchers who use these complex behaviors usually combine them with other pain behaviors descriptions such pain facial action, pain cry and changes in heart rate. All occurrences of composite behaviors are then scored at defined intervals of a specified time segment (typically, once every minute for a total 5 minutes).

Currently, composite pain indicators of neonatal pain have been utilized to test for the pain treatment effects of oral sucrose and intra-operative anesthetics. Johnston et al.[63] noted that premature neonates who were given oral sucrose during heel lancing exhibited increased sucking and consolability. Barrier et al.[60] noted that full-term neonates who did not receive intraoperative anesthetics exhibited postoperative hypotension compared to neonates who did receive the anesthetic. For neonates who did not receive the anesthetic, Barrier et al. [60] also reported increases in postoperative cry duration, in facial action and in degree of agitation. This is contrasted with reports given by Emde et al.[72] who noted reduced neonatal motor activity following un-anaesthetized newborn male circumcision. The disparate findings may be because Emde et al.[72] examined activity and neonatal sleep for up to 48 hours after surgery whereas Barrier et al. [60] described the behaviors during and immediately after the surgery.

Conceptual and Methodological Problems Associated with Neonatal Pain Research.

As this overview shows, great contributions have been made to further the science of neonatal pain. However, despite the research, some of the findings on the physiological, biochemical and behavioral correlates of newborn pain remain imprecise and inconsistent. Experts agree that no uniform technique exists to reliably measure and/or assess neonatal pain.[3, 82] Persistent measurement and assessment difficulties suggest areas for improvement. Some problems stem from imperfections that cannot be rectified given the current state of technology. Others stem from conceptual and methodological problems related with the research.

Measures of pain. The quantity, breadth and quality of neonatal pain measures obtained by researchers raise several issues in the measurement of pain. It is unclear whether investigators are remiss in designing their studies or if fundamental measurement issues are at the crux of the problem. Recent evidence from Lander et al. [34] suggests that at least some physiological measures are chaotic as they do not form a consistent relationship with pain states inter- or intra-individually. For example, when assessing newborn pain response at the group level, measures of association between cry and heart rate can sometimes be obtained. However, measures at the individual level are even more difficult to consistently obtain when pain related interventions such as non-nutritive sucrose are tested and correlation coefficients are computed among various systems such as cry, palmar sweat, heart rate and salivary cortisol. The traditional approaches to handling dissociations and to enable intra-individual comparisons have been to improve study methodology or to create standardized measures and profile charts.[80] However, as Gunner and Donzella [81] advise, the best approach may be to embrace low correlations underlying chaotic measures and to adopt a broad based psychobiological approach to understanding the newborn's variable response pattern. Instead of explaining away dissociations, the authors suggest emphasis be placed on discovering how both obvious and hidden factors, such as homeostasis, and environmental factors, such as caregiver presence, function to activate and regulate each system (e.g., cry, heart rate). They also suggest emphasis on discovering how each system in turn facilitates transition between neonatal reactivity and recovery, especially when neonates are exposed to stressors such as pain.

Another apparent shortcoming of the research is the inclination of investigators to use one or two measures of pain (e.g., physiological, biochemical or behavioral measures) when an array is available. Any such unidimensional approach results in a sparse body of pain knowledge and both a limited and fragmented understanding of what is actually a complex phenomenon. Usage of unitary pain measures may have arisen because current technology does not yet permit linkage "in real time" of the various measures of neonatal pain responses and because

neonatal pain has not traditionally been considered a multidimensional phenomenon.

A related issue is that investigators measure only few pain behaviors even though the neonate displays a wide range of behavioral actions. Movements of the face and cry following a short term invasive procedure have been the focus of research, almost to the exclusion of research on generalized body movements and complex social indicators of neonatal pain. Although immensely informative and well developed, the focused nature of the research on pain facial activity and pain cry may have inadvertently precluded development of research on the other types of behaviors neonates exhibit. As discussed, further pain research on the newborn's motor activity, their social responses and their interactions with caregivers will all deepen and broaden existing pain behavior knowledge and provide novel insight into areas that are currently not well understood such as neonatal recovery from pain.

Limited but focused research on one or two neonatal pain behaviors may have arisen because the field itself is in its infancy. Perhaps the critical mass of researchers is insufficient to broaden the scope of research beyond the few descriptions traditionally measured. Or, perhaps research approaches to the present have lead to limited discovery and, in order to broaden the scope, we will have to try new approaches to collect and further study the data.

Confounding factors. Presently deficient is any study of factors, apart from the intensity of the stimulus, which could influence neonatal pain responses. Neonates are interactive beings who shape and are shaped by their immediate environments; indeed, many external and internal factors occur within the context of any pain situation. Yet, few behavioral studies reviewed here examined the influence of internal and or external factors, now widely recognized outside the pain field as confounders of neonatal responses. Some of these confounders acknowledged in the infant psychology literature include the effects of external noise and caregiver presence on neonatal activity.[86] Still, failure to account and or to control for these factors will increase the risk of incomplete or erroneous study results; this is a methodological certainty.

Another deficiency is that researchers have not routinely documented the neonate's baseline demeanour in gauging responsiveness to pain. As Lester and Zeskind [73] suggest, sensitive neonates will likely respond to non-noxious stimuli. Also essential for concluding pain treatment effects is the inclusion of baseline measures of the newborn's response pattern. Attention to these methodological issues will enhance understanding of the pain context as well as optimize pain measurement.

Invasive procedure model. By relying on invasive procedures and deductive approaches, we have based our understanding of neonatal pain behavior on our knowledge of a few pain behaviors and on our knowledge of short-term pain, particularly mild pain caused by needle stick (heel lance). The outcome is incomplete understanding of the repertoire of neonatal pain behavior since it is highly likely neonates will exhibit different types and qualities of behaviors to different types, intensities and contexts of pain. Chronic pain has been ignored in infants. Since we usually define the term chronic in adult terms and since we study solitary invasive procedures, we have not yet explored how those conceptions would differ for newborns. We can only hypothesize that neonates exposed to repeated pain with stress at particular epochs of their development, develop chronic pain[2] or that they develop molecular level alterations to their pain system that compromise their development.[2, 19]

A related matter is the limited data collection period that accompanies the applied procedure model. Researchers use short time frames to collect data. Indeed, some pain tools stipulate that data be collected for periods of time as brief as 10 to 30 seconds following the procedure (for example, the PIPP, [74] and NFACS [57]). Reasons given draw support from the scientific principle that events must be contiguous before cause and effect can be assumed, and from our inability to measure neonatal pain perception. One implication of using limited data collection time frames is that any pain behavior (including details of the pain context), which occurs outside the data collection framework, will not be measured. In particular, the short time frames do not permit description of the characteristics of the behaviors being measured, and, because data collection is extremely short, the time frames do not permit measurement of the responses over time to rule out whether neonates respond similarly to noxious and non-noxious stimulation that occur during exposure to pain. Given the variable response patterns of neonates these types of issues may be important. Currently, our knowledge is principally confined to the presence or absence of particular behaviors without including descriptions of associated distress or other descriptions of pain such as duration. Describing distress may allow us to distinguish more clearly neonatal responses specific to pain; duration measures will enable much needed insight into the identification, meaning and implications of prolonged newborn pain and distress.

Basic versus applied research. A great deal of the research on neonatal pain is applied rather than basic. One serious implication of underdeveloped basic knowledge of neonatal pain behavior is the lack of a theoretical foundation upon which we can begin to understand and construct applied knowledge about neonatal pain. The development of neonatal pain assessment instruments illustrates the effect of this limited knowledge base. In the past few years, there has been a tremendous increase in the construction of neonatal pain assessment instruments; however, despite their development none of the instruments are valid and no single technique exists to reliably assess neonatal pain.[33] While acknowledging that validity is an ongoing process,[80] persistent inability to consistently measure the multiple correlates of neonatal pain may be because pain assessment instruments are being developed in the absence of a theoretical foundation of descriptive knowledge about the phenomenon (suggesting central validity issues). In examining their development, we noted most researchers used the literature or expert opinions of clinical experts to construct their instruments. The instruments typically contain items for scoring physiological responses such as change in heart rate and respiration and items for scoring occurrences of behavioral responses, such as facial actions (often reduced versions of the NFSC), cry and some social items such as infant state. While we agree that information obtained through the literature and from clinical experts are sound and necessary, they alone are insufficient for enabling conceptual and theoretical understanding of the complex phenomenon. Conceptual understanding also emerges from systematic study of the neonates themselves as this approach optimizes description of the full range of the behaviors as neonates exhibit them.

Inability to consistently measure the three correlates of neonatal pain [3] may result from a lack of comprehensive description of the phenomenon being measured, namely neonatal pain behavior. Descriptive understanding of any behavioral phenomenon precedes its measurement, and it is a precursor to deductive research on the topic. [21] Without thorough description there is no foundation, a solid basis from which we can understand, assess or measure various aspects of a construct soundly, particularly if the construct is complex and contextually situated. [21]

Within the pain field, pain assessment and pain measurement are acknowledged as key to effective pain treatment.[79] In the case of neonatal pain, pain assessment is especially dependent on correct identification of neonatal responses. Researchers must discover (through basic descriptive pain research), the types of pain response patterns that will cue clinicians. However, as discussed, existing behavioral descriptions are informative but incomplete and neonatal pain assessment instruments are being developed on basis of that incomplete knowledge. Clearly, we have not yet sufficiently generated the range and descriptive details needed to guide clinicians.

We have skipped the preliminary stage of describing pain comprehensively, and, in doing so, we have severely narrowed our understanding of the natural aspects of the phenomenon we are investigating. We are developing pain assessment instruments without descriptive grounding. In this field of pain research, basic description must precede assessment and measurement.

Ethological methods to comprehensively describe neonatal pain behavior

Ethological methods will generate basic and comprehensive description of neonatal pain behavior. In using these rigorous methods, complex animal behavior (actions and interactions) are systematically observed and precisely measured as they are observed. Researchers have used the systematic methods to study primate behavior,[75] infant state[76] and infant-parent interaction.[23] Because they focus on behavior, the methods are ideal for studying pain in those who do not communicate verbally, such as neonates. As noted earlier, the only pain related study we found that employed this basic unobtrusive approach was conducted by Cote et al.[20] Although that study led to a large number of pain behavior description and to the identification of five postoperative distress states in ill ventilated neonates following cardiac surgery, newborn acute pain behavior remains poorly described. Cote[85] acknowledged items were missing for scoring change in movements of the infant's wrist, shoulder, hips, knees and body positioning. The researcher also acknowledged no items for scoring limb tension and ambient sound. Likely, the ill and intubated state of neonates in Cote et al's[20] study limited the range of behaviors that could be described since intubated neonates do not cry. As well, pain behavior descriptions in that study may have been incomplete because the researchers described behaviors starting 24 hours after surgery rather than describing behaviors in response to the actual surgery.

Ethological methods are naturalistic; they are conducted to comprehensively describe behavior as individuals exhibit them.[77] Researchers begin by unobtrusively observing neonates who are thought to be experiencing pain. They use systematic procedures to describe the breadth of the neonate's behavioral response repertoire and the context under which pain is experienced. The methods involve sequential study phases wherein inductive description of a behavioral phenomenon precedes its deductive measurement.[78] The end product of the inductive phase is a reliable ethogram, offering exhaustive listings of an organism's behavior repertoire.[78]

As the reliable ethogram develops, it may be used to develop valid deductive knowledge about the behavior.[78] For example, deductive testing may be used to further our understanding of the internal and external causes of neonatal pain behavior. In turn, inquiry may permit insight into the functions of the behavior and their short and long-term consequences. Most importantly, the ethogram may be used to help construct sound neonatal pain assessment instruments which will be of benefit for pain management.

The two main ethological methods are (a) systematic observation and (b) continuous time sampling.[77] Those rigorous inductive strategies contrast with typical deductive approaches used to investigate neonatal pain behavior. In using systematic observation inductively, researchers focus their attention on the neonate and the pain event; they avoid concentrating on the immediate stimulus-response paradigm. They repeatedly and systematically observe the pain behavior of several neonates until an ethogram develops on the sample and type of pain investigated. This procedure also involves subjecting the inductively derived behaviors to repeated inter-rater reliability testing. As it develops, the reliable ethogram will serve as a credible reservoir of foundational descriptive information about the behavior. Systematic procedures thus broaden the scope of pain behavior description. They equip researchers with novel approaches to create and communicate objective, reliable descriptions of the behaviors.

In using continuous time sampling, researchers record, on a second by second basis, all occurrences of behaviors.[77] Rather than being restricted to ten second time frames or specific behaviors, researchers are free to record frequency, duration, and patterning of the behavior. The result is a precise and fine-grained description of neonatal behavior, a comprehensive description that goes beyond the usual approach of recording simple occurrences of few behaviors. In addition to describing behavior, continuous time sampling permits documentation of precise occurrences of pain related stimuli and events.[77] The value in identifying influencing factors is that they can be used to design effective neonatal pain assessment and treatment strategies.

Another important benefit to utilizing continuous time sampling is that the strategy may allow precise linkage of behavioral with physiological and biochemical data. Such linkage facilitates a multidimensional description and measure of neonatal pain and in doing so, permits researchers to work with the variable response patterns of neonates. Further, the precision by which behaviors are continuously recorded will enable an in-depth account of what is happening to the neonate undergoing an entire pain event. Those in-depth descriptions will add appreciably to the thin descriptions we now have of newborn pain.

Imperfections in neonatal pain research have resulted in a limited knowledge base as well as in our own inability to consistently measure the physiological, biochemical and behavioral correlates of neonatal pain. These imperfections include over-reliance on short-term clinical procedures that have been inadequately described; development of pain assessment instruments without basic description; overuse of unidimensional approaches; and neglect in examining extraneous factors.

Ethological methods can be used to address some of these methodological and conceptual issues. The methods hold promise for facilitating conceptually grounded understanding of neonatal pain in terms of its overall expression and meaning. In particular they equip researchers with new methodologies to describe the behaviors in greater scope and depth. Those kinds of descriptive details will benefit subsequent pain assessment and treatment efforts. Because ethological methods provide unique opportunity to work with the neonate's variable response pattern, the methods may also further insight into interrelated factors that underlie inconsistent measures of neonatal pain. The importance of generating basic descriptive information is clear. The complexities inherent in newborn pain require diverse research approaches including those that generate basic knowledge about the behavioral aspects of the phenomenon. On the basis of this overview, ethological methods are basic approaches that, in conjunction with applied forms of inquiry, can contribute to furthering the field.

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CHAPTER FOUR

An Ethogram of Neonatal Distress Behavior in Response to Acute Pain

Almost 130 years ago, Charles Darwin (1872/1972) pioneered a research technique to study emotional expression in humans and animals. Over the next century, the importance of systematic observation and detailed description of behavior evolved, as did the need to search for the immediate consequences of behavior and its adaptive value. Recent contributions (Charlesworth 1982) label the range of behavior as expressive (descriptive) and the function of behavior as regulative. Despite the merit of Darwin's approach, knowledge has only started on the descriptive and regulative aspects of most human behavior, particularly about human newborn behavior. In the field of neonatal perception, knowledge is narrow and largely involves vision and hearing (Bremner 1998; Slater & Johnson 1998). The topic of newborn cutaneous sensation receives almost no research attention. As Rovee Collier (1996) explains, while great strides have been made in our knowledge of what neonates do and what they are perceptually capable of, researchers do not understand the functional basis for most infant behavior. That issue is also true for neonatal pain although in that field, behavioral knowledge is not as evolved.

We do have some knowledge about neonatal pain. By comparing the hormonal responses of neonates undergoing cardiac surgery, Anand et al. (1985) showed that neonates who received minimal anesthesia produced a severe stress response and prolonged hyperglycemia compared to neonates who received optimal anesthesia. Findings from Fitzgerald et al. (1988) indicates newborns lack the ability to inhibit sensory stimuli, suggesting that cutaneous stimulation may be more intense for newborns than for adults. Grunau & Craig (1987) observed neonates exhibit a constellation of facial movements in response to short term pain, and Porter et al. (1988) reported neonates emit a high-pitched screech to highly invasive surgical stimulation. This research divides its findings into three domains: the physiological, the biochemical and the behavioral

Given the benefits that behavioral inquiry has for generating comprehensive knowledge about infant behavior in other fields (Bremner 1998), the behavioral domain of neonatal pain research is underdeveloped. Facial action and cry receive the most research attention and facial action is considered a main indicator of neonatal pain (Craig 1995). Research on those two pain indicators (especially facial action) has contributed greatly to our understanding of different aspects of newborn pain behavior; however, it is unlikely that facial action and cry alone represent the newborn's behavioral response to pain. Neonates are capable of expressing a wide range of recognizable behaviors that serve to optimize their communicative and survival needs (Stone et al. 1978). They likely exhibit many behaviors when exposed to varying types of pain. Reliance on few behaviors to measure a highly complex behavioral phenomenon is a threat to construct validity as it introduces a mono-operational bias (Burns & Grove 1997). Broadening the scope of description will not only permit inclusive description of the possible types, patterning and functions of the behavior but it will optimize a multi-method approach to inquiry-an approach commensurate with the complexity of the construct under study.

Knowledge about newborn pain behavior has not evolved as it has in the other fields of infant study because pain researchers were not timely in utilizing inductive inquiry to generate basic descriptive knowledge about the behaviors. By inductive, we mean the use of unobtrusive observation to systematically (reliably) describe the entire range of behaviors and the pain context. An exception is the ethologically based study by Cote et al. (1991). Those researchers systematically observed the videotaped behaviors of four full term neonates for up to12 hours starting 24 hours after chest surgery. Their inductively derived listing of behaviors included codes for infant facial expression; position of limbs, hands and fingers, feet and toes; general body movement; and state of arousal. It also contained codes for the type of care given to the infant and for environmental noise. According to Cote (1987), however, there were insufficient items for coding cry and movement in the infant's knees, for change in body position, and for ambient noise. These omissions likely occurred because postoperative care severely limited the neonate's motor activity and ability to vocalize; each had an intravenous catheter inserted into one hand, and each was intubated nasally and on a respirator. Following its creation Cote et al. (1991) subjected their reliable scheme to a factor analysis which led to the identification of five postoperative distress states: acute distress, sub-acute pain, quiet alertness, drowsiness and sleep.

Notwithstanding, the inductive approach taken by Cote et al. (1991) and their use of distress led to a large number of newborn pain behavior descriptions that conventional deductive approaches could not have generated. Within ethology, it is believed that complete description of behavior precedes its assessment and its measurement (Martin & Bateson 1998). Ethologists view these basic forms of knowledge as providing the necessary foundation for subsequent deductive inquiry about the behavior and furthering conceptual understanding (Lehner 1996). Such views may be especially relevant to the neonatal pain field because basic description of the behaviors may provide the kinds of prerequisite information needed to further pain assessment and treatment efforts. Currently, no single reliable approach exists to assess neonatal pain (Stevens et al. 1995), and problems exist in obtaining consistent measures of indicators thought to represent neonatal pain (Franck 2000). Specifically, basic description will add to existing pain behavior description; the wide range of knowledge gathered will help researchers to construct neonatal pain assessment instruments having strong psychometric properties.

In using the context of distress, Cote et al. (1991) extended description of pain behavior to include the newborn's response to a variety of normally occurring distress-provoking events. While we agree pain and distress are conceptually distinct, we also agree in taking a broad approach to describing distress in order to distinguish pain. Distress encompasses how neonates respond to the stimuli they receive. Ability to differentiate distress behavior caused by a variety of stimuli from distress behavior caused by pain is key since improved neonatal pain outcomes depend on a clinician's ability to distinguish responses specific to pain. Our ability to distinguish and assess pain may therefore lie in our broader understanding of the neonate's variable response pattern and the context under which they experience acute pain. Generating detailed knowledge about distress related pain behavior might help do this. Because Cote et al. (1991) described behaviors postoperatively; their coding scheme does not pertain to pain of the immediate surgery. As such, it cannot be used to further describe the behaviors or to descriptively distinguish between behaviors related to distress and those related to distress caused by the acute pain. For these main reasons, we did not utilize the coding scheme developed by Cote et al. (1991).

Despite having well developed knowledge mainly on pain facial action and pain cry, behavioral knowledge of newborn acute pain is incomplete. We remain unaware of the possible expressive range of the behaviors and the pain context. As well, minimal research attention has been given to distinguishing distress from pain and examining factors known to influence infant behavior, such as ambient sound (Field 1990).

In keeping with an inductive ethological approach and the context of distress, the purpose of this basic study was to generate comprehensive descriptions of distress behavior of male newborn infants to acute pain caused by circumcision and, in doing so, initiate creation of a reliable ethogram (an exhaustive listing of an organism's behavior). We focused on healthy newborns since descriptions of their behaviors may provide normative baselines for the behavior. With the long-term goal to develop a complete ethogram, we focused on circumcision pain as it is regarded as one of the most intense forms of newborn acute pain (Porter et al. 1986). Our aims were to add to the existing body of pain behavior knowledge by describing behaviors we know little about but that are commonly recognized when systematically observed. We did not include the Neonatal Facial Coding System (NFCS) to code neonatal pain facial action because the quality of the secondary data used in this study did not permit consistent coding of the behavior. Our study was descriptive, involving the collection of data on the qualitative aspects of newborn cry rather than the measurement of cry using spectral analysis. Ethical clearance was obtained to conduct the study using secondary videotaped data from a study originally conducted by Lander et al. (1997).

METHODS

Sample

The sample consisted of ten full-term healthy male infants, aged 72 hours or less, who were videotaped while undergoing circumcision. The videotapes came from a previous investigation that tested the effects of three local anesthetics in full-term male neonates for routine circumcision compared to the standard treatment of no anesthetic (Lander et al. 1997). As we were interested in describing distress behavior in response to acute pain, neonates in this study were those who received the standard treatment and who had no anesthetic for the circumcision.

Procedure

Study procedures involved selection of videotapes, preliminary observation, construction of the ethogram, training coders and reliability testing of the ethogram.

Description and selection of videotapes

The videotapes used in the Lander et al. (1997) study were of analogue rather than digital quality reflecting technology of the period. Of the videotapes available from

Lander et al.'s study, 17 were of neonates who did not receive any anesthetic or comfort measure. In this study, criteria used to select videotapes from the 17 videotapes were that (a) the baby be minimally clothed in diaper and or shirt; (b) a close up and upright view of the baby's entire body be visible (except for the toes which were for the most part hidden); (b) the photos contain the least obstructed view of the neonate (such as where surgeon or nurse obstructed the camera); and (d) ambient sounds be easily heard through headphones. Three videotapes failed to meet criteria leaving a total of 14 tapes. Of these 14, ten were selected for this study with the four remaining reserved to conduct Phase Two of the study. Phase Two, which is reported elsewhere, provides further description of the characteristics of the behaviors (frequency and duration).

Each of the 10 videotapes lasted approximately 3 hours. The duration of time that neonates were continuously videotaped for Lander et al's study provided us opportunity to comprehensively describe neonatal distress behavior to an acute form of surgical pain that many newborn males in North America experience (Porter et al. 1986).

Preliminary observation of videotapes

Before formal description of distress began, observers viewed each of the ten videotapes in a neutral manner as recommended by ethologists (Hinde 1985; Lehner 1996). The observers included the main author and a graduate student. Both were familiar with focal person sampling, with systematic and repeated observation, and with use of the technological materials used in the study. Preliminary observation helped promote an unbiased approach to description: it offered observers time to become familiar with each neonate, and it provided observers time to think about the behavior and to formulate questions about it. During preliminary observation, for example, we noted some neonates behaved similarly to noxious and non-noxious but distress inducing events. Observing such similarities helped us to later distinguish distress by comparing neonates' baseline behavior to varying events of the circumcision. Those events were diaper change, restraint application, circumcision and recovery from each of those three events.

Construction of the ethogram

Technological materials used

Valid and reliable description of neonatal distress behavior required technologies capable of capturing the rapid and concurrent nature of the previously videotaped behaviors. It involved using three video-screens, two video-play backs and headphones. Each video was capable of fast-forward, rewind, and frame-by-frame viewing (30 frames per second = 1 second intervals), features that enabled the systematic observation and description of the videotaped data.

Time encoding of the videotapes

To facilitate valid and reliable construction of the ethogram, each 3 hour videotape had a running time permanently superimposed on it, in intervals of one second each. We did this as one-second intervals enabled collection and consistent location of the behaviors in real time.

Repeated observation of the videotapes

Each of the ten videotapes were subjected to intense and repeated observation (focal person sampling). As suggested by Paterson (1992), this strategy both helped observers distinguish all that the neonates did or endured and enabled them to record change in the neonates' behavior. Repeated viewing also helped observers identify distinct and common expressions of neonatal distress (ranging from baseline behavior prior to any handling to extreme expressions of distress) as well as repetitive and pattern-like behaviors. Figure 1 illustrates the process used to conduct the repeated observation.

Heightened awareness of the pain context occurred with repeated viewing of the videotapes. Similar and dissimilar behavioral responses to noxious and non-noxious but distress provoking events were noted. These observations supported our earlier observations and guided us to further describe the behavioral responses of neonates to the seven events. We commenced by describing behaviors during the baseline event (while the neonates were at rest and prior to any handling) before proceeding to the remaining six events. The process to identify change in behavior involved comparing and contrasting behavior to each event.

With repeated viewing, it became increasing clear that motor movements were the main neonatal forms of expression. Using technologies previously described, we observed each of the neonate's anatomical regions (e.g., head, upper torso, upper extremities) in successive order. Concentrated attention on each anatomical region resulted in detailed description of the full range of distress related motor movements, their qualities, and postures. To further identify change and natural clustering in behavior we used the technique of fast-forwarding the videotape. Speeding the tape made it easier to identify when, and under what circumstances, certain behaviors grouped together. In particular, that technique enabled recognition of situations that preceded or followed behavioral expressions of distress.

Frame-by-frame viewing was particularly helpful for distinguishing configurations of rapidly occurring motor displays such as hand and eyelid movements and for facilitating descriptions of the neonate's upper torso and changes in their respiration. In some cases, frame-by-frame viewing assisted in identifying patterns of distress and their sequencing (organization), particularly patterns involving motor activity and vocalization. Other techniques such as repeated viewing and the wearing of headphones allowed description of the variation in ambient sound and neonatal vocalization (including cry). As well, playing up to three videotapes simultaneously helped us to determine if the same behavior occurred across neonates and to same events.

Repeated observation also increased our awareness of the behavioral responsiveness of neonates. Distinguishing that type of behavior enabled us to subsequently identify behaviors that were reflective of the neonate's ability to self organize in response to varying distress provoking situations. Repeated observation continued until the complete repertoire of neonatal distress behavior to circumcision was described and no new behavior was noted with additional viewing.

Systematic observation

Several procedures were used to further describe distress behavior and to structure the ethogram. Behavioral descriptions were defined to make sure others could easily identify and agree on them. As recommended (Sackett 1978), objective definitions helped ensure behavioral descriptors were reliable and unbiased. Behavioral descriptions were identified as molecular units or molar units: molecular units represent the neonate's fine motor movement (e.g., lateral stretching of the neck) whereas molar units represent their behavior in terms of an action, or an outcome of an action (e.g., frantic motor movement and inability to wind down).

These behavioral descriptions were classified according to their temporal natures. Momentary behaviors were instantaneous (measured in terms of their occurrence or non-occurrence). Conversely, enduring behaviors were lasting and of measurable quality (measured in terms of two or more seconds, the shortest amount of time some behavior lasted). Classifying the behavior in temporal terms facilitated subsequent measurement (frequency and duration) of the distress behavior (Lehner 1996).

Last, descriptions of distress were structured into non-mutually exclusive main categories and mutually exclusive subcategories. Together, those categories describe the significant behaviors of the neonates. Although most ethograms contain only mutually exclusive main categories, the non-exclusive structure of this ethogram represents the concurrent nature of neonatal behavior. Consequently, use of the ethogram requires analysis procedures appropriate for concurrent occurrences of behavior (Bakeman & Quera 1995). Once we identified each behavior, defined it, organized it into levels, and classified it, we then gave each one a distinct label. These labels and their descriptions comprised the ethogram.

Creation of data check sheet

As suggested by Hinde (1976), custom designed data collection sheets were created to collect and document, by paper and pen, rapid behaviors of the neonates on a second by second basis (referred to as continuous time sampling). Precise data entry points both allowed raters to code all behaviors contained in the ethogram and facilitated comparisons of coding at exact times for reliability purposes. An experienced rater required three hours to code one minute of videotaped data. Figure 2 is an illustration of the data collection sheet.

Training of coders and refining ethogram definitions

Prior to its testing and implementation, raters were trained in use of the ethogram, study equipment and continuous time sampling. The two raters (main author and the graduate student) separately coded a 1-minute segment of videotaped data using exact start times. We arbitrarily chose one of the ten videotapes to facilitate training, but we intentionally selected the first minute of the restraint recovery event because that event provided coders an opportunity to code for a range of the distress behaviors. Coding between raters were compared and Kappa coefficient scores tabulated. A Kappa score of 0.80 was the criterion for successful training.

When agreement scores for any behavior fell below Kappa 0.80, raters discussed the coding. In some cases, disagreements arose where behavioral definitions were ambiguous. In other cases, disagreements arose due to human error in coding. Rules were made both for deciding which subcategory item took precedence if two occurred simultaneously and for agreeing on lumping or splitting items. As suggested (Bakeman & Gottman 1997), these strategies optimized consistency in coding, and they helped refine definitions before formal use of the ethogram. Once redefined, the reliability of particular behaviors was reassessed. Raters also took increased breaks from coding to reduce error arising from coding fatigue.

Establishing the reliability of the ethogram

Following successful training and refinement of ethogram definitions, the ethogram was tested for reliability. One-minute segments from each of the four videotapes reserved for Phase Two of the study were selected. No purposeful process was used to determine which of the four cases the segments came from. However, to ensure reliability testing across distress events, we intentionally selected the four segments to represent the first minute of baseline and the first minute of the following distress events (diaper change, restraint application and circumcision).

Coders were the first author and the graduate student; both were knowledgeable about the ethogram and experienced in continuous time coding and the study equipment. Randomly drawn seconds were used for the first round of reliability checks. At exact start times, coders separately coded the randomly drawn seconds for one-taped case. However, using that approach, agreement scores were off by one or two seconds. The same pattern was observed when intra-rater reliability was conducted on the same segments of videotape. To address second differences in coding, we checked reliability for each 10-second chunk of a continuous minute as suggested by Bakeman and Gottman (1997). Again using exact start times, coders separately coded one continuous minute for each of the four taped cases (4 minutes, or 240 seconds in total). Using the same index of reliability, coding between raters were compared and Kappa scores tabulated.

RESULTS

Descriptor items composing the ethogram

Table 1 is an illustration of the completed reliable ethogram containing 235 defined behaviors organized into 35 main categories and their subcategories. The 35 main categories were further organized into two main branches: (a) 32 categories of distress related behavior (n=192 items) and (b) three categories of stimuli related behavior (n=43 items). Subcategory items represented the full expressive range of neonatal distress behavior to male newborn circumcision. The ethogram mostly contained molar units because complex motor movements are the main behavior neonates exhibit. It also contained mainly enduring and some momentary behaviors.

Distress behavior

The 32 main categories of distress related behavior represented the full range of motor and non-motor behaviors commonly expressed by ten neonates during the acute pain episode. Main category items consisted of concurrent types of behavior such as neonatal motor movement, body postures, responsiveness, self-comfort, respiration and vocalization. Also, there were categories for describing the muscle tone of the neonates' extremities and qualities of their motor movements and self-comforting actions.

Subcategory items subsumed under each of the 32 main categories represented variation in the main categories depending on types of antecedent stimuli and events neonates were exposed to. Subcategory items ranged from normal neonate behavior as observed during baseline (while the neonates were at rest and prior to any handling) to extreme and varying indications of distress as observed during circumcision and the other potentially distress provoking events of diaper change and restraint application. The following describe some of the items contained in the ethogram for each main category.

Neonatal motor movement and posture categories.

Twenty-five main categories (134 subcategory items) represented the general body and head positions of the neonates and other movements of their upper and lower extremities and torso. Variations in the quality of the movements and muscle tone were also represented. While at rest, most neonates assumed the frog position where both arms and legs were tightly flexed against their body. Following noxious stimulation (e.g., during circumcision recovery), all neonates exhibited a body position we labeled as the other; this position was characterized by bilateral leg extension and immobility. Patterns of motor immobility were accompanied by cautious responsiveness where neonates were hyper-alert to immediate surroundings.

Other variations in neonatal motor movements were noted. Neonates retained a right, left, or midline head position depending on whether they were at rest, crying and/or noxiously stimulated. While at rest, most neonates positioned their heads to the right and exhibited smooth and fluid motor movements. During rest, others laid their heads to the left and displayed tremulous or jerky movements of their upper extremities. During noxious stimulation (circumcision), however, most immediately assumed a midline head position. Their motor movements became very tense in quality or frantic.

As procedures became invasive (during actual circumcision), neonates displayed exaggerated movements of their upper torso as if to escape and some made swiping motions of their hands. As noted during preliminary observation, some neonates exhibited the same behavior to non-noxious but distress provoking events (diaper change and restraint application). Immediately following exposure to noxious, and in some cases non-noxious stimulation, most neonates re-assumed a midline head position. During that time, their cry was loud and broadcasting. Some neonates continued to display patterns of frantic motor and motor immobility following the restraint and circumcision events.

We included the descriptive range of the preceding motor and position behaviors because they represented regular behavior, varying expressions of distress and recovery patterns to pain and non-pain. We wanted to determine whether the inclusion of such a range would help distinguish distress from pain in other similar and dissimilar situations or whether it would be useful for developing descriptive knowledge about pain recovery. Most variation in neonatal motor activity involved the upper extremities: there were 30 categories for bilateral upper limb movement and only 14 for bilateral lower limb movements. This difference in lower limb movement may be because neonates were positioned supine for most of the 3 hour observation.

Responsiveness category.

The 17 subcategory items for the responsiveness category—a large number for such a study-- represent subtle differences that we observed across neonates. Similar to subcategory items for motor behavior, items for responsiveness represented variations in behavior depending on the types of stimuli and events that preceded the behavior. At rest, neonates appeared self absorbed and content, or self absorbed and irritable. As events became progressively distressful (invasive), we noted complete suppression of contentedness and some suppression of irritability. Extreme expressions of distress related responsiveness occurred during and following actual circumcision. Examples included abrupt arousal; alert with frantic screech cry; alert with guarded immobility; and hypersensitivity with frantic motor movement with inability to wind down. Again, we noted some neonates expressed some of those behaviors (although not as intensely) to diaper change and restraint application.

Respiratory sounds, vocalizations and self-comfort categories.

Neonates made up to 15 kinds of respiratory sounds and six kinds of vocalizations. Respiratory sounds ranged from no sound heard to breath holding. In fact, many neonates held their breath during the actual circumcision. There were also 12 subcategory items for describing the qualitative characteristics of cry. The types of cry sounds heard and their duration differed depending on what event or specific stimuli preceded cry. Neonates cried in a loud robust manner during restraint application, but, during some parts of the actual circumcision, their cry was a high-pitched screech. We noted increased variability in cry sound to circumcision compared to restraint application or diaper change. There were eight subcategory items for self-comfort and its qualities; these behaviors were added to represent the newborn's attempt to self-regulate in response to noxious stimulation and distress provoking events.

Distress provoking stimuli

The second branch of the ethogram included three types of distress provoking stimuli: (a) those related to ambient sound, (b) those related to specific procedures conducted on the neonates and (c) those related to spontaneous responses made by the neonates themselves. Each of these resulted in evoking immediate behavioral responses, the type and duration of which varied depending on the event and type of stimulation. For example, during the baseline event, external stimuli (like the sound of running water) did not bother the neonates. Following circumcision and within one second of hearing the sound of running water, some neonates exhibited frantic motor movements and an inability to wind down. That pattern of frantic activity was also noticed for spontaneous leg kicking following diaper change (prior to circumcision). Those three stimuli were included so that subsequent testing could ascertain if stimuli were distress provoking when tested on different neonates and in different pain situations.

Procedure related stimuli.

Subcategory items for procedure related stimuli included 13 items. They represented varying kinds of activities performed on the neonates that sometimes resulted in extreme distress. Extreme displays of distress were observed during procedures to separate the glans (insertion of a probe and retraction of the foreskin). Examples of extreme distress were high-pitched screeches, lateral neck stretching, and strenuous downward hunching of the shoulders.

Baby spontaneous behavior

The 11 subcategory items for baby spontaneous behavior varied from no such behavior to rhythmical leg kicks and startles. These stereotype behaviors were not externally evoked. Their spontaneous occurrence and the symmetrical patterning observable from them distinguished these behaviors as perhaps innate and originating internally. As such, these spontaneous behaviors were set apart from other motor responses neonates made in response to external stimuli. They were included in the ethogram to determine if they would evoke similar distress in other pain situations.

Ambient sound stimuli

Listening to the ten videotapes, 19 different kinds of sounds were heard which varied from no sound to clicking of instruments. Those stimuli were included because they are common and because little information exists about their extraneous effects.

Inter-rater reliability.

A total of 140 Kappa scores were computed for the four one-minute segments. They ranged from Kappa 0.67 to Kappa 1.00. Items that failed to achieve reliability were hand movements and finger posturing. Following use of frame by frame viewing and creation of new subcategory items, reliability of those items were K=0.90. Thus, high levels of inter-rater reliability were obtained. This is not surprising in view of the systematic procedures taken to define the behaviors and those taken to train observers and to resolve ambiguity in definitions.

DISCUSSION

In this basic study, we have demonstrated that inductive ethological methods and the context of distress were successful in generating an exhaustive inventory of distress related behaviors in newborn infants exposed to noxious (painful) and non-noxious (nonpainful) events associated with newborn surgery. The large numbers of behaviors reported clearly show neonates exhibit a wide range of distress behaviors that can be easily identified.

Of the behaviors reported in this study, some are similar to pain and stress related behaviors reported by others for fullterm and premature neonates. They include descriptions of swiping hand motions (Franck 1986) and changes in general motor activity (Craig et al. 1993) in response to heel lance; descriptions of variable cry and frantic screech cry (Porter et al. 1988) in response to newborn male circumcision; and descriptions of spontaneous excitability, sucking, muscle tone, consolability and sociability (Barrier et al. 1989) in response to other surgical procedures. Behaviors that were similarly reported in response to stress inducing situations included finger splaying, directed arm movements and neck stretching (Als et al. 1982); facial grimacing, and knee and leg flexion (Evans et al. 1997).

In this study, new descriptions reported add to the existing body of knowledge on newborn pain behavior for they represent unique or rarely described behaviors. To our knowledge, others in the neonatal pain field have not previously reported variation in the newborn's responsiveness (other than infant state and some social behaviors mentioned above) or included descriptions of neonatal gasping and breath holding. Other new descriptions include immobility and composite movements of the newborn's arms, hands, and fingers (e.g., bilateral arm extension – keeping equal distance between arms). Still others include positioning and/or movement (including quality of muscle tone) of the neonate's head and neck as well as movements of their upper torso (exaggerated shift like movements and strained downward movements of the upper shoulders).

The descriptive outcomes of this study also add to the inventory of newborn distress behaviors that Cote (1987) described. As a result of using basic systematic procedures, both studies generated an inductively derived ethogram (or behavioral coding scheme) each containing descriptions for coding eyes open, eyes shut, hands tightly fisted, hands slightly open, upper and lower limb flexion and extension, startles, sneezes and talking at bedside. The ethogram generated in this study, however, contains additional items for describing variation in those behaviors and includes behaviors that Cote (1987) does not describe, such as the consolability and responsiveness categories. It also contains novel description of externally and internally evoked stimuli, such as 19 items for coding ambient sound; and stereotyped infant behaviors such as spontaneous leg kicking and twitches. These behaviors are included in this ethogram because they were sometimes observed to produce an almost immediate cascade of distress behaviors. Few pain studies are designed to examine the effects of ambient sound, touch or other external stimuli existing beyond the stimulus-response event. Yet, factors existing within the context of any pain event are important to investigate if we are to understand either their regulative function or their interactive and possible long-term effect on the newborn infant. As a result of including such items, the ethogram can potentially help guide investigation into these important areas of study.

Although descriptions varied between this study and the one conducted by Cote et al. (1991), both contribute to our basic understanding of neonatal distress related pain behaviors because each study began with different aims. Following inductive development of their coding scheme, Cote et al. (1991) used factor analysis to test the validity of their coding scheme and to identify newborn pain related distress states. Those study outcomes were in keeping with Cote et al.'s (1991) study objectives. In this study, we avoided using a statistical grouping technique because we still consider the ethogram to be at a beginning stage of development. In agreement with ethologists (Hinde 1985; Lehner 1996), we assume that conceptual understanding of a highly complex phenomenon requires a solid foundation of descriptive information about the behavior. As it pertains to the topic of interest, a solid foundation of descriptive knowledge will develop as sampling broadens to include different populations of healthy neonates and different types of newborn distress and acute pain. Specifically, continued sampling and testing will help determine if differences in behavioral responses occur as a result of the sampling variations and it will help identify new behaviors and distinct patterning in the behavior.

Similar to Cote et al. (1991), we focused on describing neonatal pain behavior within the context of distress. That inductive and broad based approach involved non-obtrusive and in-depth observation of the neonates, observation of their behavior, and notation about the contexts under which neonates experienced their pain. Ours differed from most approaches used to study neonatal pain behavior because it went beyond the conventions of measuring pain response to an immediate stimulus. Conventional deductive approaches, which focus on measurement of predefined pain behavior within discrete data collection periods, are conducted utilizing experimental rather than inductive study designs (Christensen 1997). Their aim is to test knowledge about behavior to reduce clinical pain. Researchers who use deductive approaches assume predefined behavioral descriptions adequately represent the phenomenon under study. Another assumption underlying use of deductive approaches is that basic conceptual knowledge about a particular phenomenon is well developed. Yet, most deductive approaches have not yielded comprehensive and descriptive understanding of neonatal pain behavior expression.

In contrast to deductive approaches, the inductive approaches used in this study resulted in generating basic information about the behaviors. Because inductive approaches are inclusive, they allowed us to systematically describe how neonates behaved when they were exposed to varying distress related events and specific types of stimuli. As a result, we were able to describe a wide range of behaviors as neonates exhibited them. Because the comprehensive listings are basic forms of knowledge, they will provide the basis for further inquiry to determine if they can be used to clarify behavioral distinctions between newborn distress and acute pain responses.

In this study, comprehensive description of neonatal distress and pain also evolved because descriptor items were defined in temporal terms (enduring or momentary). Those kinds of behavioral definitions will enable subsequent coding of the behaviors in real time. This form of continuous coding behaviors is needed to distinguish distress and pain; it allows further descriptions of the behaviors in terms of their frequency and duration. Continuous coding may also enable simultaneous coding of up to 35 types of behavior at each one-second interval, facilitating an integrated view of how neonates respond to distress and pain. As technologies improve, it may be possible to link behavioral descriptions with simultaneously occurring physiological and biochemical correlates of neonatal pain in real time. We need those kinds of inclusive descriptions if we are to understand the multidimensional nature of neonatal pain.

While newborn male circumcision is a common and intense form of acute pain, descriptor items contained in this ethogram nonetheless pertain only to those populations of neonates. The ethogram is specific to circumcision and the sample of male newborns. Valid development of the ethogram requires it include behavioral descriptions of full term neonates and the types of acute pain they normally experience. Sampling other males, females, older full term neonates and varying acute pain and non-pain situations will do that.

As the ethogram develops, it will contain the type of foundational knowledge required to deepen understanding of the behaviors and their meaning for the newborn. As noted, an important benefit of the ethogram lies in its potential to generate much needed information about the characteristics (frequency, duration and patterning) of the behavior. Specifically, those kinds of descriptive details broaden our appreciation of how newborns respond to varying sensory stimuli, and with development and in combination with existing pain behavior descriptions, they will provide the kinds of description needed to help construct sound pain assessment instruments. To initiate this, the ethogram could be tested on another sample of neonates (e.g., male newborns undergoing circumcision) using second by second data collection to code the behavior.

To improve this basic study, we recommend researchers develop videotaped data to optimize the descriptive aims of their study. Although the secondary videotapes used in this study were cost and time effective and although they provided excellent opportunities for us to describe newborn distress behavior to a range of distress inducing events, there were also limitations associated with their use. To facilitate data collection, we recommend digital rather than analogue technology because digital images provide clear, crisp color images and enhanced sound. Adding several cameras and appropriately positioning them may also enable multidirectional views of the neonate and the environment. Also recommended is the use of picture in picture, zoom and split screen capabilities. They enable a focused view of a particular body part such as the newborn's face while viewing their entire body. Last, to enhance collection of contextual data, we recommend direct observation in addition to viewing videotaped data.

In sum, the behaviors described using inductive ethological methods to create a complete and reliable listing of neonatal distress behavior associated with acute surgical pain can, with further development, be added to existing pain behavior description. Such an addition will strengthen the preliminary descriptive based required to support subsequent deductive inquiry about the behaviors. While an exhaustive range of behaviors were observed and coded, the results represent only a beginning to describing the full expressive range of newborn acute pain behavior and their characteristics. Ongoing development of the ethogram will assist in differentiating between distress behavior provoked by pain and non-pain events. That distinction will be key to furthering neonatal pain assessment and pain treatment knowledge. Similar to other fields of infant study, describing the *what's* of a particular behavior is an important prerequisite to understanding the *whys*, or their regulative function. The ethogram developed in this study has the capacity to guide development of credible newborn pain behavior knowledge in these important areas of investigation.

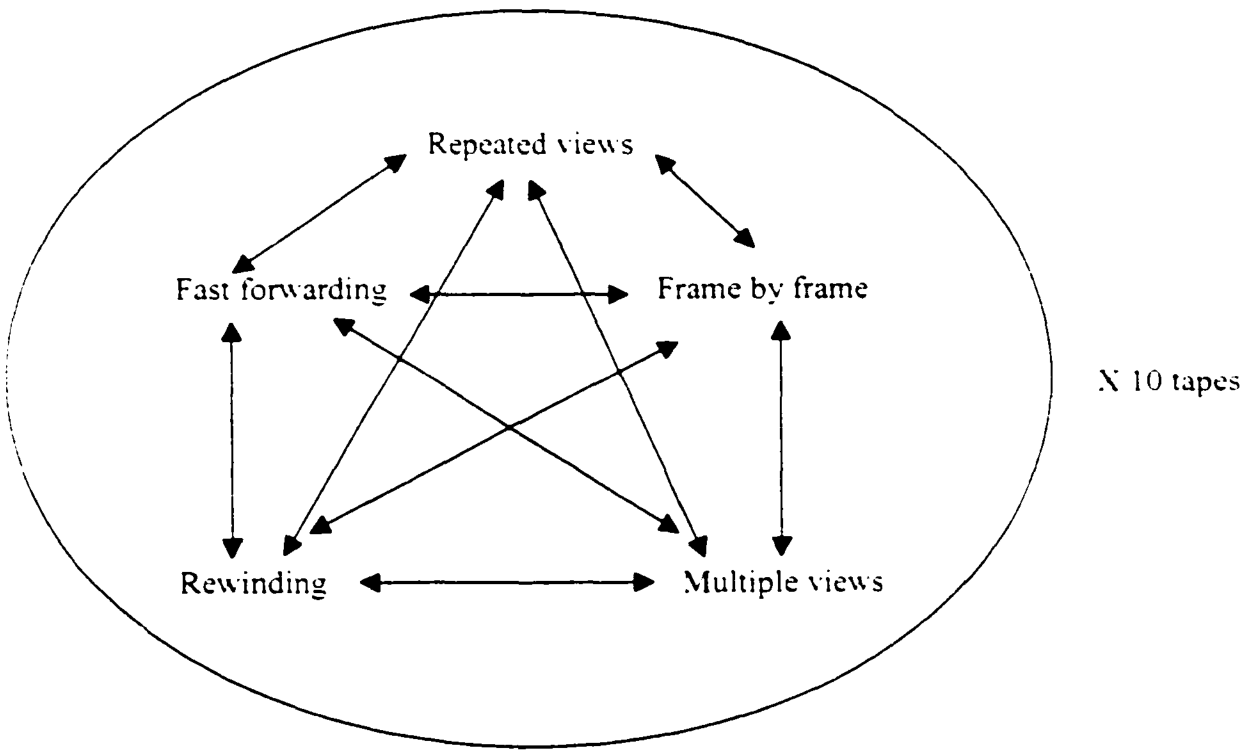

Figure 1. Process of repeated observation and time

Time required for repeated observation and coding of videotaped data:

To observe each 3 hour videotaped case (to develop the ethogram)
- 4.5 hour to repeatedly view one videotaped case x 10 cases = 45 hr.

To code 4 minutes of videotaped data (to establish the reliability of the ethogram)
- 3 hours to code 1 minute of behavior rater = 12 hours.

At each second (at total of 240 seconds), up to 34 categories of behavior were coded for reliability

Time commenced (in seconds) ________
Event ________
Case ________
Coder ________

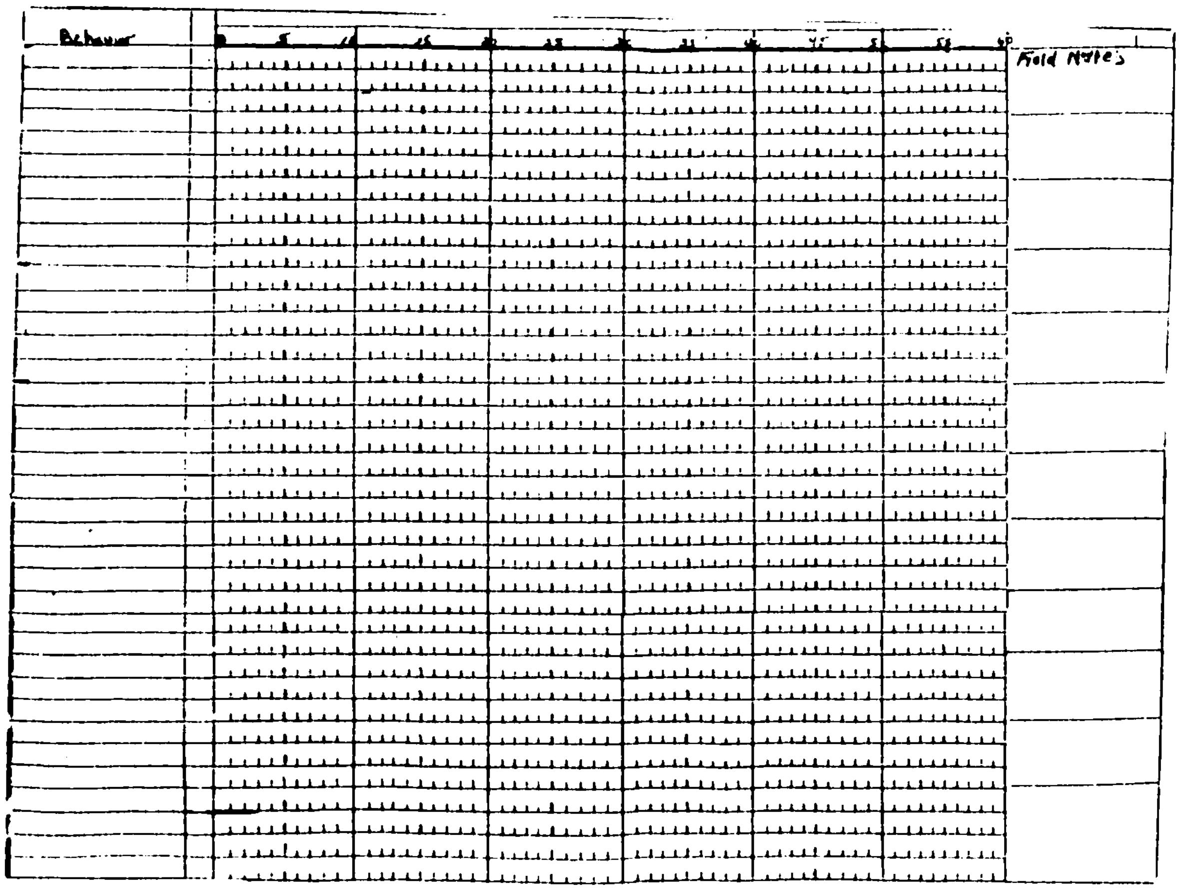

Figure 2: Data check sheet for second by second coding

Table 1: An ethogram on neonatal distress behaviors in response to acute pain: Newborn male circumcision

OBSERVED BEHAVIORS	INCLUDING DEFINITIONS

A: TYPES OF STIMULATION

1. External Stimuli During Procedure

0 Nil
1 Staff leaning (placing pressure) on baby's leg and/or pelvic area
2 Squirting water on surgical site
3 Rubbing/cleansing baby's buttocks
4 Tugging/pulling on foreskin
5 Bedding restraints or baby's legs touching surgical site
6 Cot repositioned
7 Diaper unpinned
8 Restraint applied to first arm*
9 Leg straightened/restrained to first leg*
10 Diaper dressing checked for soiling
11 Probe inserted – glans separated
12 Foreskin snipped

* there was no or little reaction to restraint or straightening of second limb

2. Behavior Provoking Sound

0 Nil
1 Whispering
2 Talking
3 Laughing
4 Hospital intercom/speaking
5 Running water
6 Noise of walking
7 Door being opened/closed
8 Noise of plastic ripping
9 Dull dropping sound
10 Clanking instruments
11 Pages being turned or shuffled
12 Paper being pulled from dispenser
13 Blankets being gathered
14 Bell or dong (possibly hospital intercom)
15 Restraints removed abruptly
16 Curtain being pulled
17 Clicking of diaper pin
18 Snap/snip and/or click/twist

Baby's Innate Behaviors

0 Nil
1 Spontaneous rhythmic kicking of one leg.
2 Synchronized, simultaneous kicking of both legs.
3 Kicking of one leg followed, within 1 sec, by kicking of other leg.
4 Attempted rhythmical leg kicking hindered by restraint.
5 Holding up one arm with hand extended
6 Holding up both arms simultaneously or in short order
7 A sneeze
8 Fart or audible expulsion of liquid from anus
9 Twitch/small, isolated, rapid nudge-like movement of a limb or the head, not generalized
10 Startle/larger than a twitch, and generalized, starting in one limb, may spread to the other limb, neck, and trunk, movements neither simultaneous nor symmetrical

B: BABY BEHAVIOR

1. General Body Position	**Positions are to be held for $\geq$5 seconds**
1 Tonic neck reflex (TNR)	1 Face oriented forward or partly turned to one side; one arm flexed and other extended - and legs in contra lateral positions - the 'fencing position' (TNR)
2 Frog position	2 Face orientation as in #1. Arms adducted at the shoulders and slightly endo-rotated, and flexed at elbows. Knees flexed low or high, and legs flexed adducted at hips
3 Other	3 Face orientated to right or left, general body immobility with bilateral leg extension. Draw to illustrate

2. Quality of General Body Movement (QGB)	
0 Nil - or very little movement	0 No or minimal movement, relaxed general muscle tone
1 Regular, small, free flowing movements; relaxed	1 Small spontaneous fluid movements of all arms legs and toes (flexion/extension, curling /uncurling). Movements last from a few seconds to a minute. With varied sequence and intensity of arm, leg, neck, & trunk movements - waxing & waning. There are superimposed rotations & slight changes in direction of the movements. Baby is relaxed and unbothered
2 Tense, irritable, not relaxed	2 Baby cries briefly, regular movements superimposed with rapid flapping, flailing, jitters or fine tremors of the upper limbs. Baby bothered but settles quickly after movements
3 Abrupt, intentional, forceful	3 Movements occur suddenly - forceful and/or intentional (directed)
4 Exerted movements, very tense	4 Movements labored - very strained, may involve facial grimacing and cry
5 Frantic movements	5 Movements spastic, chaotic & agitated (fast, escalating and uncoordinated)
6 No movements, immobile, limp	6 Limbs are kept still and extended. Normal limb integrity absent
7 Tremulous jerky, uncoordinated	7 Arm movements halted jerky-may occur with tremulous hand movements

3. Head Position	
1 Right	1 Head to right of sternum, turned 30° or more from midline
2 Left	2 Head to left of sternum, turned 30° or more from midline
3 Midline	3 Chin and nose in line with sternum - remaining 0° to 30° to right or left of nipple line.

4. Quality of Head Movements	
0 Nil	0 No head movements as described
1 Regular, smooth and relaxed	1 Small fluid like movements of neck and head. Baby relaxed and unbothered
2 Tense, irritable	2 Transitory stiffening of the muscles of neck, shoulder and facial muscles
3 Abrupt	3 Sudden jerky movements of neck/head- as if taken by surprise
4 Strained	4 Head movements not free flowing. Lateral neck stretching with stiffening
5 Very strained	5 Like #4 but here neck movements are marked.

5. Other Head Movements	
0 Nil	0 No head movements as described
1 Nod	1 Sudden downward tipping of head (neck flexion), chin points down
2 Lift up	2 Upward stiff elevation of head with little flexion of neck
3 Lateral stretching (side)	3 Neck stretched sideways and slightly back
4 Hyperextension (back)	4 Neck and head movements back and oriented slightly sideways

6. Eyes	
0 Eyes closed	0 Eye lids closed and touching each other
1 Eyes open	1 Any degree of observable eye lid opening or separation

7. Upper Torso Movements

0	Nil	0.	No such behavior noted
1	Exaggerated shift like movements	1	Strenuous squirming movements as if to flee/move away from, or out of something
2	Strenuous downward movements of shoulders	2	Strained adduction of elbows accompanied with shoulder shrugging, and neck extension. Elbows are clenched down and squeezed in towards chest

8. Self Comfort — **Self explanatory**

0	Nil (no such behavior observed)
1	Hand to mouth
2	Mouth to hand (rooting)
3	Mouth to object (rooting)
4	Suck

9. Quality of Self Comfort

0	Nil	0.	No such behavior observed
1	Consolable (successful)	1	Self consoling activities effective. Baby stops crying and/or is less upset
2	Inconsolable (unsuccessful)	2	Self consoling activities not effective. Baby resumes cry after attempts

10. Responsivity

0	No such behavior, sleeping	0	No or minimal movements, baby is quietly asleep
1	Self-absorbed, quiet content	1	Baby quietly looking ahead but at nothing in particular – no focused listening, absorbed with immediate environment; appears content
2	Self-absorbed, irritable	2	Like # 1 but baby not content, cries or fussy, not interested in surroundings
3	Quiet listening	3	Baby quiet - but aware of surroundings. Eyes track to external sound
4	Like #3 but increased arousal	4	Baby relaxed alert - motor activity, moves head, looking about, listening
5	Abrupt arousal, startled	5	Sudden shift in baby's attention movements, alerted to sudden stimulation
6	Alerted, hyper aroused	6	Baby listening intently coupled with heightened movements - still relaxed
7	Alerting, aroused with call cry	7	Eyes open or closed, head usually midline and slightly tipped back, mouth is wide open and cry is loud/ broadcasting
8	Drawn in cyclical cry	8	Baby's eyes shut, drawn into self - not engaged. Little movement, cry is repetitious
9	Hypersensitive brief frantic movements and screech cry	9	Chaotic and frantic motor movements, baby's eyes closed, cry is harsh and screech like – brief outburst.
10	Drawn in – very strained cry	10.	Movements visibly strained, face drawn/puffy, cry is strained - exhausted
11	Drawn in - very strained no cry	11.	Like #10 but here, baby makes no cry – face drawn, grimace - "cry face"
12	Alerted gaze cautious, small movements	12.	Baby alerted, attentive to external surroundings; listening intently but cautiously, movements small slow – not relaxed but cautious
13	Alerted gaze guarded, immobile	13	Baby's eyes open with brief periods of staring or fixed staring. Little or no body mobility, keeping self very very still; "immobile" "quiet as a mouse"
14	Guarded hyper alert, engaged	14	Like #13 but here, baby tracking its eyes to stimuli, look is cautious, movements are active.
15	Detached, non-alert	15	Baby not responding to stimuli. If eyes are open, there is a fixed stare or glazed appearance, baby may suddenly close eyes and shut down (little or no movements).
16	Hypersensitive, prolonged and uncontrolled, baby unable to wind down, intermittent screeches	16	Sudden, intense and/or prolonged reaction to any stimuli (hypersensitive) Cry is escalating, variations of call and frantic screech cry. Movements are chaotic, jerky, and/or uncoordinated. Baby has difficulty winding down (cry frantic motor activity) from initial frantic response, keeps reacting in a heightened manner to ongoing stimulation. More prolonged than # 9

11. Upper limb posture

1	Bilateral arm flexion, high/low	1.	Any degree of arm(s) flexion. Shoulders adducted or abducted, elbows flexed – forearms/hands rest on chest or against side of body/head.
2.	One arm extended, other flexed	2.	One arm folded, the other extended downward, hands resting on body or

			near sides of body.
3	Both arms extended down	3	Like #2 but here both arms extended with hands pointing downward

12. Bilateral upper limb movements

0	Nil	0.	Nil
1	Arms drawn together - smooth	1	Arms raised with smooth widening
2	Arms drawn together - jerky	2	Widening of arm movements are halted, spastic or quivering - not smooth
3	Arms drawn apart - smooth	3	Arms raised, brought together smoothly, hand fingers may touch
4	Arms drawn apart - jerky	4	As above but movements are tremulous and or jerky - not smooth
5	Arms drawn apart - keeping equal distance between arms	5	Arms raised and wide apart, baby maintaining equal distance between arms, often accompanied by small inward and outward arm movements

13/14. Rt/Lt Upper limb movements **Code Right and Left movements separately (arms/hands/fingers)**

0	Nil	0	Maintained arm position – no movement of arm(s)
1	Tucking un-tucking: smooth	1	Spontaneous, extension/flexion of arm with shoulder adduction abduction Momentary curling/uncurl of fingers, - smooth – hands closed fisted
2	Tucking un-tucking, jerky	2	Like #2 but superimposed with small transitory spasm like movements
3	Tucking un-tucking; tremor	3	Like #2 but superimposed with small transitory quivering movements
4	Tucking un-tucking; jerk tremor	4	Combination of #2, 3, & 4
5	Arm raised: smooth	5	Arm extended upward with hands pointing upward
6	Arm raised; wave flap	6	Like #6 but superimposed with small transitory waving flapping
7	Arm raised; jerky	7	Like #6 but superimposed with small transitory spastic halted movements
8	Arm raised; tremor	8	Like #6 but superimposed with small transitory rapid quiver like movements
9	Arm raised; jerk tremor	9	Combination of #6, 8, & 9
10	Arm thrown back	10	Sudden lifting and flinging back of arm
11	Swipe bat at	11	Up and forward extension and or abduction of arm such that arm hand motions indicate a getting at motion Intentional, directed towards getting at visible object(s)
12	Bracing	12	Baby uses arm to steady self, slight shift in body limb body position follows
13	Flaying mechanical movements	13	Arm movements are uncoordinated wide sways Seem aimless automated
14	Intentional upper limb movements	14	Movements are directional, forceful but no specific stimuli noted Not previously described

15/16. Posture of Rt/LtHand/Finger

1	Hands fisted	1	Palms closed, fingers tightly clenched
2	Hands open, fingers loose curled	2	Palms open with little separation between fingers. Fingers loosely curled
3	Hands open, 2 or more fingers hyper extended - splayed	3	Palm open with hyperextension and widening of spaces between two or more fingers.
4	No distinct hand posture, constant movements	4	No discernable posture, hand movements are constant and variable

17. Hand presentation

0	Nil	0	No such hand presentation, movements are constant variable
1	Fists palms, side or front facing	1	Palms open or closed, arms are raised with hands fist pointing upwards and facing forward or orientated to face each side of baby's head

18. Hand movements

1	Variable, relaxed, regular	1	Hand movements are relaxed and free flowing, small repetitive curl uncurl
2	Variable, not relaxed	2	Hand movements are not relaxed nor free flowing They are halted

19. Type of hand movements **Self evident**

0	Nil
1	Touch self
2	Hit slap self

3	Scratch/claw self		
4	Grasping		
5	Cradling head with hands, occurs with crying		

20. Wrist movements

0	Nil	0	No such movement observed
1	Exerted flex. restraint	1	Any degree of sustainable (>2 sec) wrist flexion extension with or without rotation, notable working against restraint as if to free self of it

21. Quality of upper limb movements

0	Regular, relaxed	0	Small, free flowing movements; baby unbothered
1	Tense, not relaxed	1	Movements visibly tense or stiff, movements bother baby, usually with cry
2	Abrupt	2	Sudden movements of upper extremities as if taken by surprise, forceful
3	Very strained, labored	3	Tense slow or labored movements of upper extremities labored in effort
4	Frantic	4	Movements are chaotic, flaying and/or spastic. Not wide sways – change rapidly
5	Not relax, immobile	5	Limbs are stiff or limp. Baby is not relaxed, keeps self very still, immobile
6	Tremulous, uncoordinated	6	Limb movements jerky, fine tremor

22. Upper limb muscle tone

0	Nil - regular	0	Muscle tone maintained, relaxed no stiffening
1	Tense	1	Increased muscle tension
2	Stiff and strained	2	Like #2 but here more pronounced
3	Lack muscle tone	3	Flaccid tone to upper extremities, limp
4	Tremulous	4	Muscle tone is affected by tremulous jerk like movements of upper limbs

23. Lower Limb Postures

0	Nil – no such posture	0	No such posture noted
1	Bilateral flexion with kicks	1	Bilateral hip/knee flexion, high/low with spontaneous kicks
2	Heels on bed	2	Heels on bed – knees up
3	One leg straight, the other folded	3	One leg extended, the other flexed
4	Both legs straightened	4	Both legs extended (may be straight or slightly arched/bowed)
5	Flexion of legs/no kicks	5	Both legs flexed at knee, no kicking position maintained > 2 seconds

24. Bilateral Lower Limb movements

0	Nil	0	No such behavior noted
1	Bilateral leg kicks	1	Spontaneous & rhythmical simultaneous/ bilateral knee flexion/extension
2	Alternating leg kicks	2	Leg kicks rhythmical as above but alternating

25/26. Rt/Lt limb movements

0	Nil	0	No such behavior noted
1	Brace	1	Baby using leg/feet to steady self and change body position. Noted to occur over time to return to original body position
2	Rubbing leg against something	2	Using any part of leg or foot to rub self or against object
3	Jerky movements	3	Abrupt momentary jerky movements of leg(s)/knee(s)
4	Fine tremor	4	Abrupt momentary fine tremor-like movements of leg(s)
5	Swipe or swat at	5	Forward extension and or abduction of leg/foot such that leg/foot are directed towards getting at and moving something away
6	Immobile - leg extension	6	Leg extended, keeping self very still

27. Quality of lower limb movements

0	Regular - relaxed	0	Smooth, rhythmical, free flow, uninhibited
1	Tense	1	Movements strained not relaxed, with cry and intermittent irritability
2	Abrupt, forced	2	Sudden movements of lower extremities, large flinch like, not smooth
3	Strained exerted	3	Like #2 but more enduring, movements exerted, labored
4	Very strained (tense)	4	Like #4 but extenuated
5	Immobile, lacking muscle tone	5	No movements, immobile keeping self very still muscle tone can be stiff limp floppy

28. Lower limb muscle tone

	Normal	1	Lower extremities supple, not stiff or limp
2	Tense, irritable	2	Some tension noted in muscle tone, intermittent
3	Stiff strained	3	Like #2 but here muscle tone is increased, limbs stiff
4	Limp	4	Decreased muscle tone, limbs flaccid, limp looking

29. Respiration — **Self Evident**

0	No such respiration noted
1	Catching
2	Rapid inspiration with breath holding
3	Suck in through pursed lips
4	And hold
5	Gasp
6	And hold
7	Gag
8	Grunt
9	Yawn
	Swallow
	Hiccup
12	Snort
13	Holding breath
14	Sneeze

30. Vocalization

0	Nil - no such vocalization	0	No such vocalizations
1	Whimper	1	Soft periodic eh eh eh sounds
2	Fuss	2	Intermittent squawks accompanied with irritability, not soft like #2
3	Groan	3	Deep and inarticulate sound that is low and mournful, low gravelly, not cry
4	No cry sound, cry face	4	No vocalization/no cry sound audible, face strained/puffy or grimacing
5	Cry	5.	Any audible cry sound

31. Cry characteristics

0	No such cry characteristic	0	No such cry characteristics or no cry
1	Low pitch soft	1	Low pitch – soft sounding – not a whine or whimper
2	Loud, strong robust	2	Loud amplified - strong robust (broadcasting, mouth wide open)
3	High pitch - screech like	3	Harsh screech
4	Sustained, strained cry	4	Hoarse strained sounding cry that is sustained
5	Sob	5	Intermittent cry interspersed with gulps or short repetitious bouts of inspiration

32. Cry (characteristics)

0	No such cry characteristics	0	No such cry characteristics
1	Gradual	1	Cry slow to start
2	Abrupt	2	Cry is sudden, explosive
3	Escalating	3	Cry urgent, quickening in pace
4	Rapidly repeating maintained	4	Same pattern of cry sound that repeats in short succession
5	Weak exhausted	5.	Cry is weak faint sounding – baby appears exhausted

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CHAPTER FIVE

DESCRIBING NEWBORN DISTRESS BEHAVIOR TO ACUTE PAIN

1. INTRODUCTION

Researchers traditionally use deductive (experimental) approaches to measure the physiological, biochemical and behavioral dimensions of acute neonatal pain. While deductive approaches are fruitful when basic description of pain exists as a foundation for measurement, the approaches are ineffective when basic descriptions are absent. In most cases, investigators acquire the basic information by observing and asking individuals to verbally describe and/or rate various aspects of their pain experience. Newborn infants, however, cannot provide verbal accounts that may assist in developing the descriptive base required to support hypothesis testing and measurement of pain. In those instances, investigators must draw on the neonate's behavior since behaviors are one of the most direct and objective ways to learn about neonates and their pain (Craig, 1995). Thus, to be meaningful, deductive inquiry into neonatal pain must be grounded in basic inductive description of the behavior. In this study, inductive research means research that utilizes unobtrusive and systematic (reliable) observation to help generate comprehensive description of the newborn's pain behavior and the pain context.

Mainly, however, neonatal pain research is deductive and focused on measurement of the behavior rather than on its inductive description. The typical approach to inferring neonatal pain involves testing for the occurrences of a number of responses (physiological, biochemical and or behavioral) assumed indicative of neonatal pain and utilizing a short-term pain model hypothesized to cause neonatal pain (mainly heel lancing). From this body of deductive research, varying aspects of clinical pain are reported. For example, lower neonatal facial action scores and/or spectrogram analysis of pain cry indicate that sucrose (Johnston and Stevens, 1996), rocking (Compos, 1994) and fentanyl (Barrier et al., 1989) are effective neonatal pain treatment strategies. Other studies show that newborn cries (Porter et al., 1986) and facial actions (Grunau et al., 1990) systematically vary with intensity of pain stimuli.

While it is clear that current research has resulted in a wealth of pain related findings, researchers remain unable to consistently measure the multiple responses of neonatal pain (Franck and Miaskowski, 1997; Stevens et al., 1995).

Since behavioral knowledge provides unique insight into neonates and their pain, research on that particular domain may assist to further pain assessment and measurement efforts. Examination of the neonatal pain behavior research reveals that although a highly informative body of knowledge on pain cry and pain facial action has developed, newborn pain behavior remains poorly described. Because researchers mainly focus on a limited number of pain behaviors, and because they test for these using short term pain models, they have not described the complete range of the behaviors; nor have they tested them in response to the varying types of pain neonates experience. There is little descriptive information on the behavioral responses of newborns who experience chronic pain or types of surgery. Moreover, because they primarily employ experimental designs, researchers collect behavioral data using short time frames (typically coding occurrence of behavior at 10 second intervals of one minute).

The implications of utilizing few behaviors, short term pain models and short data collection time frames is that understanding is severely limited regarding the possible types and temporal characteristics of the pain behaviors. There is information about the frequency of some pain behaviors; however, little information exists about their duration or patterning. The only duration data we have is of pain cry. Yet, knowledge of the entire expressive range of the behaviors and their characteristics is required to ultimately assist clinicians to identify and respond to neonatal pain. Furthermore, duration knowledge is key to understanding important but poorly understood topics such as neonatal response patterns up to 72 hours following exposure to significant pain.

A related issue is that extraneous factors that fall outside the short data collection times frames may go undetected; if so, they will also not be controlled for. For example, few neonatal pain researchers control for ambient sound even though that factor is known to influence newborn responses (Field, 1990). Failure to control for extraneous variables increases the risk of making erroneous study conclusions because causative components of the pain stimulus response pattern are not fully tested. Further, reliance on short data collection periods may curtail study to determine if control of extraneous variable(s) has any pain treatment benefit. An added implication is that researchers indirectly minimize the context under which neonates, as interactive beings, experience pain.

In response to the acute noxious stimulation of surgery, neonates exhibit consistent increases in heart rate (Owens and Todt, 1984), a high pitched cry (Porter et al., 1986) and a physiological stress response (Anand and Hickey, 1987). Neonatal responses are not specific to the acute noxious stimulus; neonates also cry in response to cold and other distress provoking events such as hunger (Johnston and O'Shaughnessy, 1987). However, despite this recognition, few researchers distinguish distress from pain.

Distress encompasses how neonates respond to the range of stimuli they receive, including stimuli that are non-noxious (non-painful) in origin. Distress is reflected in the variable nature of neonatal response patterns. While we agree that pain and distress are conceptually different, we believe it may be possible to distinguish pain if it is viewed as an extreme grade of distress. By conceptualizing distress along a continuum and taking a broad approach to comprehensively describing it, we may be able to differentiate between distress, behavior related to distress, and behavior related to distress caused by pain from surgery. Differentiating kinds of distress may lead to a better understanding of their similarities and differences, especially in terms of what evokes them and how neonates exhibit them. Clearer differentiation may also further insight into how distress interacts with pain, and what short and long-term implications distress has for neonates who undergo pain. It is especially important since pain assessment and pain treatment are contingent upon differentiating responses specific to pain (McGrath, 1989).

The model of newborn distress, and basic study approaches have been utilized to describe newborn pain behavior. Cote et al. (1991) focused on distress and used systematic observation to inductively generate a detailed listing of the behaviors and description of five behavioral distress states (quiet alert, drowsy, sleeping, acute distress, and sub-acute distress) in full term ill neonates following chest surgery. Despite the large numbers of behaviors, Cote (1987) acknowledged missing items. Omissions likely occurred because neonates were intubated, which limited their vocalization; as well, they had an intravenous catheter inserted into one of their hands, which limited upper limb movements. Also, Cote (1987) did not include descriptions for lack of response, perhaps because neonates, in that study, could not exhibit the behaviors. This is important since up to 50% of neonates do not cry and some display little motor movement in response to noxious stimulation (McGrath and Unruh, 1987). The basis underlying lack of response is not well understood and only beginning to be studied in premature neonates (Johnston et al., 1999). We decided against using the coding scheme developed by Cote et al. (1991) because it was not based on the actual surgery (the authors described behavior starting 24 hours after surgery). Principally, we could not use that coding scheme to distinguish between behavior related to distress and behavior related to distress caused by surgery.

Clearly, significant gaps in our basic understanding of how neonates normally express distress and acute pain indicate a fundamental lack in pain behavior description. Incomplete knowledge on the topic calls for alternative approaches both to add to exiting deductive approaches and to generate basic level information on the behaviors.

To generate fine-grained descriptions and to help distinguish distress behavior specific to newborn pain, researchers need to conduct basic observational research. The purposes of this ethologically based study was to inductively describe newborn distress behavior in terms of its frequency and duration and, in doing so, distinguish it in response to noxious and non-noxious but distress provoking events associated with newborn surgical pain (including descriptions of the behaviors following distress events). Because we conceptualized distress along the continuum, we selected the acute noxious event to be newborn male circumcision, and we selected the non-noxious events to be diaper change and restraint application. Ethical clearance was obtained to conduct the study using secondary videotaped data from a study conducted by Lander et al. (1997).

2. METHOD

2.1. Sample

The sample for this basic observational study consisted of 4010 1-second intervals of videotaped data rather than individual subjects. The videotapes, recorded originally for a study about circumcision (Lander et al., 1997), were obtained as secondary sources of data. The videotapes were of four full term (more than 38 weeks gestation) healthy male neonates at rest or experiencing a variety of events as described. The four cases were part of the control group in the original study; none received an anesthetic or comfort measure, and, because the original study was controlled, all underwent the same seven events. Neonates had a mean age of 29.75hours (SD =12.53h). Table 1 summarizes neonatal characteristics and maternal factors during labor.

2.2. Materials

The coding scheme used in this study was derived from an earlier phase of the research. In that phase, videotapes of 10 male newborns undergoing circumcision without anesthetic were observed systematically in order to inductively describe the entire range of distress related pain behaviors. The result was a reliable ethogram.

Ethograms are fundamental to ethological studies as they provide the basic information required to further describe the behavior and to test hypotheses about it (Patterson, 1992). This ethogram contained 235 behavioral descriptions (objectively defined) representing the full expressive range of neonatal distress behavior to acute pain. It was organized into 35 main categories and subcategories divided into two branches. The first branch contained 32 categories for coding variation in neonatal motor movements, body postures, responsiveness, self-comfort actions, respiration and vocalization. The second branch contained three stimulus categories for coding procedure related stimuli, ambient sound and spontaneous responses (such as startles).

In any ethological study, researchers find it preferable to employ previously developed coding schemes; however, in this study, we did not code newborn facial action using the popular Neonatal Facial Coding System because the picture quality of the secondary videotapes was not clear enough to permit consistent coding. The amount of missing data would have compromised study results. The facial data that we did collect were highly visible facial movements such as eyes open and closed, eyes tracking, and facial grimacing. In addition, because our study was descriptive, we collected cry data for qualitative description of pain cry rather than for spectral analysis. Reports of high positive correlations between qualitative descriptions of cry and their spectrogram analysis lend support to our descriptive approach (Porter et al., 1986).

2.3. Procedure

2.3.1 Selection of videotapes. Of the 52 videotapes from the Lander et al. (1997) study, 17 involved neonates who were in the control group. Those 17 cases provided the secondary data for the earlier phase of the study and this study. Selection criteria for both study phases were that (a) newborns be minimally clothed in diaper and or shirt; (b) a close up and upright view of the baby's entire body be visible (except for the toes which were for the most part hidden); (c) they contain the least obstructed view of the neonate (least number of occasions where the surgeon or nurse obstructed the camera); and (d) ambient sound be easily heard through headphones. Of the 17 videotaped cases, three failed to meet criteria and were thus discarded. Of the remaining 14, ten were selected for the first study phase and four were selected for this study. The four cases selected for this study were ones that enabled optimal testing of descriptor items composing the ethogram, and they permitted collection of the frequency and duration data. The criteria used to select the four videotapes from the 14 were that they (a) offer the very best views of the neonate (with the least number of occasions where the surgeon or nurse obstructed the camera); (b) offer the best clear picture quality; and (c) be of neonates who display a range of behaviors across events (including lack of response). To facilitate coding and ongoing reliability checks, each of the four videotapes chosen were encoded with a permanent running time (in 1-second intervals) that appeared in the bottom right hand screen of the video.

2.3.2. Training of coders. The two coders in this study were the main author and a graduate student, both of whom were knowledgeable about the ethogram and the study equipment. They received training in continuous coding during the earlier phase of the study. In addition to earlier training, this was done by selecting a one-minute segment from each of the four videotapes selected for this study. Those four segments represented the first minute of each distress event (diaper change, restraint application and circumcision) and the first minute of baseline (before any handling of the neonate). The four, one-minute segments were then broken down into 1-second intervals and coded using exact start times. This yielded 240 chunks of data for all four cases (60 second each) that were subjected to inter-rater reliability analysis. A Kappa score of 0.80 was the criterion for determining successful training and initial reliability testing of the ethogram.

To conduct reliability assessments, coders scored same behavior for approximately the same duration of time, but agreements in coding between raters were sometimes one or two seconds off (particularly when change in behavior occurred). To test this further, we conducted intra-rater reliability and found the same pattern occurred. As recommended by ethologists (Bakeman and Gottman, 1997), agreements in scoring were thus calculated for each 10-second chunk of the second by second data, rather being calculated for each second. Although that strategy likely overestimates agreements, it corrected for minimal second differences in coding between raters. Once the criterion of Kappa 0.80 was achieved, the coders commenced coding the four tapes.

2.3.3. Observation schedule. The period of videotaped observation consisted of seven sections that reflected surgical and research procedures (baseline, application of arm and leg restraints, diaper change, circumcision, post restraint application, post diaper change and post circumcision). These seven procedures will be referred to as *events*. We noted the time codes that designated the beginning and end of each of the seven events. That information provided us with the duration of events for all subjects. Since our aim was to describe distress behavior by event, our method required that coding occur over equal periods of time for each video case using same start times. Thus, we set the duration of the event to be the maximum amount of time each distress event lasted across cases. The duration of the post distress events were then matched such that equal time segments for all seven events were delineated. This resulted in identifying equal three minute segments for all seven events except diaper change and post diaper change which took about 1 minute each. Table 2 presents the seven events and the average duration of observation. A total of 67 minutes of tape was coded in the study (4010 seconds in total).

2.3.4. Coding of behavior within event. The baseline event was coded first for each of the four videotapes. Each of the remaining six events were coded in the same manner. The 3-minute baseline event was viewed in 10-second chunks. Each 10-second chunk was partitioned into 1-second intervals for coding. Coders examined the data in each 1-second interval for the occurrence of any behavior described in the 35 categories.

Using the accepted technique of paper and pen (Hinde, 1982), coders recorded, onto a specially designed data check sheet the type of behavior and times the behavior began and ended. That method of data collection made it possible to precisely document concurrent occurrences of up to 35 types of behavior and stimuli at each second.

Documenting occurrences of items in the ethogram required repeated viewing, rewinding and frame-by-frame viewing of the videotapes. When all 1-second intervals of the first event in the first tape were analyzed, coders proceeded to the second and subsequent events. Only when the videotape was completely coded did raters proceed to the next videotape sample. In keeping with ethological methods (Lehner, 1996), coders maintained field notes of situations observed outside the realm of the coding schema. The notes provided contextual information.

2.3.5. Inter-rater reliability of coding. To further test reliability in coding, at least three, one minute segments were sampled from each of the four videotaped cases used in this study. This lead to a total of 14 minutes of videotaped data that were subjected to reliability testing. For each of the four-videotaped cases, testing usually involved the first minute of baseline and the first minute of two distress events (diaper change, application of restraints, or circumcision), or their respective post distress event periods. Although the sampling procedure used in this study was not random, the procedure enabled repeated reliability testing for all 35 categories of behaviors for each of the four cases. Those sampling approaches may have optimized reliability testing compared to random sampling since each behavior was tested across cases and across the seven events. They were conducted to ensure procedure replicability and observer accuracy when coding behavior by event - two of main reliability requirements (Bakeman and Gottman, 1997)

The 14 minutes were coded and the results subjected to reliability analysis. Using the same procedures established during the training session, we inspected agreements in coding at each 10-second interval. A Kappa index of 0.80 indicated reliable coding.

2.3.6. Analysis of the coded behavior. Simple descriptive statistics were used both to describe duration and frequency of distress related behavior and to distinguish distress in response to varying pain and non-pain situations. To calculate the descriptive statistics, items in the ethogram were classified as either *enduring* or *momentary* (Paterson, 1992). Within ethology, enduring behaviors possess appreciable time; they yield information about the frequency and duration of the behaviors (Lehner, 1996). The behaviors are composed of a series of linked motor actions or combinations of complex behaviors. In this study, we defined enduring behaviors as those lasting two or more seconds; they included almost all behaviors in the ethogram. Although by adult standards, two-seconds may seem brief, the time is representative of rapid neonatal motor activity. We set the minimum at two seconds to capture rapid change in the behaviors (frequency), and to document durations. In this study, percentage duration was the percentage of time neonates spent assuming a particular behavior for a particular event. It was calculated as follows: a = number of seconds that the behavior occurred for each case, and b = total duration of the event (1 or 3 minutes); therefore, percent duration (%D) = a / b x 100.

Frequency was also computed for a small number of momentary behaviors contained in the ethogram. In ethology, momentary behaviors represent very rapid occurrences of motor actions that cannot, or would not, be logically calculated in terms of duration (Lehner, 1996). In this study, momentary behaviors included hand swipes.

3. RESULTS

3.1. Inter-rater Reliability

For the 14 minutes of videotape selected for reliability testing, a total of 386 Kappa scores were computed. Scores ranged from K=0.60 to K=1.00 with 339 reaching the criterion of reliability (Kappa = 0.80). The 47 that failed to reach criterion were some of the complex behaviors including some of the cry, upper and lower extremity (including movements of the head, fingers and legs) and the responsiveness categories.

Because they are not as objectively defined as anatomical behaviors, complex itmes require raters to use subjective judgments when coding (Bakeman & Gottman, 1997). Although we utilized slow-frame technology, the rapid and blended nature of hand and finger movements made it difficult to achieve agreement in start times. In such cases, ethologists recommend complex behaviors be redefined through consensus and ongoing reliability testing (Bakeman & Gottman). We created five new subcategory items for the responsiveness category, four for the upper extremities, and two for lower extremities. Three items for cry were eliminated as they already existed in some of the responsiveness subcategories, and two items were collapsed for hand and finger movements. Upon retesting and consensus, the items achieved criterion, indicating they were reliable.

3.2. ***Data reduction: Descriptively distinguishing distress and post distress behavior***

We descriptively distinguished distress by inspecting duration and frequency scores for all coded behavior; we then compared and contrasted these to baseline and to each of the three events that neonates were exposed to during circumcision (diaper change, restraint application and actual circumcision). The criterion for selection of the behaviors was that they occurred during the actual circumcision and also observed during diaper change and or restraint application events. Sixty-eight of the 192 items in the 32 categories of the ethogram were selected. We concluded these 68 items represented distress.

Of these 68 behaviors, two representing the neonate's upper and lower extremities were obstructed on the tape at least 20% of the time by the surgeon or nurse. This prevented thorough analysis of frequency and duration for those two items. The two items were discarded, thus reducing the total to 66 items. To reduce redundant categories, 26 behavioral items that represented right and left anatomical regions were combined (e.g., right and left hand movements). Those 26 behaviors were combined because the separate anatomical items did not add unique description. Thus, the 66 behavioral items were distilled down to 40, and these defined neonatal distress. The items and their definitions can be found in Table 3.

Of the 40 distress items, 13 occurred only during circumcision. Some of the 40 items also occurred across the three distress events. Twenty-seven behaviors occurred during circumcision, 24 occurred during diaper change, and 17 occurred during restraint application (restraints prevented coding of most movements of the upper and lower extremities). In Table 4, distress behavior items are rank-ordered according to their duration and then according to their frequency as they occurred during diaper change, restraint application, baseline and circumcision. The behaviors are numbered to match their definition as described in Table 3. Scores are presented according to the numbers of neonates who expressed the behaviors. Behaviors exhibited by three or four neonates are labeled "common", while those exhibited by one or two are labeled "individual differences."

Similar procedures were used to distinguish distress following each of the three distress events. We reasoned that return to baseline behavior would indicate recovery from distress, but that distress and some unique behaviors would occur following each distress event. We inspected duration and frequency scores for all coded behavior and compared and contrasted these to baseline and to each of the three events post distress event. We selected behaviors if they occurred during baseline (a phase that did not contain distressful events) and occurred during the post circumcision, post diaper change and post restraint application events (events that involved sustained distress or return to baseline)

Twenty five behaviors were selected. In Table 5, the 25 items that represent post distress event behaviors are rank-ordered in terms of their duration following diaper change, circumcision, baseline and restraint application. Similar to presentation of the distress items, scores for the post event behaviors are presented according to the number of neonates expressing the behaviors and the frequency of each behavior. Findings reported below represent common behaviors unless otherwise specified.

3.2.1. Behavioral items occurring during baseline and each of the three distress events. As noted on Table 4, right-sided head positioning, hands held tightly fisted, self-absorbed irritability and cry all occurred during baseline and each of the three distress events. Those four behaviors were included as part of the 40 distress behaviors because their percentage durations either decreased or increased along the continuum of distress.

During the three minute baseline event, neonates positioned their heads right sided for 94% of the time. They held their hands in a tight fisted position for approximately one half of baseline; they were self absorbed and irritable for one third of the event; and they cried in a broadcasting and loud manner for about one quarter of the time.

3.2.2. Behavioral items crossing distressing events. Cry was a primary expression of distress as it ranked high in terms of percent duration for each of the three distress events.

3.2.3. Behavioral items occurring during diaper change. There were six common distress related behaviors exhibited by at least three neonates during diaper change. Neonates cried for the one half of the one-minute event (53%). They also spent a large percentage (at least 76%) of the event with their heads positioned to the right. For over half of the event, their upper limb movements were tense. Similar to baseline, they held their hands in a tightly fisted position; they cried in a loud and robust manner; and they were self absorbed and irritable for about one third of the event. Finger splaying occurred for the least amount of time (14%). Review of the stimuli related data showed that tense head and upper limb movements occurred when the neonates' legs were held upright for diaper change. Increases from baseline irritability, loud robust cry and finger splaying occurred during skin cleansing.

3.2.4. Behavioral items occurring during application of restraints. During the restraint event, there were ten common distress behaviors. Although most of those behaviors also occurred during diaper change, during the restraint event their frequency and duration were markedly increased or decreased. Neonates cried for more than half of the three-minute restraint event. For about one half of the event, they held their hands tightly fisted, and when they cried in a loud and robust manner, their heads were positioned midline or right facing. During the restraint event, neonates spent less than 18% of the time self-absorbed irritable; however, they had frequent hyperextension of their head and neck, and they cried in an abrupt and explosive manner. New behaviors were an exhausted and weak cry (9%) and strenuous downward shoulder movements (3%).

3.2.5. Common distress behaviors exhibited during circumcision. During circumcision, 24 common distress behaviors occurred. Those behaviors also occurred to some degree during diaper change and restraint application; however, their frequency and percent duration during circumcision was higher. Cry occurred for the majority (76%) of the three-minute circumcision. During the event, there was great variability in cry sound. Within a space of a few seconds and especially when the surgeon inserted the probe to separate the glans, cry shifted from being hoarse and strained to exhausted and weak sounding and from abrupt and explosive to loud or rapidly repeating. For at least 63% of the event their upper limbs appeared stiff and they positioned their heads midline. Neonates extended their hands and positioned them side or front facing. There were frequent occurrences of very strained hyperextension movements of the neck.

Behaviors that occurred for approximately one third of circumcision were: right sided head positioning, finger splaying and hands held tightly fisted. Neonates spent approximately one quarter of the event exhibiting strenuous downward movements of their shoulders. For that period, their faces appeared drawn and stained when they cried. Neonates also displayed prolonged bouts of hypersensitivity and an inability to unwind and this was interspersed with episodes of upper limb tenseness and immobility.

During approximately a tenth of circumcision, the qualities of the neonate's upper limb movements were tense, jerky and or tremulous. They also shifted their shoulders in an exaggerated manner as if to escape. Least occurring behaviors during circumcision were self-absorbed irritability (6%), and a drawn in responsiveness with strained facial grimacing and no cry (7%) and brief hypersensitivity with inability to wind down (8%).

3.2.6. Behavioral items for circumcision alone. As seen in Table 4, a total of 13 expressions of extreme distress occurred during circumcision alone. These were very strained, labored or flaying movements of the upper limbs; high-pitched screeches; bilateral arm extensions; and breath holding. Behaviors that occurred frequently were abrupt, intentional, swiping and frantic motions of the hands. Those extreme expressions of distress occurred in response to cleansing just before circumcision and during procedures to separate the glans (insertion of a probe and retraction of the foreskin). Of the 13 expressions of extreme distress, all four neonates expressed six behaviors. They were strained and frantic movements of the upper limbs, high pitched screeches, bilateral arm raising and widening, breath holding and abrupt intentional arm movements. In all cases, the six behaviors occurred within two seconds of procedures to separate the glans.

3.2.7. Individual differences for the three distress events. Finger splaying, crying in a loud and robust manner and slapping self were common expressions of distress that occurred in a graded manner across the three distress events. Those behaviors, however, were exhibited for prolonged durations by two of the four neonates. For example, one neonate spent the majority of the one minute diaper change crying (68%), and he splayed his fingers for one third of the event. The other neonate spent one quarter of diaper change exhibiting similar distress, but, in addition, he also exhibited a hypersensitive responsiveness with frantic motor movements and an inability to wind down (hereafter referred to as hypersensitivity). Review of the data check sheet showed hypersensitivity occurred immediately after staff removed a dressing from the neonate's surgical site, before skin cleansing. In the original study, all neonates had a dressing applied on the surgical site to retain the placebo anesthetic cream. Still, a third neonate exhibited hypersensitivity for one third of the restraint event and for one percent of the diaper event. That neonate displayed the behavior within two seconds of his restrained legs trying to spontaneously kick and of his hand and arm movements becoming tremulous and jerky. Although most neonates exhibited distress to all three events, we noted the forth neonate exhibited few distress behaviors.

3.3. Behavioral Items Following Each of the Three Distressing Events.

3.3.1.Post diaper change. As observed in Table 5, there were few common distress related behaviors following diaper change. Neonates spent the largest percentage (53 %) of the three-minute post event displaying baseline tucking and un-tucking movements of their upper limbs. Neonates were also self absorbed and irritable for approximately one third of the event. Following diaper change, neonates quickly re-established their baseline behaviors; they did not exhibit immobility.

3.3.2. Post restraint application. There were fifteen common distress behaviors identified for the three-minute event following restraint application. All neonates kept their lower limbs motionless for a large percentage (44%) of the three minute event. They either assumed a posture of bilateral hip flexion with kicking or bilateral leg extension with immobility. When they attempted to spontaneously leg kick during the first minute of the event, the result was small and incomplete; movements were tense and strained. They spent approximately equal periods being self absorbed and irritable and self absorbed and content. Their general body movements and muscle tone varied from being active to being immobile, and from appearing relaxed to appearing tense. For over a quarter and into the second minute of the event neonates exhibited smooth and rhythmical leg kicking, and smooth tucking and un-tucking of their upper limbs. They spent 13% of the time quietly listening, 7% crying loud and robust, and 4% bracing their lower limbs to change their body position.

3.3.3. Post circumcision. There were 14 distress related behaviors that were commonly exhibited by at least three neonates following circumcision. Neonates spent most (47%) of the post circumcision event with both of their legs extended and immobile and for 34% of the time, their entire body was immobile, not relaxed. Patterns of lower limb immobility were similar to the patterns observed following the restraint event, but, during circumcision recovery, bouts of immobility lasted longer--the effect of restraint application was controlled for. Immobility was also accompanied by a responsiveness that included increased arousal and alert but tense listening. Neonates were self absorbed and irritable for about one quarter of the event. During that time and with increased activity, neonates exhibited very strained movements of their head and they assumed a drawn in responsiveness where their cry was broadcasting or cyclical in nature. They spent 25% of the event (toward the latter part) spontaneous kicking both legs and 7% quietly listening.

3.3.4. Individual differences. As observed during the diaper change and restraint events, two neonates uniquely expressed hypersensitivity following each of the three distress events. Following diaper change and circumcision, one neonate was hypersensitive for almost one half of the diaper event and one half of the circumcision event. Just before exhibiting the behavior, that neonate had had a bout of regular jerky arm movements. One other neonate exhibited hypersensitivity for a small percentage of time following restraint application and for approximately one quarter of the post circumcision event. Review of the stimuli data show that in each case, hypersensitivity occurred within two seconds of neonates being exposed to otherwise neutral stimuli (e.g., sound of running water). Post circumcision, hypersensitivity was prolonged and interspersed with bouts of leg extension and immobility.

3.4. Field Notes and Qualitative Data.

Descriptions obtained from the hand written notes of the coders contributed background information for the study. Coders questioned whether some of the distress behaviors they were coding were reflective of neonates attempting to reposition themselves. Another notation concerned the facial appearances of neonates. Although facial action was not scored, coders noted that the faces of some neonates were smooth and puffy rather than furrowed and creased, as they had expected, particularly during the most invasive phase of circumcision. Coders also remarked that post restraint and circumcision, neonates appeared as if "trying" to remain motionless; they described neonates as "frozen and motionless".

4. DISCUSSION

In this study, describing newborn behavior in response to varying distress-inducing events differs from the typical approach of measuring few pain behaviors to a particular pain event. Others have taken a similar broad approach. Cote et al. (1991) focused on distress in order to describe newborn pain states following chest surgery. Porter et al. (1986) focused on stress and employed a biosocial model to successfully measure-graded cry to varying stress inducing events associated with newborn male circumcision. In using that approach, Porter et al. (1986) viewed cry as an index of underlying neonatal stress and biological integrity. Here, the focus on distress and utilization of basic ethological methods led to fine grained description of the types and temporal characteristics of neonatal distress and this in turn helped distinguish distress and pain related behaviors along the continuum of distress. In particular, this study's use of systematic observation and continuous time sampling led to the identification of an extensive listing of newborn distress related pain behavior. Of the 40 behaviors, other researchers have previously described change in the neonate's general motor activity (Craig et al., 1984); neck stretching, finger splaying, and directed arm movements (Als et al, 1982b) in full term and premature neonates exposed to stress or pain. Items unique to this study include the responsiveness behaviors, spontaneous leg kicking, and immobility. Their large numbers show newborns exhibit a wide range of identifiable distress behaviors.

In addition to describing the range of distress behavior, the ethological technique of continuous time sampling (coding the behaviors second by second) also led to unique and precise descriptions of the frequency and duration of most behaviors contained in the ethogram. Although not commonly produced, duration data is important for two reasons. First, understanding how long neonates spend exhibiting distress deepens our appreciation of their pain experience; the current approach of measuring simple occurrences of the behaviors only limits that understanding while duration data goes beyond to inform us of the quality of those occurrences. Incomplete reporting has likely occurred because most neonatal pain researchers collect their behavioral data using very short time frames. Second, duration data provides a beginning basis for determining duration baselines, which may in turn assist in studying the nature and implication of short and long-term distress.

Indeed, in this study, the prolonged time neonates spent exhibiting extreme distress surprised us. Neonates held their breath, cried strenuously, frantically moved their upper limbs and torso, and expressed very strained movements of their head and neck for prolonged durations during the three minute circumcision. Since newborns are vulnerable to consequences of high-energy loss (Sperling, 1996), one wonders about the physiological cost that excessive distress, during pain, has on neonates. To our knowledge, breath holding has not been previously reported in the neonatal pain literature.

The strategy of rank ordering the duration measures was especially useful as it enabled us to identify graded distress in the 40 distress behaviors. Graded distress behaviors were those related to non-noxious but distress provoking events and behaviors related to distress provoked by acute surgical pain. Our results suggest that increase in type, frequency and duration of distress behavior reflects an increased level of distress event. Circumcision resulted in extreme distress; restraint application resulted in some distress; and diaper change resulted in minimal distress. Before drawing comparative conclusions, though, further inductive description is required to ensure the ethogram is representative of all full-term neonates and their pain behaviors. Repeated Measures ANOVA could then be used to test for significant differences in distress by event. An alternative would be to use the sequential analysis programs developed by Bakeman and Quera (1995). Because sequential programs are designed to handle continuous but concurrent data, they offer sound ways to identify distinct patterning in the behavior; consistent patterns that may have predictive value.

One of the most important findings of this study concerned the 13 expressions of distress that occurred only during circumcision and the common expressions of distress that occurred the most frequently and for the most prolonged periods during circumcision compared to the restraint application and diaper change events. Descriptions that are reported by Porter et al. (1986) as well as in this study include variation of cry, rather than a single type of cry, and harsh screech cries during the most invasive phase of circumcision. Behaviors that were unique to this study and not reported elsewhere include exaggerated shift-like and strenuous downward movements of the neonate's shoulders as well as very strained, labored, flaying and/or frantic movements of their upper and lower extremities. These types of behavior suggest escape like actions and although they are distinct, they are somewhat similar to behaviors reported by Franck (1986) who also described limb withdrawal and swipe like arm motions during newborn heel lancing. Ongoing testing will decide whether the 13 behaviors and prolonged and or frequent expressions of extreme distress are reliable and valid indicators of acute newborn pain. If so, their combination with existing descriptions will assist in constructing sound neonatal pain assessment instruments.

In addition to providing the types, characteristics and graded expressions of distress behaviors, we provided novel description of distress following each distress event. Findings show that neonates regain most of their baseline behaviors almost immediately after diaper change followed by restraint application. Prolonged immobility and distress however occurred following the circumcision. For that event, neonates likely remained immobile because they were still in severe pain. They may also have remained immobile to reduce further energy loss, or because they were positioned supine for prolonged periods on a circumcision board. The behavior may also have reflected hyper vigilance as observed in the animal literature (Brick, 1998) or a brief traumatic state (Drell et al., 1993).

Another important finding concerned the individual differences in expression of neonatal distress. That individual difference in distress expression occurred does not mean that common distress behaviors specific to acute pain do not exist. Instead, unique expressions of distress may signal important underlying factors that influence an individual neonate's ability to respond to any form of stimuli. The expressions may reflect individual differences in the neonate's temperament. They may also reflect either the individual neonate's ability to self organize in the face of ongoing stimuli or their ability to inhibit incoming sensory inputs. In this study, the two neonates who uniquely expressed hypersensitivity weighed less and displayed jerky upper limb movements throughout the observation period, including baseline. Those behaviors are similar to ones exhibited by highly reactive premature neonates whose motor response patterns indicate an inability to respond flexibly, persistently and/or resourcefully to novel or stress events (Als et al., 1982a). As those authors suggest, episodes of behavioral disorganization are taxing to premature neonates and may even result in an infant who fails to thrive. Unique expressions of distress in full term neonates, such as hypersensitivity deserve further study. Research will help determine the basis of the individual differences and their short and long-term implications. Research will also help determine whether control of such differences leads to improved pain assessment or if they may be used to develop screening and pain treatment protocols.

In this study, initial difficulties in establishing reliability for some of the complex behaviors arose because those kinds of behaviors are difficult to define in precise and objective terms. Bakeman and Gottman (1997) argue that complex behaviors are necessary as they provide important information that molecular behaviors do not. In this study, one of the most insightful descriptions of extreme distress emerged from coding the responsiveness categories. It demonstrated that for some neonates, prolonged and uncontrolled displays of strained motor activity and cry occur in response to otherwise neutral stimuli. Those complex behaviors lend insight into the quality of newborn interaction. As such, they may be key to understanding how neonates respond to the range of stimuli they receive and understanding how distress affects the individual neonate's ability to cope with or recover from pain.

In the ethological animal literature, researchers have used complex behaviors to describe facial expression in non-human primates (van Hoof, 1967). With continued testing, those complex behaviors achieved valid and reliable description. Similarly, the validity and reliability of the ethogram used in this study will rest on its continued testing, as this process will enable refinement of existing items and the possible addition of new behaviors. Continuing to develop the methodological quality of the ethogram is important since it serves as the basis for further inquiry about the behaviors (Lehner, 1996): including female and older neonates and broadening the scope of distress and acute pain situations will do this. The ethogram can also be used to study poorly understood areas such as neonatal pain recovery and gender related differences in newborn distress expression. Since no single measure stands to represent the multidimensional nature of neonatal pain, behavioral descriptions will also need to be linked in real time with facial data, physiological and biochemical neonatal pain indicators. Improvements in technology will permit these important developments.

In this study, the secondary videotapes were cost effective and they facilitated description of newborn distress behavior to varying distress events. However, this study could be improved by creating videotapes that are specific to the descriptive aims of the study and by extending videotaping to include behavioral descriptions of distress 48 hours post surgery. Other recommendations include utilizing direct observation to optimize description of the pain context. Digital rather than analogue technology would improve the quality of the videotaped image, its color and its sound. As well, picture in picture, split screen and zoom will facilitate a focused but full view of the neonate and their environment.

In conclusion, findings of this basic research show the benefits of employing systematic ethological approaches to reduce gaps in basic understanding of neonatal pain. While it is impossible to know how neonates perceive pain, describing pain along the continuum of distress and obtaining precise frequency and duration measures of the behavior proved successful: they helped identify circumcision as an extreme grade of neonatal distress, and they helped identify distress behaviors that occur in response to both noxious and non-noxious distress events. Ability to distinguish pain behavior is an important prerequisite to assessing and measuring neonatal pain. Continuing to build a foundation of descriptive information will help develop a strong body of pain behavior knowledge capable of supporting deductive inquiry. Clearly, the complexity of neonatal pain benefits from the use of diverse research approaches. In this study, the basic knowledge achieved in using ethological methods justifies its ongoing use in the field.

Table 1: Demographics of neonatal study subjects and maternal factors during labor

	Baby One	Baby Two	Baby Three	Baby Four
Neonatal Characteristics				
Age in hours	15h	25h	44h	35h
Mode of delivery	Vaginal	Vaginal	C Section	Vaginal
Weight at birth	3040gms	3515gms	4805gms	3360gms
Total feeds	1	Nil	1	2
Time last feed	0745	0400	0700	0200
Baseline start time	0748	0505	0751	0529
Baseline state	Awake	Awake	Awake	Awake
Maternal Characteristics				
Labor induced	Yes	Yes	N/A	No
Drugs labor	Demoral, Gravol	Tylenol	Tylenol	Nil
Drugs post labor	Tylenol, Darvon	nil	Tylenol #3	Syntocinon
Anesthetic during labor	Nil	Local	Epinephrine	Epinephrine

Table 2: A list of events and their durations

Event	Duration (in minutes)
1. Baseline - the baby is resting supine in a bassinet, prior to any physical intervention required for the circumcision study	3
2. Application of bilateral arm and leg restraints	3
3. Recovery from application of restraints	3
4. Diaper change	1
5. Recovery from diaper change	1
6. Circumcision procedure	3
7. Recovery from circumcision procedure	3
Total Time	17

Note: Events occurred in the order presented

Table 3: Definitions of 40 distress behaviors occurring across events: Circumcision, diaper change, application of bilateral arm and leg restraints and during circumcision alone

Type of behavior	Definition of the behavior
1. Cry	
2. Sustained: cry sounds hoarse and strained	
3. Exhausted: cry is faint depleting, face strained/ tired	
4. Abrupt: cry is sudden, explosive	
5. Rapid: cry urgent, quickening in pace, few breaks - repetitive	
6. High Pitched Screech: cry is very shrill, harsh and sharp at onset – short	
7. Arms raised, fists/palms open facing to front/side	7. Palms open or closed, arms extended with hands/fists pointing upward, facing forward or oriented to face each side of baby's head
8. Head positioned midline (more or less)	8. Head usually resting at 0 degree's where chin and nose are in line with sternum (nipple line) – but can move 30 degree's to either the right or left of that midline position.
9. Upper limbs, very strained	9. Slow labored movements of upper extremities
10. Upper limbs, stiff	10. Pronounced limb tension
11. Head, very strained movements	11. Movements of the head marked. Lateral neck stretching with stiffening evident – movements slow
12. Upper limbs, frantic	12. Motor movements of upper limb spastic, chaotic/agitated (fast occurring/ uncoordinated). Unlike #18, limb movements are not wide sways – rather, they are short occurring and rapidly changing
13. Head positioned right	13. Head to right of sternum, turned 30° or more from midline
14. Fingers splayed	14. Palms open, hyperextension/widening of spaces between 1 or 2 fingers
15. Hands tightly fisted	15. Palms closed, fingers curled/tightly clenched
16. Drawn in and exhausted - but	16. Responsiveness where motor movements are

Type of behavior	Definition of the behavior
calling out, marked facial grimacing with cry	visibly tense, face creased or puffy, facial muscles strained – cry exhausted in quality
17. Shoulders, strenuous downward movements	17. Strained adduction of elbows with strained hunching of shoulder and neck extension. Elbows clenched down, squeezed in towards chest.
18. Upper limbs, flaying	18. Arm movements are uncoordinated wide sways that seem aimless. Not as rapidly changing as #12.
19. Hypersensitive, brief episode of uncontrolled motor movements with screech cry	19. Brief responsiveness where motor movements are spastic, chaotic and agitated (fast occurring, and uncoordinated). Unlike # 26, episode is brief and cry is a high pitch screech
20. Upper limbs, immobile – not relaxed	20. Limbs are stiff or limp. Baby is not relaxed, immobile
21. Shoulders, exaggerated shift like movements	21. Exaggerated movements of baby' upper torso shifting of the shoulders and/or lifting of self– as if struggling to escape from something
22. Upper limbs, tense	22. Increased tension of upper limb movements, however, not stiff
23. Calling out, cry is loud and broadcasting	23. Eyes open or closed, head is usually in midline position, and slightly tipped back, mouth is open wide- cry is loud/ broadcasting
24. Upper limbs, tremulous/jerky	24. Transient spastic, halting and/or quiver like movements of upper limbs
25. Bilateral arm extension, equal arm distance	25. Arms extended upward, hands/fist open or closed but facing each side of baby's head, distance between arms equal, small rhythmical inward and outward movements of the arms, occurs with cyclical cry
26. Hypersensitive, prolonged uncontrolled - motor movement with cry (intermittent screeches) baby unable to wind down	26. Responsiveness where sudden, intense, and/or prolonged reaction to any stimuli. Cry escalating; variations in call and frantic screech cry. Motor movements chaotic, jerky,

Type of behavior	Definition of the behavior
	or uncoordinated. Baby has difficulty winding down from initial frantic response, reacts in a heightened manner to ongoing internal/external stimulation.
27. Breath holding	27. Self evident
28. No cry but pronounced facial grimacing, cry face	28. Baby appears to be crying but no cry - face creased or puffy -very strained
29. Self absorbed, irritable	29. Baby quietly looking ahead but at nothing in particular not content, crying /fussy, not interested in surroundings
30. General body movements, effortful - labored	30. Quality of whole body movements are labored, very tense
31. Drawn in but calling out, cyclical cry	31. Baby's eyes shut, drawn into self - not engaged. Little motor movement, cry is repetitious
32. Upper limb, limp	32. Flaccid or floppy appearance to upper extremities
33. Neck hyperextension	33. Neck and head stretched back and slightly sideways
34. Upper limbs, abrupt intentional	34. Movements of upper limb directed – forceful
35. Hand(s) movements, swiping	35. Abrupt immediate and intentional movement of the arm and hand – aimed specifically to swat at, wipe away or remove something
36. Neck, lateral extension	36. Neck stretched sideways and slightly back
37. Respiratory - gasping sound	37. Self evident
38. Hands, cradle head with hand(s)	38. Self evident
39. Hands, clutching motions	39. Abrupt grabbing motions of hands (usually to linen or thin air).
40. Hand(s) scratch or claw self	40. Self evident

Table 4A

Neonatal distress behavior: Ranked by order of mean duration and then frequency for diaper change and restraint application events

DIAPER CHANGE

D#	Rank		%	f	n
		Exhibited by 3 or 4 neonates			
13	1	Head positioned right	76	19	4
22	2	Upper limbs, tense	61	8	4
15	3	Hand(s) tightly fisted	57	13	4
1	4	Cry	53	10	3
29	5	Self absorbed and irritable	31	12	4
14	6	Fingers, splayed	14	8	3
		Exhibited by 1 or 2 neonates			
23	7	Calling out, cry loud and broadcasting	39	11	2
7	8	Fist/plams extension front side facing	27	1	2
8	9	Head, midline postioning	23	19	2
4	10	Cry, abrupt- explosive	12	4	2
16	11	Drawn in exhausted, call cry, facial grimacing	10	1	1
5	12	Cry rapidly repeating	9	2	1
24	13	Upper limbs, tremulous jerky	8	3	1
3	14	Cry, exhausted weak sounding	6	1	1
26	15	Hypersensitivity, prolonged and uncontrolled with cry, baby unable to wind down	6	1	1
2	16	Cry- sustained hoarse and strained	6	1	1
11	17	Head movement, very strained	3	1	1
10	18	Upper limbs, stiff	2	1	1
28	19	Drawn in exhausted - facial grimacing, no cry	2	1	1
20	20	Upper limbs, no movement, not relaxed	2	1	1
19	21	Hypersensitive, brief frantic motor movements with screeches	1	1	1
21	22	Exaggerated shift like movements of shoulders	1	2	1
40	23	Hand motions, scratch or claw self	n.a	3	1
33	24	Neck, hyperextension movements	n.a	4	2

RESTRAINT APPLICATION

D#	Rank		%	f	n
		Exhibited by 3 or 4 neonates			
1	1	Cry	60	23	4
23	2	Calling out, cry loud and broadcasting	47	18	3
15	3	Hand(s), tightly fisted	46	3	4
13	4	Head postioned right	44	19	4
8	5	Head postioned midline	23	31	4
29	6	Self absorbed and irritable	18	23	4
4	7	Cry, abrupt - explosive	12	10	4
3	8	Cry, exhausted and weak sounding	9	8	3
17	9	Strenuous downward movement of shoulders	3	12	3
33	10	Neck, hyperextension movements	n.a	11	3
		Exhibited by 1 or 2 neonates			
5	11	Cry- rapidly repeating	17	6	1
26	12	Hypersensitivity, prolonged and uncontrolled with cry, baby unable to wind down	9	2	1
11	13	Head movement, very strained	8	1	1
2	14	Cry- sustained hoarse and strained	4	5	2
28	15	Drawn in exhausted - facial grimacing, no cry	2	4	1
31	16	Drawn in - cyclical cry	2	1	1
36	17	Neck, lateral extension movements	n.a	8	2

Note. D # = definition number; Rank= ordered by greatest duration and then greatest frequency as 3 or more neonates expressed the behaviors and as 2 or less neonates expressed the behaviors, % = percentage of time (duration) neonate(s) spent assuming a behavior for that event, f = occurrences of rapid occurring behavior; n = number of neonates exhibiting the behavior; n.a = no duration scores calculated as refer to momentary types of behavior; % scores do not add up to 100 because each of the scores represent the most prominent behavior within a particular category of distress.

Table 4B
Neonatal distress behavior: Ranked by order of mean duration and then frequency for baseline and circumcision events

BASELINE

D#	Rank		%	f	n
		Exhibited by 3 or more neonates			
13	1	Head positioned right	94	17	4
15	2	Hand, tightly fisted	66	41	4
22	3	Upper limbs, tense	47	12	4
29	4	Self absorbed and irritable	29	26	4
1	5	Cry	21	13	4
14	6	Fingers splayed	7	27	4
8	7	Head postioned midline	4	9	3
		Exhibited by 1 or 2 neonates			
23	8	Calling out, cry loud and broadcasting	20	11	2
4	9	Cry, abrupt- explosive	5	3	2
24	10	Upper limbs, tremulous - jerky	3	7	2
5	11	Cry rapidly repeating	3	2	2
31	12	Drawn in, cyclical cry	2	2	2
7	13	Fists/palms raised front/side facing	2	2	1
2	14	Cry, sustained hoarse and strained	2	2	1
3	15	Cry, exhausted, weak sounding	1	1	1
33	16	Neck, hyperextension	n/a	7	2

CIRCUMCISION

D#	Rank		%	f	n
		Exhibited by 3 or more neonates			
1	1	Cry	76	43	4
7	2	Fists/palms raised front/side facing	64	11	3
8	3	Head postioned midline	63	20	4
10	4	Upper limbs, stiff	47	21	4
11	5	Head movements, very strained	45	24	4
22	6	Upper limbs, tense	36	13	4
13	7	Head positioned right	35	18	4
14	8	Fingers splayed	32	36	4
2	9	Cry, sustained hoarse and strained	29	34	3
15	10	Hands, tightly fisted	29	25	4
16	11	Drawn in exhausted, facial grimacing, cry	26	20	4
17	12	Strenuous downward movement of shoulders	25	31	3
3	13	Cry, exhausted weak sounding	25	24	4
26	14	Hypersensitivity, prolonged uncontrolled with cry, baby unable to wind down	20	6	3
5	15	Cry rapidly repeating	18	14	3
4	16	Cry, abrupt- explosive	16	17	4
20	17	Upper limbs, no movement, not relaxed	13	6	3
21	18	Exaggerated shiftlike movements of the shoulders	12	15	4
24	19	Upper limbs, tremulous and jerky	11	13	3
23	20	Calling out, cry loud and broadcasting	11	9	4
19	21	Hypersensitive, brief frantic motor movements with screeches	8	13	3
28	22	Drawn in exhausted - facial grimacing, no cry	7	7	4
29	23	Self absorbed and irritable	6	6	4
33	24	Neck, hyperextension	n/a	21	4
		Exhibited by 1 or 2 neonates			
31	25	Drawn in, cyclical cry	9	6	2
40	26	Hand(s) scratch or claw self	n/a	14	1
36	27	Neck, lateral extension	n/a	10	2

OBSERVED ONLY DURING CIRCUMCISION

D#	Rank		%	f	n
		Exhibited by 3 or more neonates			
9	1	Upper limbs, very strained and labored	49	25	4
6	2	Cry- high pitch harsh screech	11	20	4
25	3	Bilateral arm extension, maintaining equal arm distance	11	20	4
27	4	Breath holding	8	15	4
18	5	Upper limbs, flaying	n/a	23	3
34	6	Upper limbs, abrupt and intentional	n/a	14	4
12	7	Upper limbs, frantic	n/a	10	4
35	8	Hand(s), swiping motions	n/a	8	3
		Exhibited by 1 or 2 neonates			
30	9	General body movement, very tense strained	24	6	2
32	10	Upper limbs - limp	6	1	1
37	11	Respiratory - gasping sound	n/a	10	2
38	12	Hands, cradle head	n/a	8	2
39	13	Hands, clutching motions	n/a	5	2

Note D # = definition number; Rank= ordered by greatest duration and then greatest frequency as 3 or more neonates expressed the behaviors and as 2 or less neonates expressed the behaviors, % = percentage of time (duration) neonate(s) spent assuming a behavior for that event, f = occurrences of rapid occurring behavior; n = number of neonates exhibiting the behavior; n/a = no duration scores calculated as refer to momentary types of behavior; % scores do not add up to 100 because each of the scores represent the most prominent behavior within a particular category of distress;

Table 5A

Neonatal distress behavior: Ranked by order of mean duration and then frequency for post diaper change and post circumcision events

POST DIAPER CHANGE

Rank		%	f	n
	Exhibited by 3 or 4 neonates			
1	Right upper limb, regular tucking and un-tucking of arms	53	5	3
2	Self absorbed, irritable	29	8	3
	Exhibited by 1 or 2 neonates			
3	Bilateral hip knee flexion with leg kicks	67	2	2
4	Lower limb muscle tone, regular	40	3	2
5	Left upper limb, regular tucking and un-tucking of arms	40	2	2
6	General body movements, free flow, relaxed	27	3	2
7	Rhythmical leg kicking, smooth and relaxed	27	3	2
8	Hypersensitivity, frantic motor movement with cry, unable to wind down	15	2	1
9	Upper limbs - variable freeflow	14	3	2
10	Drawn in- cyclical cry	13	3	1
11	Self absorbed, content	9	2	2
12	Alert, tense listening	7	1	1
13	Calling out, cry loud and broadcasting	6	2	2
14	Quietly listening	4	2	2

POST CIRCUMCISION

Rank		%	f	n
	Exhibited by 3 or 4 neonates			
1	Right lower limb extended and immobile	58	32	4
2	Lower limb muscle tone, tense irritable	56	7	4
3	Left lower limb extended and immobile	47	22	4
4	Bilateral lower limbs, extended and immobile	37	19	4
5	General body movements, no movement, immobile, not relaxed	34	11	4
6	Lower limb muscle tone, lack muscle tone - limp	28	10	3
7	Bilateral hip knee flexion with leg kicks	25	20	4
8	Self absorbed and irritable	25	19	4
9	Right upper limb, regular tucking and un-tucking of arms	23	20	3
10	Drawn in- cyclical cry	20	14	3
11	Bilateral hip knee flexion, no leg kicks	19	10	4
12	Calling out, cry loud and broadcasting	15	11	4
13	Alert, tense listening	4	4	3
14	Quietly listening	2	5	4
	Exhibited by 1 or 2 neonates			
15	Lower limb brace, postion change (Rt)	26	10	2
16	Lower limb muscle tone, stiff	22	3	1
17	Hypersensitivity, frantic motor movement with cry, unable to wind down	19	4	2
18	Lower limb muscle tone, regular	17	2	1
19	Head movement quality, very strained	12	1	1
20	Upper limbs, variable, freeflow	11	3	2
21	Left upper limbs, regular tucking and un-tucking of arms	8	6	2
22	General body movement, tremulous, jerky	5	6	2
23	Self absorbed, content	2	2	1
24	General body movement, free flow, relaxed	2	2	1
25	Rhythmical leg kicking, smooth and relaxed	2	2	1

Note: Rank = ordered by greatest duration and then greatest frequency as 3 or more neonates expressed the behaviors and as 2 or less neonates expressed the behaviors; % = percentage of time (duration) neonate(s) spent assuming a behavior for that event; F = occurrences of rapid occurring behavior; n = number of neonates exhibiting the behavior; n a=no duration scores calculated as refer to momentary types of behavior; % scores do not add up to 100 because each of the scores represent the most prominent behavior within a particular category of distress

Table 5B
Neonatal distress behavior: Ranked by order of mean duration and then frequency for baseline and post restraint application events

BASELINE

Rank		%	f	n
Exhibited by 3 or 4 neonates				
1	Bilateral hip knee flexion with leg kicks	83	22	4
2	Left upper limb, regular tucking and un-tucking movements	62	23	4
3	Right upper limb, regular tucking and un-tucking movements	58	12	4
4	Rhythmical leg kicking, smooth and relaxed	45	22	4
5	Upper limbs - variable, freeflow	45	15	3
6	General body movements, free flow, relaxed	42	13	4
7	Self absorbed, irritable	31	26	4
8	Self absorbed, content	31	18	4
9	Lower limbs, regular	29	8	3
10	Calling out, cry loud and broadcasting	27	11	3
11	Right lower limb brace, position change	2	5	3
Exhibited by 1 or 2 neonates				
12	Right lower limb extended and immobile	20	5	2
13	Left lower limb extended and immobile	7	5	2
14	Bilateral lower limb extended and immobile	7	5	2
15	Quietly listening	3	8	2
16	Bilateral hip knee flexion, no leg kicks	3	2	2
17	General body movement, no movement, immobile, not relaxed	3	2	2
18	Drawn in, cyclical cry	3	2	2
19	Lower limb muscle tone, lack muscle tone - limp	2	1	1
20	Lower limb muscle tone, stiff	1	1	1

POST RESTRAINT APPLICATION

Rank		%	f	n
Exhibited by 3 or 4 neonates				
1	Lower limb muscle tone, tense irritable	45	13	4
2	Lower limb muscle tone, regular	45	8	4
3	Bilateral hip knee flexion with leg kicks	44	32	4
4	Bilateral hip knee flexion, no leg kicks	44	19	3
5	Rhythmical leg kicking, smooth and relaxed	30	7	4
6	General body movement, free flow, relaxed	29	12	4
7	Right upper limb, regular tucking and un-tucking movements	23	12	4
8	Self absorbed, irritable	22	24	4
9	Left upper limb, regular tucking and un-tucking	22	20	4
10	Self absorbed, content	19	8	3
11	Upper limbs, variable, freeflow	19	8	3
12	General body movements, no movement, immobile, not relaxed	16	10	3
13	Quietly listening	13	7	3
14	Calling out, cry loud and broadcasting	7	6	3
15	Lower limb brace, postion change (Lt)	4	9	3
Exhibited by 1 or 2 neonates				
16	Lower limb muscle tone, stiff	12	8	2
17	Alert, tense listening	10	5	2
18	Lower limbs, immobile, lack muscle tone	11	5	1
19	Bilateral lower limb extended and immobile	8	8	2
20	Head movement quality, very strained	8	1	1
21	General body movements, tremulous, not relaxed	7	12	2
22	Right lower limb extended and immobile	5	4	2
23	Drawn in, cyclical cry	5	4	1
24	Hypersenstivity, frantic motor movement with cry, unable to wind down	1	1	1
25	Left lower limbs extended and immobile	1	1	1

Note Rank = ordered by greatest duration and then greatest frequency as 3 or more neonates expressed the behaviors and as 2 or less neonates expressed the behaviors; % = percentage of time (duration) neonate(s) spent assuming a behavior for that event; F = occurrences of rapid occurring behavior; n = number of neonates exhibiting the behavior; n a=no duration scores calculated as refer to momentary types of behavior; % scores do not add up to 100 because each of the scores represent the most prominent behavior within a particular category of distress

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CHAPTER SIX

General Discussion and Conclusions

In the past 25 years, we have shifted from viewing human neonates as buzzing states of confusion to acknowledging them as interactive beings who demonstrate sophisticated perceptual and communication competencies (Slater & Johnston, 1998). These insights have primarily come from utilizing developmental frameworks and basic observational methods to study newborn response patterns (Rovee- Collier, 1996). The purpose of this ethologically based research was to apply basic observational methods to the study of neonatal pain for the purpose of contributing descriptive level information about the pain behaviors. However, like any new approach, the value of the method will lie in its ability to further current understanding of the topic and in its ultimate potential to contribute to improved neonatal pain outcomes. In summarizing the manuscripts contained in this document and discussing their interrelatedness, the value of ethological methods and the outcomes of this dissertation research are discussed in terms of their advantages and limitations as well as the promise such methods hold for the science of nursing and the field of neonatal pain research.

Advantages of Ethological Methods and Achievements of This Research

In Manuscript One, the philosophical fit between the science of nursing and the science of ethology were examined to determine the usefulness of ethological methods for generating basic descriptive knowledge about human behaviors for nursing. Determining the fit between underlying philosophical assumptions is important for several reasons. Although not explicated in any of the manuscripts, the issue of philosophical orientation fundamentally underlies the process in establishing construct validity of behavioral constructs that are complex and not directly observable, such as pain (Kerlinger, 1979). As perspectives for practice, research and scholarship, philosophical orientations underlie how disciplines seek to research topics of interest to them and how they develop their respective bodies of knowledge (Salsberry, 1994).

As suggested in Manuscript One, employment of compatible methods from the science of ethology may help construct a credible and sound body of knowledge about human behaviors commensurate with the scientific and professional aims of nursing. In addition, the benefits of employing basic research designs and inductive systematic observation were discussed by way of contrasting the typical behavioral approaches used in nursing with those used in ethology. Arguments in support of ethological methods, as outlined in Manuscript One, may provide interested nurses the incentive to conduct basic observational research. These basic investigations could involve inductive use of systematic observation and subsequent deductive approaches to develop a middle range theory about a particular behavioral phenomenon. If developed, a middle range theory would have favorable impact on nursing as it would equip clinicians with credible integrated knowledge about the phenomenon that is directly applicable for guiding their practice. Details of how the two-phased ethological approach could be employed were illustrated in Manuscript One and later elaborated upon in Manuscripts Three and Four.

In Manuscript Two, an overview of the research literature on neonatal pain, and in particular, on neonatal pain behavior was presented. The overview revealed that major advancements have occurred as a result of incorporating neurodevelopmental frameworks to the study of newborn pain. The review also indicated a gradual evolution, over the past two decades, in the focus and design of the research. While some researchers have regarded neonatal pain as a multidimensional phenomenon (Stevens, Johnston, Petryshen & Taddio, 1996), others have pursued measuring only one or two of its dimensions (the physiological, biochemical or behavioral). Of the individual responses measured, some were noted to be developmentally sensitive, such as infant state. However, some were based on *a priori* descriptors borrowed from the adult pain literature and assumed representative of neonatal pain (Franck & Miaskowski, 1997). The overview also showed most research on the three dimensions of neonatal pain were applied and deductive; emphasis on applied inquiry likely occurred because studies were originally designed to improve clinical pain outcomes as opposed to being designed to develop basic theoretical knowledge not immediately useful for clinical application.

While the applied and deductive nature of the research evidently resulted in a wealth of pain measurement findings and while composite measures of neonatal pain were starting to be developed, correlations between and among the measured indices were also evidently difficult to assess and or measure consistently over time. Also neonatal pain assessment instruments were being developed despite the measurement difficulties researchers were faced with. The review also revealed other important issues such as the dearth of basic studies to ground conceptual understanding and support construction of the applied knowledge, and the problematic adherence to describing neonatal responses to an immediate pain stimulus even though newborn response patterns are highly variable and not always specific to pain. Critiqued as well are the conventions of collecting pain behavior data using few pain behaviors; relying on extremely short data collection time frames; and utilizing short-term pain models.

On the basis of the overview, the argument was made that some of our current approaches to investigating neonatal pain are imperfect and that some might underlie current difficulties in assessing and obtaining consistent measures of neonatal pain. The argument adds that the research, and in particular the focused nature of the behavioral research, may have inadvertently overshadowed the importance of further behavioral inquiry, and that the lack of comprehensive description of newborn pain behavior may be delaying conceptual understanding of the entire phenomenon. Knowledge of the imperfections in the research and consequent gaps in comprehensive understanding of neonatal pain behavior provided the basis for suggesting basic ethological methods and for using the context of distress to add breadth and depth to the exiting body of behavioral knowledge on the topic. This basis rests on the belief that behaviors provide the most direct and objective means for learning about neonates and their pain (Craig & Grunau, 1995). Ethological methods were presented as novel approaches to expand the range, scope and descriptive detailing of the behaviors including descriptions of the pain context. As Wall (2000) predicts, advancements in pain knowledge will come not only from improving pain outcomes but from understanding the context in which pain resides.

In addition to permitting description of the context of pain and identifying internal and external factors influencing the newborn's behavioral response to noxious and other forms of sensory stimuli, ethological methods were proposed as they promised to add a multi-method approach to the valid study of neonatal pain. That approach is in keeping with the complex nature of the construct under study. As Streiner and Norman (1998) argue, a multi-method approach may help increase the generalizability of behavioral findings, and generalizability helps in the valid construction of neonatal pain assessment instruments. While an inability to assess neonatal pain underlies current problems in neonatal pain treatment, basic behavioral description were proposed as important solutions to solving some of these problems as they represent important perquisites to developing sound pain assessment information.

In Manuscript Three (Phase One) and Manuscript Four (Phase Two), ethological methods and the context of neonatal distress were employed to address some of the knowledge and research shortcomings raised in the first two manuscripts of the dissertation. Similar to the basic study conducted by Cote, Morse and James (1991), the two-phased basic research, reported in this document, represented basic and broad based approaches to the study of neonatal pain expression.

Specifically, in this study, the decision to focus on describing neonatal distress afforded unique opportunity to "work" with the variable response pattern of the neonates. Because the approach was not limited to the immediate stimulus-response paradigm, it promised to lend to a broader perspective for understanding how neonates normally respond to the range of sensory stimuli they receive when exposed to pain. Other researchers agree in taking broad approaches to study infant related phenomenon. Experts from the fields of infant development predict that novel insight into the meaning of newborn stress and coping will come from observing neonates as they interact with their environments and linking behavioral data with simultaneously occurring physiological data (Gunner & Donzella, 1999). This prediction is based on the belief that behaviors reflect a complex matrix of underlying regulative processes. In taking a broad approach, Gunner and Donzella advise against the fruitless pursuit of trying to find correlational relationships between the multiple independent yet integrative responses of newborn stress reactivity. Instead, they suggest more research to understand just how overt and hidden stress related processes interact to regulate and modify each other, such as those involving caregiver presence, infant state and cortisol levels.

In Phase One of the study, the use of inductive ethological methods led to successful creation of a reliable ethogram which included an exhaustive listing of neonatal distress behaviors. Unlike the ethogram developed by Cote et al. (1991), which contained descriptions of postoperative distress behaviors, the ethogram developed in Phase One contained descriptions of behaviors specific to surgery and other distress provoking but non-noxious events. Differences in how each of the two basic studies was conducted resulted in different contributions. In this study, the strategy of systematically describing behaviors to the actual surgery and avoiding an inferential approach to reducing the large data set helped describe the range of distress behaviors for the events observed. The large numbers of behaviors reported support claims made in Manuscript Two that neonates exhibit a wide range of recognizable behaviors to distress provoking situations, including those that are noxious. Some of the findings reported in this study confirmed reports made by others, whereas, others represented novel descriptions that will add to the body of knowledge on newborn pain and distress behavior. Collectively, the range of descriptive outcomes supports the argument for basic inductive approaches to further conceptual understanding of newborn pain and distress. They provided the basis for a continued basic study on the behaviors in Phase Two of the research.

In Phase Two, one of the most important reasons for employing ethological methods and taking the broad based approach of focusing on distress was that the strategies offered credible research alternatives for generating fine grained descriptions of the behaviors and they provided unique approaches to descriptively distinguish between neonatal distress and neonatal pain. Inability to distinguish distress from pain has been a difficult clinical and research issue that has had theoretical and clinical implications. As discussed in the animal pain literature, distress functions to activate neural pathways in the limbic system responsible for processing emotional responses to pain, fear and anxiety (Rowen, Stephens, Dolins, Gleason & Donley, 1999). Perhaps in distinguishing distress, ongoing basic research might help further insight into the multiple dimensions of neonatal pain, including the now nebulous emotional component.

Results of Phase Two showed that newborns do indeed exhibit distress in response to both noxious and non-noxious stimulation. Findings of the 26 distress behaviors across noxious and non-noxious distress events support claims made by Johnston and O'Shawgnessy (1987) about the nonspecific nature of neonatal pain response patterns. They also support the findings of Breau, McGrath, Camfield, Rosmus and Finley (2000) who maintain that distress is an inherent component of acute pain. Together the findings suggest neonates respond to most stimuli in a distressful manner.

However, this research also showed that it is possible to distinguish newborn distress behaviors that are specific to acute pain stimulation (extreme distress). Specifically, those findings came from utilizing ethological strategies to define neonatal distress behaviors in temporal terms and rank ordering them by duration. They resulted in producing a precise graded description of newborn distress and identifying responses specific to the acute pain of newborn male circumcision. They also led to novel description of the amount of time neonates spent exhibiting acute pain; all adding important description about the quality of the behaviors. In this study, most of the 27 distress behaviors reported occurred the most frequently and they lasted the longest during the circumcision event compared to the restraint application event or the diaper change event. Of those 27 behaviors, 13 additional behaviors occurred only during actual circumcision, and, of those, all four neonates expressed six of the behaviors: high pitched harsh screech, abrupt and intentional movements of the upper limbs, very strained, frantic and labored movements of the upper limbs, breath holding and bilateral arm extension and maintaining equal distances between the arms. The last four are unique to this study, as they have not been previously reported in the neonatal pain literature.

In this study, the ability to distinguish the 13 expressions of extreme distress (acute pain) may have occurred because the study involved testing newborn male circumcision; acknowledged as one of the most intense forms of acute pain (Porter, Miller & Marshal, 1986). While results of this study also indicate that it is possible to distinguish between grades of non-noxious distress, it is unclear if behaviors in response to less intense forms of acute pain can also be commonly distinguished. It may be that neonates receive less intense forms of acute pain as generalized distress. If so, those findings will nonetheless less be important as they will guide further inquiry to determine their implication, particularly for neonates who may lack the developmental capacity to inhibit incoming sensory stimuli. Ongoing testing of the ethogram to different types and intensities of newborn distress and pain will further distinguish behaviors specific to pain.

A related benefit to using distress to study neonatal pain was that it led to the identification of individual differences in newborn distress expression (the consistent hypersensitivity exhibited by two of the neonates). As suggested, hypersensitivity may be reflective of the individual newborn's developmental ability to self-organize in response to sensory stimulation, particularly at this epoch in newborn development. If consistently observed elsewhere, their occurrences call for further inquiry to study the interactive effects of distress on pain and to determine its role in neonatal coping and recovery from pain. It may be that newborn hypersensitivity may be predictive of prolonged distress following exposure to pain (indicating delayed recovery from distress and pain) for particular neonates. If so, this will be important for nursing, for it is basic knowledge that may provide direction for individualized newborn pain care and the impetus for further developing strategies to prevent and or treat neonatal distress and pain. The benefits of basic knowledge for guiding theory based nursing practice were discussed further in Manuscript Two.

As explained in Manuscript Three, no attempts were made to subject the ethogram to validity testing following its inductive creation. In addition to the other reasons given, the rationale for this decision was methodological in nature. As Suen and Ary (1989) explain, one of the most fundamental validity requirements for creating a behavioral coding scheme (an ethogram) is that it be representative and exhaustive. Although this research is exploratory, continuing to develop the ethogram through increased sampling as well as testing it in pain and non-pain situations will help strengthen the content and construct validity of the ethogram. The range of representative and reliable descriptor items contained in the developed ethogram will in turn help construct neonatal pain assessment instruments having strong psychometric properties.

Study Limitations

In this study, limitations associated with use of the secondary videotaped data are discussed in Manuscripts Three and Four. Additional limitations involve subject information, types of behaviors sampled and costs associated with the research. Gestational age is an important variable which may account for the individual expressions of distress reported in Phase Two. Although neonates in this study were all over 38 weeks gestation, as taken from the maternal prenatal care documents (personal communication B. Brady-Fryer, July 2, 2001), it is unclear how gestational age of the neonates were actually calculated. As Dodd (1996) maintains, neonates of differing gestational age exhibit and respond to stimuli differently. The two neonates who displayed hypersensitivity may have lacked ability to inhibit incoming sensory inputs as a result of their gestational age. Such hypersensitivity may render some newborn infants highly receptive to ensuing pain stimulation (Fitzgerald, 1991). Having clear information about gestational age and the ability to select for this confounding variable will help clarify and/or give direction to the preliminary finding that increased sensitivity and prolonged recovery can occur in response to otherwise neutral stimulation.

Another important factor known to influence neonatal response patterns is infant state (Prechtl, 1974). Although most neonates in this study were awake and alert at the start of data collection for all seven events, we did not code for infant state during the course of each observation period. Inclusion of already defined descriptions of infant state, such as those developed by Prechtl, may improve the quality of study findings since it provides supplemental knowledge of the neonate's regulative capacity. Their inclusion may also be instrumental in describing the newborn's behavioral response during the extended postoperative period (up to 72 hours after surgery), particularly to determine if neonates who are exposed to intense acute pain, such as circumcision, sleep for extended periods following the surgery. If so, those findings will support suggestions made by Prechtl about the restorative and regulative function of sleep during early human development. Further, inquiry into infant state and neonatal pain may advance descriptive understanding of neonatal recovery from prolonged and or repetitive pain.

Another limitation of this study pertained to the cost of conducting the research. For the four cases, in Phase Two of the study, for example, it took approximately 1696 hours to code 67 minutes of continuous data. Although the benefits of generating basic data offset the costs, this behavioral research was expensive and labor intensive as it required technologies capable of capturing and precisely recording fast occurring neonatal motor movements. As well, the two-phased study required employment of a qualified research assistant to help conduct ongoing reliability testing of the ethogram and to assist with continuous time coding. In the future, event recorders and updated digital equipment will help facilitate collection and immediate storage of the data as it is observed. These technological advances may also help reduce any error resulting from the second by second coding of multiple behaviors via pencil and pen method.

Data Analysis Issues

The ethogram developed in this research differs from most of those described in the ethological literature: while most ethograms consist of a number of exclusive behavioral categories, this ethogram consisted of 35 main categories that were not in themselves mutually exclusive (although each consisted of subcategory sub-items that were mutually exclusive). The non-exclusive nature of the main categories, however, is representative of newborn motor behavior which is rapid and co-occurring.

The atypical nature of this ethogram (dependency of main descriptor items) subsequently limits the types of statistics that can be appropriately performed on the behavioral data. Other than simple descriptives (frequency and duration) more sophisticated analyses such as those associated with sequential patterning in the behavioral data have to be conducted using specialized programs such as Sequential Data Interchange Standard (SDIS) and Generalized Sequential Querier (GESQ) (Bakeman & Quera, 1995). Yet, given gaps in basic description of the frequency and duration of most neonatal pain behaviors, descriptive statistics are ideal and timely and they provide the basis for subsequent research into the nature and implications of prolonged distress.

When no new behaviors can be described with further sampling and testing, the ethogram may then be reduced to facilitate meaningful analysis of the behaviors. Such reduction may first involve combining behaviors that represent same phenomenon (to reduce redundancy) and assigning appropriate weighted averages to relevant but extremely rapid occurring behaviors that might otherwise be eliminated if subjected to a statistical grouping technique. It may also involve considering the intuitive or contextual meaning of the behaviors. Following these qualitative reducing strategies, the ethogram may then be subjected to a factor analysis procedure to identify groupings in the data and to help test its internal structure. Other deductive strategies may include factorial or comparative approaches to help determine the interactive effects of distress on pain and to comparatively distinguish distress by event. As discussed, those forms of inquiry await further development of the ethogram and appropriate data reduction strategies.

It may be argued that the small numbers of neonates sampled in this study are too few to make conclusive study statements. In ethological-based studies, the unit of analysis is behavior, and, in addition, sampling usually involves subjects, time and events (Sackett 1978). Yet, because we analyzed behaviors as they occurred by event, and because the 35 categories of (235 individual) behaviors were sampled over 4020 seconds, ample data was available for precise descriptive level findings. Because this study is basic and findings are preliminary, ongoing investigation is indisputably required before any generalizations can be made about the study findings reported.

Implications for Nursing and the Neonatal Pain Field

Since nursing deals with complex behavioral phenomenon and non-verbal populations, the ethological methods described in this study may provide guidance for knowledge development in such areas. However, the primary outcome of Phase One (Manuscript Three) will not have direct or immediate practice benefits since it represents basic descriptive level information that is of conceptual rather than of practical benefit. For example, the ethogram itself cannot be used to assess neonatal pain. As explained in

Manuscript One, the benefits of the ethogram will lay in its potential to develop a strong foundation of descriptive information for nursing (and the neonatal pain field). Advancements in these areas and their relevancy for nursing will come from conducting basic research on the behavior and integrating it with applied knowledge, as in development of a middle range theory on newborn pain assessment. Conducting basic research within the context of an applied problem is a suggested new approach to integrating basic and applied research in the associated fields of infant development and infant psychology (Rovee-Collier, 1996; Schwebel, Plumert & Pick, 2000). For the developmentalist, this synergistic approach to knowledge development could arise from combing basic knowledge about developmental processes and combining it with knowledge about the practical everyday functioning of the processes (Schwebel et al.).

As a form of basic information, the reliable ethogram provides researchers a credible means for furthering fundamental descriptive understanding of newborn distress behaviors that are associated with acute pain. As discussed, we currently lack this knowledge, and such paucity may underlie some of the current conceptual and methodological problems in the neonatal pain field (as reviewed in Manuscript Two). With further inclusion of inductively derived descriptor items (through continued testing), the reliable ethogram will assist in constructing conceptually grounded neonatal pain assessment instruments. This development will have significant relevance for nursing practice in that inductive approaches may add items that are clinically relevant to the behavioral component of a neonatal pain assessment instrument. These may include the inclusion of simultaneously occurring stimuli (e.g., touch and sound) when scoring for pain and recording neonatal responses over time to obtain an overview of the pain context and the trajectory of the neonate's pain response pattern.

Because the ethogram contains basic knowledge, it will also have the added potential to broaden the scope of neonatal pain investigation in areas not yet described or understood. In this way, the ethogram may be used to investigate questions about neonatal distress behaviors that emerge from the practice setting. Because findings from Phase Two are preliminary, continued study is required. However, descriptions of extreme expressions of neonatal distress, novel descriptions of distress duration and the individual differences in hypersensitivity are important basic descriptions that can be investigated for their potential in informing and guiding clinicians to correctly identify neonatal pain behavior. Development in these areas will contribute to our fundamental understanding and ability to assess neonatal pain, all to improve newborn pain outcomes.

Future Directions

This ethological-based research provides the basis for continued basic description of neonatal pain behaviors and subsequent deductive inquiry about them. Before it can be generally applied to develop clinically relevant pain knowledge, the ethogram must demonstrate that it is representative of newborn acute pain and distress (valid) and that it can be applied consistently (reliable). This will mainly be achieved through continued development of the ethogram involving several steps. Each of the steps involves sampling healthy human neonates who are of similar gestational ages. Each step involves non-intrusive description of newborn distress behavior within the context of acute pain and application of ethological methods, including using Kappa reliability procedures.

First, sampling must be broadened to include pain behavior description of other male newborns as they experience different types of neonatal acute pain, such as heel lance and other forms of newborn surgery. That approach will optimize construct validity of the ethogram; it will test the extent to which behaviors composing the ethogram are representative of male newborn infants who undergo varying types of acute pain and associated distress. As discussed, it is unknown if a less intense form of acute pain can be clearly distinguished. Such knowledge can only be explicated through continued inductive development of the ethogram to determine the extent to which neonates exhibit different behaviors to different intensities of distress and acute pain.

Once saturation is achieved in those sets of studies (meaning no further distress behaviors can be described in male newborns to varying types and intensities of acute pain), sampling may then be broadened to include female neonates of similar gestational ages who also experience similar kinds of acute pain and distress. Inclusion of those types of studies will not only help further test the validity and reliability of the ethogram (and possibly augment it), they will also contribute to the dearth of investigation on gender expression of pain during very early human development.

Currently, findings on gender differences in human pain expression during infancy and childhood are discrepant although more consistent findings are reported in the adult pain literature with females reporting pain more than males (Fillingim, 2000). Within the infant pain literature, some researchers report females display increased facial expressions in response to repeated physical exam (Gunner, Conners & Isensee, 1989), and venipuncture (Guinsburg et al. 2000), while others report no gender differences in behavioral or physiological responses to heel lance pain (Owens & Todt, 1984; Stevens, Johnston & Horton, 1994). Increased pain behavior in female children and female adults are thought to be due to social modeling (Unruh, 1996); yet evidence is emerging of gender differences in pain behavior in the animal research literature (McClure, 2000).

Guinsburg et al. (2000) believe that discrepant findings about gender differences in infant pain expression occurred because of the absence of a gold standard to assess and measure infant pain. In his meta-analysis on gender differences in facial expression, McClure (2000) suggests that opposing findings might have occurred because researchers tested mild pain and used short-term pain models. To strengthen the methodological quality of the studies, McClure recommends increasing sample size, testing pain that is repeated or prolonged in nature and utilizing longitudinal study designs. Basic approaches may also assist with comparative analysis of the frequency and duration of distress related pain expression between newborn males and females.

Inductive studies to describe newborn distress behavior in female newborns to varying kinds of acute pain (including surgery and short term invasive procedures) will continue until saturation is reached and the ethogram is deemed representative of healthy male and female neonates and varying kinds of acute pain. At this point, the ethogram can be subjected to the reduction process described earlier. Common behavioral descriptions arising from use of the ethogram can then be used to construct the behavioral component of a neonatal pain assessment instrument. This will involve combining the behavioral descriptions with already developed descriptions of newborn acute pain behavior, such as facial action and adding these with physiological and biochemical neonatal pain indicators such as change in heart rate and oxygen saturation.

Because the developed ethogram will represent a descriptive database about newborn distress related acute pain behaviors, behaviors composing it can be used to assess distress in ill full term neonates exposed to acute pain or to assess the behavior in full term neonates exposed to repeated bouts of noxious and non-noxious but distress provoking events. The ethogram may also be used to conduct comparative analysis. This might involve using the ethogram to describe distress behavior in neonates of varying gestational ages, of varying severity of illnesses, or of premature birth. Yet, ongoing comparative testing may reveal that the developed ethogram is not applicable to neonates of different ages because neurodevelopmental shifts occur at about the 20^{th} day of human life (Beland & Fitzgerald, 2001), meaning that fullterm neonates older than 20 days of age may exhibit less variability in distress expression because they are more neurologically able to inhibit incoming sensory stimuli. While creation of an ethogram for neonates younger than 20 days of age may be specific to only very young neonates, the fast accumulating evidence of the harmful effects of early pain (Anand, 1998) call for in-depth behavioral studies: we need to determine whether developmental differences in newborn pain expression exist and, if so, can these behavioral differences be used toward further investigation? Can the developed ethogram be used, for example, to distinguish graded expressions of distress and pain over time in both newborns and older infants who were exposed prenatally to psychotropic agents now suspected to alter neonatal stress and pain reactivity (Grunau, Oberlander, Fitzgerald, Misri & Riggs, 2000)?

Clearly, the complexity inherent in newborn pain expression demands broad based forms of inquiry including basic and applied research approaches. On the basis of this research, continued use of ethological approaches is justified for both the science of nursing and the neonatal pain field. Basic behavioral approaches hold promise for helping to create the theoretical foundations upon which we can understand and construct applied knowledge about complex phenomenon affecting humans, particularly those who are unable to communicate verbally. Most important, however, is the promise that continued basic investigation holds for deepening our conceptual understanding of newborn pain and distress and the promise it holds for distinguishing pain and furthering pain assessment efforts, challenging but most important keys to improving neonatal pain outcomes

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TABLE A1: NEONATAL PHYSIOLOGICAL AND BIOCHEMICAL RESPONSES TO NOXIOUS STIMULATION

Authors/Sample	Stimulus	Responses Measured	Findings
Rawlings et al., 1980[1] N= 10 fullterm healthy 48-72 hrs old	Circumcision	TcP02 Heart rate Respiratory rate	During circumcision, tcP02 decreased to lower level of pain and remained low with continuing pain. Following circumcision, tcP02 levels increased or exceeded baseline measures. There were significant increases in heart rate and respiratory rate during and after circumcision.
Porter et al., 1988[2] 49 1-2 day old healthy fullterm males responses before, during and after circumcision	Circumcision	Vagal tone Cry acoustics	Vagal tone significantly reduced during severe stress of circumcision and these reductions paralleled significant increases in pitch of neonatal pain cry. Baseline individual differences in vagal tone predicted physiological and acoustic reactivity to subsequent stress.
Benini et al., 1993[3] N= 27 full term 1-3 days old Randomized control	Circumcision	Heart rate Sa02 Facial action Cry acoustics	Compared with baseline, all newborns demonstrated increases in heart rate, decreased oxygen saturation, more facial actions during all phases of procedure. Compared with placebo, EMLA (eutectic mixture of local anesthetics) significantly attenuated pain responses (lower heart rate, high oxygen saturation and less facial activity) No significant differences groups in spectral crying parameters
Bozzette, 1993[4] N= 20 pre and fullterm ill newborns 1-19 days old observation study	Heelstick	Heart rate Respiratory rate Sa02 Motor activity Facial behaviors	Following heelstick, there were significant increases in heart rate, facial behavior, motor responses and behavioral state. Also post decrease in Sa02.
Lewis & Ramsey, 1985[5] N=74 infants at 2, 4, 6 & 16 months of age Longitudinal	Routine immunization	Salivary cortisol Peak facial and vocal expressions 0-3 scale	Cortisol levels collected at baseline, examination and immunization at 4 time points) - videotaping of immunization procedure. Behaviors coded at each 5 second interval. Infants showed an increase in salivary cortisol level over baseline at 18 months that was similar to cortisol levels at 6 months. Cortisol levels showed a decline between 2 and 6 months. Findings suggest shift in adrenocortical functioning occurs by 6 months of age.
Lander et al., 1997[6] N=52 full term health 1 - 3 days of age	Circumcision	Heart rate Cry Methemoglobin level	Placebo group exhibited increased heart rate, high pitched cry throughout and following circumcision. Ring block equally effective throughout all stages of circumcision, dorsal penile block/EMLA (eutectic mixture of local anesthetics) not effective for foreskin separation. Methoglobin levels highest EMLA group
Harpin & Rutter, 1982[7] N= 36 healthy fullterm	Heelstick	Palmar sweat	Autolet less painful than manual pinprick. Autolet group returned to resting palmar sweating level significantly faster than manual lancet group.

Authors/Sample	Stimulus	Responses Measured	Findings
Anand et al., 1985[8] 33 infants, 26 term and 7 preterm	Patent Ductus Arteriosis (PDA) Surgical ligation	Stress Response with minimal anesthesia Glucose, lactate, pyruvate alanine ketones. Glycerine at 0-6-12 and Postoperative mortality	Results show newborns can mount substantial endocrine and metabolic stress response (hyperglycemia and hyperlactatemia associated the release of catecholamines and inhibition of insulin). Preterms and fullterms displayed specific differences. Differences also between neonates given different anesthetic agents.
Williamson & Evans, 1986[9] N=24 healthy fullterm Male newborns 11 dorsal penile block 13 no anesthetic	Circumcision	Cortisol pre and post circumcision	Stress response not reduced by administration of lidocaine. Blood sampling and anesthetic injection did not evoke adrenal response in uncircumcised control. Elevated cortisol levels in neonates given dorsal penile block
Anand et al., 1987[10] N=16 ill premature	PDA surgical Ligation Randomized to Nitrous Oxide Curare or Nitrous oxide & Curare & Fentanyl groups	Postoperative: urine nitrogenous compound levels at 2-3 days; Glucose-Insulin -Lactate Pyruvate-Alanine-Ketones Glyceron Glucagon Corticosteroids Aldosterone Epinephrine and Nor epinephrine at 0-6-12-24 hrs;clinical stability	Fentanyl group showed decreased stress response (decreased epinephrine and increased N20/02, lower duration of hyperglycemia, less urine metabolites) intra-operatively and up to 24 hr postoperatively. NE significantly lower at 24 hr Glucagon & Corticosteroids significantly lower at end of surgery. Aldosterone significantly lower up to 12 hr. Infants receiving only Nitrous oxide and Curare were most clinically unstable postoperatively
Anand et al., 1987[11] N=28 preterm neonates Randomized control trial	PDA surgical Ligation Randomized to Nitrous Oxide & Curare with or without Fentanyl	Postoperative concentrations of : plasma adrenalin, noradrenalin, glucacon, aldosterone, corticosterone and pyruvate	Fentanyl group had significantly lower concentrations of hormonal postoperative response. Non-fentanyl group had higher circulatory metabolic complications postoperatively. Findings are that preterm neonates can mount a stress response to surgery under anesthesia with nitrous oxide and curare and that prevention this response by Fentanyl anesthesia may be associated with improved postoperative outcomes.
Gunnar et al., 1989[12] N= 49 full term Examined twice to discharge examinations on 2 consecutive days	Examination over two days	Salivary/Plasma cortisol Behavior state	There were significant elevations of cortisol only in response to 1st examination although neonates continued to exhibit behavioral distress. Authors raise question of novelty in regulating increases in adrenocortical activity.

Authors/Sample	Stimulus	Responses Measured	Findings
Grunau et al., 1990[13] N=36 healthy newborn (age 2.2h) Counter balanced design Each neonate received 3 procedures in counterbalanced order	IM injection Application of triple dye to the umbilical stump Thigh rub with alcohol	Facial action Latency to Cry	Invasive procedure (IM injection) resulted in greater total face activity, shorter latency to cry and longer duration of first cry. Comparison of two non-invasive procedures showed more facial activity to thigh rub compared to dye application (cotton tip) Researchers acknowledge methodological difficulties in examining cry data as no standardized protocol for selecting cries for spectral analysis.
Arendt et al., 1991[14] N=20 fullterm infants Cardiac activity measured 6 times on 2 consecutive days to determine if repeated measures or heart rate variability are correlated Consecutive sampling	Observation of normal response pattern	Behavioral state Heart period Heart rate variability	The short term variability observed between and within individuals do not support single assays of heart rate variability be used to identify at risk infants or to predict developmental outcomes
Anand & Hickey, 1992[15] N= 45 1 week old ill neonates Randomized to: N=30 deep intraoperative anesthesia with sufentanil with opiate infusion 24 hours. N=15 lighter anesthesia with halothane/morphine with some morphine/diazepam N=15 Sufentanil or Sufentanil /fentanyl groups	Surgery (open heart)	B- Endorphin-E- NE- Glucose- Aldosterone- Cortisol- Insulin- Glucagon- Lactate Clinical Complication Mortality	Neonates who received deep anesthesia showed significant decreases in all stress responses measured. Neonates who received lighter anesthesia had more severe hyperglycemia and lactic academia during surgery. Authors conclude physiological responses to stress are attenuated by deep anesthesia and postoperative analgesia with high doses of opoiods following newborn cardiac surgery. Deep anesthesia reduces neonatal morbidity and mortality
McIntosh et al., 1993[16] N= 20	Heelstick	Heart rate Respiration Oxygen, CO2	In response to heelstick, significant increase in heart rate, respiratory rate, oxygen and CO2 tensions during stab phase
Pokela, 1994[17] N= 84 mechanically	Endotraceal Suctioning	B-Endorphine Cortisol	Saline group showed significant longer durations of hypoxemia (Tcp02- Sa02) and or arterial blood oxygen saturation during treatment procedures. Those

Authors/Sample	Stimulus	Responses Measured	Findings
ventilated neonates N=42 received Meperidine N=42 received saline 15 minutes before suctioning or routine daily nursing care Evaluate opioids to reduce hypoxemia and hemodynamic instability associated with routine intensive care procedures Randomized control	Routine Nursing Care	Glucose Heart Rate Blood Pressure Tcp02- Sa02 Pain score	neonates also displayed greater behavioral distress. Authors conclude that newborns with respiratory difficulties suffer hypoxemia in response to routine care. Opioids beneficial in reducing hypoxemia and associated distress.
Gunnar et al., 1995[18] N= 50 fullterms To investigate neonatal stress to subsequent temperament	Heelstick	Salivary Cortisol Behavioral State Heart Period Vagal Tone	Baseline vagal tone predicted cortisol in response to heelstick (vagal tone index of neonates ability to react to stressors). Heelstick evoked more crying, shorter heart periods, lower vagal tone and higher cortisol. Those scores were associated with lower scores on temperament scale at 6 months (mothers scored). Vagal tone and salivary cortisol not significantly related – thus need to assess both in ontogeny of stress-temperament relations.
Abad et al., 1996[19] N=28 healthy preterm neonates (less than 37 weeks gestation) Comparative random allocation 3 grp (spring water, sucrose, sucrose with water and 24%)	Venipuncture	Cry duration	Measures taken immediately after venipuncture. Group treated with the sweetest solution spent less total time crying during procedure
Johnston et al., 1996[20] N=89 Group N=53 - 32 wks Group N= 36 - 28 wk Cross sectional design	Heelstick	Heart rate Oxygen saturation Facial action	Earlier born neonates have less behavioral responses than later born neonates. The number of invasive procedures was primary factor that explained the differences. Earlier born had higher heart rates, lower oxygen saturation before and during procedure.

Authors/Sample	Stimulus	Responses Measured	Findings
Gunnar et al., 1996[21] N=72 N=54 2 group longitudinal design Adrenocortical response group one at: 2, 4, 6 and 15 months of age to physical exam with inoculations and to exam with no inoculations	Physical exam with inoculations and mock exams with no inoculations	Salivary cortisol	Exam-inoculation procedure: cortical levels high at 2 months, decreased significantly by 4 months - also similar shifts between 6 and 15 months. By 15 months significant increases in cortisol from pre to post test. Exam only procedure: cortisol levels decreased between 2 and 4 months - by 4 months no posttest increase in cortisol. Behavioral distress decreased between 2 and 4 months but increased again at 15 months. No correlations between cry and cortisol during 2-6 month exam inoculations procedures but obtained at 15 months. Behavioral and hormonal reactions may follow different ontogenetic pathways.
Johnston et al., 1999[22] N=120 preterm infants - 20 wks post-conception age Cross sectional - comparative (24 newborns who showed a no response pattern to PIPP were compared to 96 newborns who did show a pain response to PIPP)	Heelstick	Apgar at 5 minutes, severity of illness Sex Race Wake/sleep Previous study sessions Total number of noxious procedures Time since last procedure	Factors that explained difference between group responses were postnatal age at time of study, post conception age at birth, time since last painful procedure and wake/sleep state. Neonates who were younger, asleep and had undergone painful procedures were less likely to demonstrate a behavioral or physiological response to heelstick pain.
Oberlander et al., 2000[23] N=21 former low weight neonate N=24 full term neonates of normal weights Comparative	Finger lance	Facial activity Cardiac autonomic reactivity	Measures taken at baseline, lance and recovery periods. Biobehavioral responses similar between groups however low weight babies had less intense parasympathetic withdrawal during lance and a more sustained sympathetic response during recovery than control group did. As well, low weight babies showed a two staged recovery period.
Abad et al., 2001[24] N=51 postnatal age 4 days (38 males, 13 females) Randomized 4 treatment group (EMLA, sucrose, EMLA plus sucrose, water)	Venipuncture	Total cry time Heat rate Respiratory rate Oxygen saturation	Measures taken baseline, immediate following venipuncture and 2 and 4 min afterwards. Significant decrease in cry duration in sugar alone and in the EMLA plus sugar group. Significant attenuation of immediate heart rate response in the sugar alone group. Study shows 24% oral sucrose compares favorably with EMLA cream.
Moore 2001[25] N=40 infants 2 groups (those receiving Ametop and those receiving placebo gel) Comparative double blind	Heelstick	Facial expression Change in heart rate Ease of cannulation	Ametop applied 30 minutes prior to procedure. Those receiving ametop showed decreased facial expression, change in heart rate. No correlation found between gestation, weight or previous experience with cannulation. Use of Ametop recommended to reduce pain irregardless of infants age, weight or previous experience with pain procedure.

TABLE A2: NEONATAL BEHAVIORAL RESPONSES TO NOXIOUS STIMULATION

Authors/Sample	Stimulus	Responses Measured	Findings
McGraw 1941[26] N= 75full term from birth – 4 years Longitudinal	Pinprick	Gross Body Movements, Cry	Newborns responded to pinprick with diffuse body movements and cry. Motor responses became more specific at 12 months. Interpreted to mean newborns respond reflexively to noxious stimulation.
Fisichelli et al , 1969[27] N=124 term infants Descriptive	Rubber Band Snaps To Heels	Bursts And Duration Of Cry	Great individual variation but clear trend toward decreased cry activity at 2-6 hours followed by increased activity. Developed cry index (threshold)
Fisichelli et al , 1974[28] N=58 healthy fullterms Descriptive	Rubber Band Snaps To Heel	Cry (Temporal Features)	Younger infants (5hr to 2 days) had significantly longer latency to cry and shorter cry times – infants 2 days to 12 weeks had shorter latency and longer cry times – older infants (12 weeks to 1 year) had gradual increase in latency and shortening of cry time. Large variation in cry length, freq & interval
Rich et al,, 1974[29] N=124 term & 6 preterms Descriptive	Pinprick	Gross Motor Movement Vocalization	In response to pinprick, fullterms moved both arms and legs followed by grimacing and crying. Motor responses of fullterms increased with increased stimulation - followed by habituation. Five of the 6 preterms moved lower legs only, didn't grimace/cry
Michelsson, 1983[30] N=29 healthy newborns Random 2 group assignment	Kept In A Cot During The 90 Minutes After Birth Body Contact With Mother	Cry	Newborns kept from their mothers cried ten times more than those who were placed in close body contact. Cry was characterized as a signaling or discomfort cry, elicited by separation from the mother
Johnston & Strada, 1986[31] N=14 Descriptive	Routine Immunization	Heart rate Crying Body movements	Initial response to injection characterized by drop in heart rate, long high pitched cry followed by period of apnea, rigidity of torso and limbs and facial expression of pain. Wide individual variation, facial actions most consistent,
Franck, 1986[32] N=10 healthy terms 4 hrs of age Descriptive	Heelstick	Gross Motor Movement, Cry, Behavior state – video	In response to heelstick newborns responded to heelstick with immediate withdrawal of both affected and unaffected legs, followed by facial grimacing and crying

Authors/Sample	Stimulus	Responses Measured	Findings
Porter et al., 1986[33] N=30 normal male newborns Comparative	Circumcision	Cry (spectra analysis)	Significantly longer cries to most invasive procedures (shorter quiet intervals, short more frequent vocalizations, higher frequencies, greater variability). Adult listeners judged most invasive procedure cries as most urgent. Subjective judgments and objective spectral analysis data agree. Cry systematically varies with respect to intensity of painful stimuli
Grunau & Craig, 1987[34] N= 140 fullterm Descriptive	Heelstick	Cry, Facial Expression, Behavioral state	Awake - alert but inactive infants had most facial activity; those in quiet sleep had least facial activity and longest latency to cry. Boys showed shorter time to cry and retention of pain facial activity following heel lance. Authors interpret facial action variation across sleep/waking states to indicate biological and behavioral pain context affects pain behavior expression.
Fitzgerald et al., 1988[35] N=11 preterm 26-32 wks Comparative with newborn rat pups	Heelstick	Flexor reflex	Preterm neonates of less than 30 weeks post conception age had very low reflex thresholds, by 37.5 weeks they were equivalent to normal term neonates but these are well below adult levels. Repeated stimulation of foot of preterm resulted in habituation as observed in adults (sensitization also occurred in rat pup). Premature may lack ability to control sensory stimuli.
Fitzgerald et al., 1989[36] N=17 preterm 26-32 wks Comparative	Heelstick	Flexor reflex	Flexor reflex threshold was significantly lower in lanced heel compared to non-lanced heel. Reflex reversed with EMLA but not placebo
Barrier et al., 1989[37] Two groups of infants (1-7 months of age) Group 1 Fentanyl Group 2 Placebo Random 2 group assignment Postoperative, responses observed at 30, 60, 90 and 120 minute intervals	Minor Surgical Procedures	Sleep proceeding hour Facial action Quality of cry Spontaneous motor activity Spontaneous excitability Flexion of fingers and toes Sucking, Muscle tone, Consolability, Sociability	Study conducted to measure postoperative pain levels in infants, tested using 10 item scoring system (complex behaviors included). Infants observed post-operatively at 30, 60, 90 and 120-minute intervals. Over entire course of observation, 54% of infants in Group 1 had satisfactory analgesia compared to 18% in Group 2. No significant differences in Group 1 and Group 2 in oxygenation, carbon dioxide elimination, blood pressure, heart rate or temperature

Authors/Sample	Stimulus	Responses Measured	Findings
Grunau et al , 1990[18] N= 36 healthy full term Counterbalanced order	IM Inject, Umbilical Thigh Rub	Cry Latency/Pitch Facial action	Cry latency and pitch different for invasive & non-invasive procedure. With injection, total facial movement & latency significantly increased. No correlation btw facial expression and cry.
Cote et al., 1991[19] N=3 ill fullterm Ethological systematic Observation	Cardiac Surgery	Body postures movements Heart rate Respiratory rate	Increased heart rate, body movements. Five pain behavior states identified. acute distress, sub-acute pain, quiet alertness, drowsiness, sleeping
Craig et al., 1993[40] N= 56 pre and fullterm Comparative	Heelstick	Facial action Body movement Heart rate Sa02, TcPo2, TcC02	Neonate with gestational ages 25-27 weeks showed changes in heart rate to heel lance but only heart rate varied with age. Body activity, facial actions diminished in preterm neonates compared to fullterms. Authors identify facial action as most specific measure of pain response
Johnston et al., 1993[41] N=80 20 preterm, 20 full term IM Vit K 20 2 month olds injection DPT 20 4 month olds injection DPT 2 months and 20 full term 4 month olds Cross sectional design	Heelstick	Facial expression (NFCS) Cry (spectral analysis)	Responses were different for preterms compared to older neonates and responses of fullterms were different from the rest of the group; but responses of 2 and 4 month olds were similar. Premature group displayed higher pitched cries, more horizontal mouth stretches and more taut tongue compared to fullterms. Authors conclude premature neonates have the capacity to communicate pain but in an attenuated way. Their cries serve survival function
Stevens et al., 1993[42] N=40 neonates between 32 and 34 post conceptual age and less than 5 postnatal days of age Descriptive	Heelstick	Facial action Cry Heart rate Oxygen saturation Intra cranial pressure	Physiological responses were significant but not specific to pain. Behavioral responses more promising - premature neonates behavioral responses similar to those of fullterm.

Authors/Sample	Stimulus	Responses Measured	Findings
Lawrence et al., 1993[43] N= 38 full terms 90 minutes of videotape To Test Neonatal Infant Pain Scale (Nips) before, during and after each procedure Comparative	Data Collected 2 Min Before And 3 Minutes After Capillary, Venous Or Arterial Needle Insertion	Facial action Cry Breathing Arm movements Leg movements State of arousal	The significant differences in NIPS scores over time indicate scale measures intensity of infant responses to intrusive procedures. Authors conclude NIPS is objective tool that must be used in conjunction with continuous and thorough infant assessment.
Hadjistavropoulos et al., 1994[44] N=36 neonates Comparative	Non-Invasive Thigh Rubs Vitamin K Injections	Facial action Cry	Sixteen women observed videotapes of infants undergoing procedures. Cry variables added little to the prediction of ratings in comparisons to facial ratings. Cry commands attention but facial activity rather than cry accounts for majority of variation in adults' judgment of neonatal pain.
Ramenghi et al., 1996[45] N=15 healthy premature neonates, 32-34 wks Sucrose evaluated on 2 separate occasions and no more than 2 days apart Sterile water/1m25% sucrose Blind cross over design	Heelstick	Cry duration Facial action To evaluate benefits of Sucrose	Significant reduction in duration of first cry, percentage of time spent crying 5 minutes after heel lance and facial actions scores for sucrose group. Authors conclude sucrose has analgesic effects in healthy premature neonates.
Stevens et al., 1994[46] N=124 premature neonates	Heel stick	Severity of illness Behavioral state Cry	Measures taken at baseline, during and following procedure. Increased facial action and cry (fundamental frequency of cry, harmonic structure and peak energy). Behavioral state was found to influence facial action and severity of illness modified cry acoustics. Neonates who were asleep showed less facial action and those with increased severity of illness had increased cry responses.
Fearon, et al., 1997[47] N= 15 preterm Group 1 = swaddling following Group 2= no swaddling Comparative	Heel stick	Heart rate Arousal Facial action	After procedure, infants less than 31 weeks post conceptual age displayed an immediate and spontaneous return to behavioral patterns before procedure. Infants 31 weeks post conceptual age or older displayed protracted behavioral disturbances that were significantly reduced by swaddling.

Authors/Sample	Stimulus	Responses Measured	Findings
Johnston et al., 1997[48] N=85 preterm Sucrose alone Simulated rocking alone Sucrose and rocking Placebo Random 4 group assignment	Heelstick	Heart rate Facial actions	No difference between simulated rocking and control groups in either facial actions or heart rate. Groups who received sucrose alone or in combination with rocking showed less facial actions than rocking alone or placebo groups.
Ramelet, 1999[49] N=85 Survey	Survey of nurses	Cues that nurses use to differentiate between pain and agitation in critically ill infants	No significant difference found between cues nurses use to assess pain and agitation. Apart from diagnosis, nurses used the following to inform their decision making – own judgment (99%), parents (90%), infants' environment and documentation (78%). Further research warranted distinguishing between pain and agitation in critically ill infants.
Rosmos, 2000[50] N=26 infants Comparative to distinguish if differences in pain response evident between Chinese and non-Chinese infants.	Immunization	Facial action cry	Measures taken for 30 seconds after introduction of needle. Chinese infants showed greater total facial action and cry. No significant difference between groups for circadian rhythm and gender.
Butt & Kisilevsky, 2000[51] N=14 preterm neonates 29 to 36 wks gestation Tested benefits of music and non-music conditions between neonates who were less or greater than 31 wks gestation Mixed model ANOVA	Heelstick	Heart rate Oxygen saturation State of arousal Facial activity	Stress response (increased heart rate, decreased oxygen saturation, increased state of arousal and increased facial action) greater in older group. For older group, music resulted in more rapid return to baseline heart rate, behavioral state and facial activity.

Authors/Sample	Stimulus	Responses Measured	Findings
Evans et al., 1997[52] N= 30 low birth weight infants aged 48 hours or less Comparative	Suctioning Skin Puncture Dressing Change Removal Of IV Line Insertion Of Gastrointestinal Tube Total Position Change Drug Administration Per IV Line, Withdrawal Fluid Umbilical Cord	Grimace Slight cry Increased cry expression Knee/leg flexion	Four pain responses present 75 to 100% following suctioning, skin puncture, dressing change, removal of IV line and insertion of gastrointestinal tube (painful procedures). The behaviors were present 49 to 69% following the non-painful procedures of total position change, administration of drug via IV line, and withdrawal of fluid from umbilical cord
Anand et al., 1999[53] Exposed neonatal rat pups to needle prick/cotton tip rub up to 4 times per day or once a day Examined pain threshold to repetitive pain stimulation longitudinal (newborn and at adulthood) Comparative 2 group repeated measures (needle prick, cotton tip rub)	Repetitive needle prick to alternate paw	Defensive withdrawal Alcohol preference Weight gain	Rats who received needle prick twice per day had significant increases in weight gain compared to rats that received cotton tip stimulation twice per day. Decreased pain latency noted in rat pups receiving up to 4 heel pricks per day. As adults rats – those who received 4 needle pricks per day had increased preference for alcohol, decreased latency in exploratory and defense withdrawal. Data suggest repetitive pain in neonate pups may lead to an altered development of the pain system associated with decreased pain thresholds during development.

Authors/Sample	Stimulus	Responses Measured	Findings
Larson et al., 1998[54] 120 healthy fullterm Venipuncture group Heel lance small lancet group Heel lance large lancet group Random 3 group assignment	Heel lance	Facial action Cry	Neonates undergoing venipuncture cried less and had less facial actions compared to neonates who underwent heel lancing. Venipuncture took less time to complete compared to the heel lance procedures.
Grunau et al., 2000[55] N=64 extremely low weight birth premature neonates Convenience sample	Endotracheal suctioning Chest physio Diaper change Nasogastric feeding	NIDCAP (neonatal individualized developmental care and assessment program system) - body activity Change in heart rate Sleep/wake states	Tremors, startles and twitches not related to discomfort – after controlling for background variables finger splay, leg extension were significantly related to ongoing procedures. Facial brow raising function of number of invasive procedures. Recommend ongoing study of body activity over longer observation periods.

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