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Contextual Influences on the Facial Expression of Pain in the Neonatal Intensive Care Unit

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A thesis submitted to the School of Graduate Studies and Research of the University of Ottawa as partial fulfilment of the requirements for the degree of Doctor of Philosophy

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Abstract

Recently, investigators have become increasingly interested in developing methods that would accurately identify neonates who are experiencing pain. Given that neonates are unable to provide verbal reports of their pain, several indirect assessment tools (e.g., facial expression, physiological and hormonal/metabolic changes in response to painful events) have been presented in the literature. In addition, previous research has uncovered several contextual variables that impact on the expression of pain in neonates, such as behavioural state, gestational age, weight, illness severity, analgesic use, and number of previous procedures. However, the methodological limitations of these studies have prevented the development of a more comprehensive model of contextual influences on pain behaviour either by not considering these variables simultaneously or by using a restricted sample. In the present study, the facial expressions of neonates in the tertiary neonatal intensive care units of a children's hospital, and a general hospital with maternity facilities, were videotaped during a routine venepuncture procedure to determine the degree to which the various contextual variables influence pain behaviour. Using covariance structure analyses, this study found support for a well-fitting model that explained 94% of the observed covariance in the data. Specifically, 27% of the variance of the facial expression of pain was influenced by behavioural state, and illness severity. There was also an indirect effect of physical maturity on pain behaviour, mediated through illness severity. The number of previous procedures was not found to impact on subsequent pain behaviour, and this path was removed from the model. Finally, the ability of analgesic medication to attenuate the experience of subsequent pain could not be tested because too few neonates received such medication during their stay in the NICU.

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Introduction

Although numerous studies have examined the experience of pain in adults, a corresponding body of literature has not been as extensively developed for paediatric pain (Bush, 1987; Varni, Jay, Masek, & Thompson, 1986; Weisman & Schecter, 1991). Generally, the experience of pain in infants and children has only relatively recently become a topic of empirical investigation (Ross & Ross, 1988). Several reasons exist for the delayed interest in research on the experience of pain in children. First, there is the misconception that children, and particularly neonates (infants less than one month of age), do not feel pain as intensely as adults because of the relative immaturity of their nervous systems (McGrath & Craig, 1989). Early arguments posited that neonates did not possess the physiologic mechanisms necessary for pain perception because myelination of the nervous system was not complete at birth (Anand & Hickey, 1992).

For example, McGraw's (1941) observations of newborn infants' reactions to heel lances led her to report that pain perception was unlikely until the infant was three months of age. In this study, McGraw (1941) followed the reactions of 75 infants, from birth to approximately four years of age, in response to a pin prick using a blunt safety pin. Although many of the neonates in her study cried, and withdrew their limbs, McGraw (1941) interpreted their behaviour as primarily reflexive and not indicative of pain.

However, more recent, and methodologically sound, research has refuted these claims. For example, it is now known that myelination is not necessary for the neonate to perceive pain (Anand & Carr, 1989; Anand & Hickey, 1987; Fitzgerald & Anand, 1993) and research has demonstrated that neonates do exhibit behavioural distress during painful procedures (Anand & Hickey, 1987; Grunau & Craig, 1987; Grunau, Johnston, & Craig, 1990). In fact, myelination simply reduces the time necessary to carry a somaesthetic or nociceptive impulse along the appropriate neural pathway, and this is compensated for in infants by the shorter distances that a signal must travel (Anand & Hickey, 1987). Other misconceptions include the belief that children recover quickly from painful events and do not remember them, fears that children will become addicted to narcotic pain medication, and that narcotics dangerously depress respiration in children (Eland & Anderson, 1977).

Purpose of the Study

The literature relevant to the experience of pain in infants will be reviewed in order to provide the reader with sufficient background in the previous research, and the importance of developing valid methods of assessing pain in neonates. This will be accomplished by first outlining the physiological basis of nociception and the implications of the gate control theory of pain to the experience of pain in infancy. This review will also discuss the recent literature on infant memory, as it pertains to pain in infancy, followed by the ramifications of leaving pain untreated.

The review will conclude by outlining the necessity of accurately determining the degree to which various contextual variables impact on pain behaviour. For example, the infants' behavioural state (e.g., ranging from quiet sleep to active awake, and crying) has been shown to impact on the intensity of the infants' response to painful events (Grunau & Craig, 1987). Other factors that impact upon the neonate's response to pain include: (1) the severity of the infants' physical condition, with more severely ill babies displaying a less robust expression of pain; (2) the gestational age of the neonate, with older infants responding more vigorously; (3) previous experience with pain leading to atypical, or exaggerated pain responses (Franck, 1986; Taddio, Goldbach, Ipp, Stevens & Koren, 1995); and (4) the administration of analgesics to alleviate pain. Thus, the purpose of this study is to delineate the relative influence of each of these contextual variables on the neonate's response to pain.

The Experience of Pain in Infants

Infants do possess the neural networks necessary to perceive nociceptive input fully (Fitzgerald & Anand, 1993). However, how they interpret, or how well they remember, painful events is still the subject of considerable speculation (Campos, 1993; Craig & Grunau, 1993; Johnston, 1993). In the past, the undertreatment of pain in neonates was justified by the assumption that infants do not possess the neural structures necessary for the experience of pain, and, even if they were capable of pain perception, there would be no consequences for pain experienced in infancy because it could not be remembered. The following section will examine the implications of the gate control theory of pain for our understanding of the experience of pain in infants, and describe new developments in the study of infant memory.

Theories of Pain

Pain is a subjective experience that is related to, but not necessarily predicted by the amount of tissue damage present, or the amount of observed behavioural distress. Furthermore, Melzack (1986) has conceptualized pain as a multidimensional experience consisting of sensory, affective, and evaluative components. Consequently, pain can be managed not only through the use of pharmacological or surgical intervention, but through the use of psychological pain interventions that modulate the transmission of afferent neuronal impulses (McGrath & Unruh, 1987; Zeltzer, Anderson, & Schechter, 1990).

Prior to the development of the gate control theory, pain was typically conceptualized as a sensory experience that varied in intensity with the relative amount of tissue damage that had occurred (Barber, 1959). Two earlier theories, the Specificity and Pattern theories of pain, are examples of models that embraced the notion that the experience of pain was the sole result of nociceptive sensory input (Melzack & Wall, 1988).

Specificity Theory. This theory was first proposed by Descartes in 1664, and is still frequently taught as fact in modern neurology textbooks (Melzack & Wall, 1988). Basically, the specificity theory maintains that there is a specific set of cutaneous receptors that deliver nociceptive, or pain, signals directly to the central nervous system. Furthermore, it was believed that cutaneous receptors were composed of four distinct types that relayed sensory information directly to the appropriate centre in the cortex. These receptors were believed to be specific for cold, warm, touch, and pain stimuli.

This theory led to three primary assumptions regarding the experience of pain: 1) receptors are differentiated and specialized; 2) each sensory spot beneath the skin contained a single specific receptor; and 3) there was a one-to-one relationship between the intensity of a particular stimulus and the psychological experience of pain. Of these three assumptions, only the first, that receptors are specialized, has received empirical support.

Basically, nerves consist of three classes: 1) sensory afferent; 2) motor axons that cause muscle contraction; and 3) sympathetic axons for autonomic functions, such as sweating and blood flow (Bonica, 1990a). Within the first class, there are four major types of cutaneous receptors that are classified according to their conduction velocity, the type of stimulus that

evokes a response, and response characteristics (Bonica, 1990a; Melzack & Wall, 1988). These include: 1) Type I, or Aβ receptors, connected to large myelinated afferents, that respond to mechanical stimuli, have a high threshold for heat, and are thought to signal pain of long duration; 2) Type II, or Aδ receptors, connected to small, myelinated afferents, that respond to mechanical and heat stimuli, and are believed to play a role in the first sensation of pain; 3) receptors connected to the large, unmyelinated C-fibres, that respond to mechanical and heat stimuli and certain chemicals; and 4) receptors that respond to cold.

Although these receptors are somewhat specialized, they are not unimodal, and may respond to one or more different types of stimuli. Furthermore, there is not a simple relationship between the type of nerve fibres stimulated, and the actual experience of pain. Thus, there are many qualities of the pain experience that remain unexplained by this theory.

Pattern Theory. In contrast to specificity theory, pattern theory suggests that the experience of pain is the result of a specific pattern of neuronal impulses on undifferentiated receptors, rather than on specific receptors (Bonica, 1990b). Thus, it was believed that when cutaneous receptors received extreme stimulation from the periphery, the pattern of that stimulation would be interpreted, in the cortex, as pain (Bonica, 1990b; Melzack & Wall, 1988; Wall, 1989). This early theory of pain suggested that the sensory experience directly corresponded to the amount of external stimulation. Therefore, other factors, such as the contextual variables included in this study, would not be expected to play a role in the pain experience.

Gate Control Theory. The gate control theory of pain, proposed by Melzack & Wall (1965), has had a significant impact on our understanding of clinical pain. This theory is based primarily on observations of animal and human subjects responding to acute painful stimuli delivered to receptors located beneath the surface of the skin. Basically, Melzack and Wall (1965) posit the existence of a "gating mechanism" located in the substantia gelantinosa layer in the dorsal horns of the spinal cord. This gate is believed to modulate the amount of nociceptive input that is allowed to enter the central nervous system from the periphery. Both large- and small-diameter fibres terminate in the substantia gelantinosa, and the gating process is thought to be influenced by the relative amount of neural input received from both of these fibres. That is,

Melzack and Wall (1965) stated that nociceptive and somaesthetic signals compete with each other, and that innocuous stimulation activates interneuronal systems (possibly the opiod system) that inhibit nociceptive signals from being transmitted to the central nervous system.

However, the inhibitory mechanisms of the large fibres, and excitatory mechanisms of the small fibres, and how they are mediated in the substantia gelantinosa, remain unexplained (Melzack, 1986). Despite this limitation, this component of the gate control model has lead to the development of a number of clinical interventions, such as transcutaneous electrical nerve stimulation (Fowler-Kerry & Lander, 1987) and dorsal column stimulation (Krainick & Thoden, 1984). These interventions have been shown to reduce pain significantly compared to the use of "placebo" machines that did not deliver any afferent neuronal stimulation.

In addition to postulating the existence of a spinal gating mechanism in the dorsal horns, and the influence of large and small fibres on this mechanism, Melzack and Wall (1965) hypothesized that there was a specialized set of fibres, projecting to brainstem and cortical structures, which activate various cognitive processes related to affect, cognition, and attention. Once activated, these structures are thought to influence the spinal gating mechanism through descending efferent projections. For example, cognitive processes (which are influenced by memory of previous pain experiences, culture, anxiety, and attention) are thought to mediate the spinal gating mechanism through pyramidal fibres that project to the dorsal horns (Melzack, 1986).

By including a description of descending mechanisms involved in the perception of pain, Melzack and Wall (1965) have provided a plausible physiological explanation for psychological factors observed to influence pain. For example, soldiers who are wounded on the battlefield are more likely to present with lower pain levels than civilians with similar injuries (Beecher, 1955). This facet of the gate control model has lead to the inclusion of many cognitively based coping strategies in the self-management training programs offered to adult pain patients (e.g., Turk & Meichenbaum, 1988; Turk & Melzack, 1992).

Compared to adults, the coping behaviours of infants are limited (e.g., sucking on their fingers or hand), and they often must rely on caregivers to help effectively regulate their behaviour (e.g., through distraction, swaddling, providing a pacifier). The fact that infants do not

have access to specific cognitive coping strategies increases the likelihood that they experience nociceptive inputs as painful. Furthermore, one might infer that the experience of pain in newborns is likely to differ qualitatively from pain experienced by adults. This is due to the fact that infants are not cognitively equipped to attach meaning to their pain, or understand that the pain may be of a time-limited nature (Craig & Grunau, 1993). Thus, even though infants are equipped physiologically to perceive pain, they do not have the ability to mediate painful experiences cognitively. Consequently, one implication of the gate control theory of pain is that newborn infants may actually experience higher levels of pain than adults.

Furthermore, Gate Control Theory does not take into account neonatal physiology, and the significant impact it has on the experience of pain in infancy. In particular, Fitzgerald and colleagues have gathered evidence to suggest that infants, in particular preterm neonates, may actually experience elevated pain levels, compared to adults (c.f., Andrews & Fitzgerald, 1994; Fitzgerald & Anand, 1993). For example, Andrews and Fitzgerald (1997) point out that neonates have an abundance of afferent projections to the spinal cord, few efferent projections, and densely distributed receptors for NMDA and substance P. They posit that these differences lead to exaggerations in neonatal responses to nociceptive stimuli. In addition, given the plasticity of the developing nervous system, Andrews and Fitzgerald suggest (1997) that neonatal neurophysiology can be permanently altered following injury.

Taken together, these findings suggest that not only do neonates experience pain, but that it is possible that their experience of pain is actually greater than that of adults. Attempting to quantify the neonatal experience of pain, as a result of these findings, becomes an even more complex issue. For example, although seriously ill, premature neonates may be more sensitive to nociceptive stimuli, they may be unable to express their pain because of their diminished repertoire of behaviour. In this instance, equating the expression of pain with the experience of pain would be inaccurate.

In conclusion, theories of pain that explicate the integration of psychological and physiological components of pain were presented to clarify the existence of infant pain. In this regard, it is of great importance to delineate accurate methods of identifying neonatal pain. This

also speaks to the education of clinicians who may gain a greater appreciation for the variables associated with the expression of pain in neonates.

Memory for Pain

Although not directly related to the study of contextual variables, a brief discussion of memory in infancy is included. This is to provide the reader with sufficient background to evaluate early arguments that suggested it was not necessary to assess or treat infants in pain because they could not remember the experience. It has generally been assumed that infants, due to the immaturity of their nervous systems and lack of experience, are severely limited in all aspects of memory (cf. Lipsitt, 1990; Rovee-Collier, 1986). Consequently, some have argued that infants are likely not to suffer any severe consequences from exposure to repeated invasive events. However, despite the likelihood that infants may not remember specific pain experiences, it has been suggested that they are at risk for the development of atypical patterns of pain expression (Anand & Hickey, 1987; 1992). For example, Grunau, Whitfield, and Petrie (1994) found that, in a 2-year follow-up of preterm and full-term infants, mothers reported that their preterm infants remained relatively inexpressive in response to painful stimuli.

More recent research has refined the paradigms previously used to study infant memory. This has resulted in a reduction in the performance demands placed on infants during the tasks, and has provided a more realistic picture of their cognitive abilities (Diamond, 1985; Mayes, 1989). In addition, the neural structures necessary for the long-term retention of memories (e.g., the hippocampus, amygdala, thalamic nuclei, and the mamilliary bodies) are sufficiently developed in neonates (Anand & Hickey, 1987). Although the abilities of young infants are severely limited compared to older children and adults, infants appear to be capable of remembering a great deal more than research in this area first indicated. As a consequence, it is inadvisable to assume that infants would not experience any effects from repeated invasive procedures on the basis that they would not be remembered.

Although it is beyond the scope of this paper to provide a full review of the literature on infant memory, a brief discussion of some of the recent important developments in this area will be covered in order to familiarize the reader. In particular, the work of Rovee-Collier and associates, using her conjugate reinforcement paradigm, is relevant in that she documents the

trajectory of memory in the infancy period, and how those memories may be reactivated in the presence of various cues (Hill, Borovsky, & Rovee-Collier, 1988; Rovee-Collier, 1986; 1990;1997; Rovee-Collier & Hayne, 1987). Basically, in the conjugate reinforcement paradigm, infants are trained to move an overhead mobile by kicking a foot which is tied to the mobile with a ribbon. The more vigorously an infant kicks, the more the mobile moves. Thus, the infants receive reinforcement for moving the mobile, and the response rate is determined by the infants' rate of kicking when presented with the cue (the mobile). The infants' baseline rate of kicking is measured before training, and later compared to response rates after training when the ribbon is removed from the ankle.

Using this paradigm, Rovee-Collier (1986; 1990; Rovee-Collier, Patterson, & Hayne, 1985) found that infants, who were as young as two months of age, would quickly increase their response rates after training. Additionally, it appears that three month old infants remember after a delay as long as eight days, and that by two weeks there is no evidence of previous learning. A similar pattern in gradual decline of previous learning has been demonstrated in two month old infants. However, the younger infants appear to have completely forgotten the task after three or four days.

In another study, Rovee-Collier, Patterson, and Hayne (1985) found that, by providing the infant with brief contextual cues, the previously forgotten memory for the conjugate reinforcement task can be reactivated. For example, cues such as a novel crib or playpen liner or placing the infant in the same room where training occurred can be enough to reactivate a previously "forgotten" memory. More recent research has documented that three month old infants could encode and remember features (e.g., a specific number or letter on a mobile) and relationships between features (e.g., certain background colours that are always paired with a specific number or letter) on their training mobiles (Bhatt & Rovee-Collier, 1997).

Other researchers are beginning to extend the work of Rovee-Collier into other sensory modalities, such as memory for auditory stimuli. For example, Jusczyk and Hohne (1997) found that eight month old infants preferred listening to a list of words that had occurred frequently in three children's stories that the infants were exposed to over a two week period. Spence (1996)

also found that infants as young as one month old were able to remember a nursery rhyme, repeated by their mothers, after a three day interval.

Given the results of these studies, it is highly unlikely that infants would remember specific relationships they had seen on a mobile, and yet not remember a salient event such as a venepuncture or circumcision. Furthermore, it has been suggested that specific contextual cues could play an important role in the reactivation of memories for painful experiences (Campos, 1993). For example, 6-24 month old infants have been shown to present with anticipatory anxiety before receiving immunization injections, indicating that by this time they have some memory for the context in which many painful events occur (Craig, McMahon, Morison, & Zaskow, 1984). In conclusion, given that infants have a more sophisticated memory system than was assumed even ten years ago, it is highly unlikely that infants have no memory for previous painful events. Therefore, the denial of pain alleviating interventions, or the failure to develop accurate methods of assessing infant pain, based on the belief that infants cannot remember such experiences, is not be supported by the literature in this area.

Consequences of Untreated Pain in Neonates

There is mounting evidence to suggest that pain in infancy has long-term consequences. The implications of these findings for the present study are that by understanding the influence of the contextual variables on the expression of pain in neonates, clinicians are in a better position to recognize pain when it occurs, thereby attenuating the long term effects of the experience. One possible reason to reduce exposure to pain is that unremitting crying in sick or premature infants may theoretically cause intraventricular haemorrhaging; a major cause of death in Neonatal Intensive Care Unit (NICU) infants (McCaffery & Beebe, 1990). Furthermore, infants who experience numerous painful procedures can also become cyanotic, bradycardic, tachycardiac, hypoxic, and hypercapnic, and display large adrenocortical stress responses if their pain is not alleviated (McCaffery & Beebe, 1990).

Perhaps the most dramatic illustration of the consequences of leaving pain untreated comes from a study conducted by Anand and Hickey (1992). They compared the outcomes of infants who received either deep anaesthesia (high doses of sufentanil), with continuous infusion of fentanyl for the 24-hour period following surgery, to infants who received lighter anaesthesia

(halothane plus morphine) and intermittent doses of intravenous morphine and diazepam following surgery. The infants who received the more aggressive pain management approach had lower post-operative mortality and morbidity rates, and showed decreased hormonal and metabolic responses, than the group that received the more conservative approach to pain management.

Fewer studies have examined the long term consequences of pain in infancy (e.g., Grunau, Whitfield and Petrie,1994;Taddio, Goldbach, Ipp, Stevens & Koren, 1995) . However, evidence gathered from animal studies suggests that immunological response is compromised when animals are exposed to painful events (Herzberg, Murtaugh & Beitz, 1994; Page, Ben-Eliyahu & Liebskind, 1994; Sacerdate, Manfredi, Biachi & Panerai, 1994). The physiological disruption that occurs as a result of pain seems to increase the irritability of infants (Craig & Grunau, 1993). This irritability makes it more difficult for caregivers to interact positively with their infants, that may have implications for the later social development of those infants (Campos, 1993).

Another example of the long-term effects of pain during infancy comes from a study conducted by Grunau, Whitfield and Petrie (1994). This study reported that Extremely Low Birthweight (ELBW) premature toddlers, who received numerous invasive procedures while they were hospitalized in the NICU, were viewed by their parents as relatively inexpressive of pain compared to heavier premature and full-term toddlers. Taddio, Goldbach, Ipp, Stevens & Koren, (1995) found the opposite effect when they compared the behavioural pain response to a routine vaccination of healthy male infants who had been either circumcised or not circumcised. Results indicated that the circumcised infants presented with a greater behavioural pain response and cried longer than the uncircumcised infants, suggesting that circumcision may affect the experience of pain months after the procedure was performed.

Taddio, Katz, Ilersich and Koren (1997) recently completed a follow-up study of infants who had participated in a clinical trial of the topical anaesthetic EMLA. The infants who had been circumcised had received either EMLA or a placebo cream for their procedure. Compared to a control group of uncircumcised male infants, the infants in the placebo condition presented with the greatest amount of facial action, cry duration, and adult ratings of pain for a routine

vaccination at four or six months of age. The pain behaviour of infants who were treated with EMLA appeared to be in a central range on all the measures, but only differed significantly from the other two groups in the adult ratings of pain.

All of these studies point to the long term impact of exposure to painful events in infancy. Although there appear to be some inconsistencies in the type of effect observed in these studies, Andrews & Fitzgerald (1997) point out that the flaccid reactions of premature infants, and the exaggerated responses of other infants, are actually the result of their immature physiology. For example, somatosensory signals are relatively inconsistent in the neonatal period, leading to a lack of response in some infants. They also suggest that the postnatal period is a critical time for neurodevelopment, and that the sequencing of various events can later permanently alter pain pathways, and subsequently heighten some pain responses.

Measurement and Assessment of Pain in Infants

Due to the subjective nature of pain, researchers have been unable to develop consistently reliable and valid assessment tools that would quantify the experience of pain. As a result of the inability to develop an objective 'pain thermometer,' the self-report of patients is often considered the gold standard when assessing or measuring pain. Although it not possible to interview infants about their pain, it is possible to observe their reactions to painful stimuli. Generally, infants respond to pain in a diffuse and unorganized manner, and these responses appear to be perceptually dominated (Bush, 1987; McGrath & Craig, 1989). That is, infants are not able to organize an effective coping response, or regulate their emotions, to the same degree as older children. Therefore, neonates are less likely to be affected by the "evaluative" and "affective" dimensions of the pain experience. For example, in neonates and infants up to six months of age, there is no anticipatory anxiety (Craig, McMahon, Morison, & Zaskow, 1984). Only crying and gross motor movements are observed in response to the painful stimulus, and these reactions do not last long after the stimulus has been removed. Older infants (6-24 months) begin to show signs of anticipatory anxiety during immunization injections. After the injection these infants show anger at the nurse who gave the injection, and anger is the dominant response by 20 months (Craig, McMahon, Morison, & Zaskow, 1984).

Currently, there are a variety of methods that can be used to indirectly assess the degree to which an infant is experiencing pain. Strictly speaking, however, these measures provide only an indication of the amount of distress evoked in painful situations. Nonetheless, all of the methods of assessing this distress are assumed to be valid indicators of pain, as they vary in response to procedures that are thought to be painful (i.e., procedures that involve tissue damage) (Craig, Whitfield, Grunau, Linton & Hadjistavropoulos, 1993; Grunau & Craig, 1987; 1990; Grunau, Johnston & Craig, 1990). In addition, they reliably discriminate between non-invasive procedures, and invasive procedures of varying levels of severity (Craig, Whitfield, Grunau, Linton & Hadjistavropoulos, 1993). Broadly speaking, these assessment tools can be classified as either behavioural or physiological, and are discussed in more detail in the following sections.

Behavioural Indices. In adults, extreme differences exist in the degree to which individuals behaviourally express their pain. These individual differences are thought to be the result of a variety of factors, including culture, social modeling, and prior experience with pain (Craig, Prkachin, & Grunau, 1992). Thus, verbal self-report of pain is considered the current "gold standard" for assessing the subjective experience of pain in adults (Jensen & Karoly, 1992; Turk & Melzack, 1992).

However, adults and older children may, for a variety of reasons, choose to distort their self-report of pain (Craig & Grunau, 1993). For example, older children often deny that they are experiencing pain because they are afraid of receiving an injection to relieve their discomfort (McGrath & Brigham, 1993). However, it is unlikely that the expression of distress in infants is distorted in such a manner, and the observation of their behavioural reactions to painful events may be a purer indicator of discomfort in this particular population (Craig & Grunau, 1993). The behavioural reactions that are measured in infants in response to pain include: facial expression, body movements, and cry.

Facial Expression. The facial expression of pain in infants is thought to be the most sensitive and reliable indicator of pain (Craig & Grunau, 1993; Johnston & Strada, 1986; McIntosh, Van Veen, & Brameyer, 1993). Overall, the facial expression of infants takes on a relatively stereotypical, temporally organized configuration in response to painful events: the mouth stretches vertically and horizontally, the eyes close tightly, the brow pulls together and

appears to bulge, the tongue takes on a taut, "cupped" shape, and the naso-labial furrow deepens (Craig & Grunau, 1993). This configuration resembles the facial expression of pain in adults, except that adults will often keep their eyes open, and do not present with a stretched mouth or cupped tongue (Craig, Prkachin, & Grunau, 1992).

In order to systematize the use of neonatal facial activity in response to pain, Grunau and Craig (1987; 1990) developed the Neonatal Facial Coding System (NFCS). This coding system was designed to identify objectively facial activity associated with painful events through anatomically based depiction; a description of the various components of the scale appears in Table 1. NFCS was derived from the Facial Action Coding System (FACS) developed by Ekman and Friesen (1978) by incorporating those facial actions typically associated with pain. The FACS is an atheoretical coding system that identifies all possible facial movements, not only those associated with pain. In contrast, the NFCS only identifies those movements associated with pain, and requires significantly less training. Validity of the use of the NFCS has been established through its ability to discriminate between painful and non-painful events (Craig, Whitfield, Grunau, Linton & Hadjistavropoulos, 1993; Stevens, Johnston & Horton, 1994). In addition, inter-rater reliability for the NFCS, as measured by percentage agreement between raters, has consistently fallen above .80 in the studies in which it has been employed (e.g., Craig, et al., 1993; Grunau & Craig, 1987)

Body Movement. Although infants are typically thought to respond to pain in a diffuse and disorganized manner, reactions have been found to vary in response to the source of distress (Craig & Grunau, 1993). Furthermore, nurses report that limb movement and torso activity are two of the variables they use to determine if preterm infants are experiencing pain (Pigeon, McGrath, Lawrence, MacMurray, 1989). Despite the salience of body movement in describing the behavioural response to pain, only one study has systematically studied its use in neonates. Craig, et al. (1993) developed the Infant Body Coding System (IBCS) to study the body movements of preterm and fullterm infants in response to a heel stick. A principal components analysis of the IBCS revealed a single component accounting for 50.5% of the variance of the body activity in response to the heel stick. In addition, the IBCS was able to discriminate between painful and nonpainful events in all age groups (newborns at 25-27 weeks, 28-30 weeks;

31-33 weeks; 34-36 weeks; 37-41 weeks). Inter-rater agreement was also found to be .83, as measured by percentage agreement between raters; indicating the IBCS is also a reliable measure of body movement in neonates.

Physiological Indices. A variety of indices have been used to measure the relative amount of physiological distress that occurs in relation to painful events in both adults and children (Craig & Grunau, 1993; McIntosh, Van Veen, & Brameyer, 1993). At one time it was hoped that this form of pain measurement would provide a reliable, objective form of quantifying pain, without the subjective biases that are present in verbal self-reports of pain (Polatin & Mayer, 1992). However, higher levels of physiological arousal are not always correlated with higher self-reports of pain in adults (Melzack, 1986). Thus, physiological measures share some of the same methodological problems of behavioural measures (Craig, Whitfield, Grunau, Linton, & Hadjistavropoulos, 1993).

One benefit of including physiological measures in the study of infant pain is that they provide an additional dimension by which to examine the experience of pain. Furthermore, these indicators are relatively easy to obtain, as most tertiary care nurseries routinely monitor heart rate, respiration, transcutaneous O_2, transcutaneous CO_2, and O_2 saturation levels (McIntosh, Van Veen, Brameyer, 1993). However, given that these measures tend to peak, and take longer to reach baseline levels, after the invasive event has occurred, it would appear that facial expression is the more sensitive indicator of pain in infants.

Contextual Influences on Infant Pain Behaviour

Behavioural State. Although the ability of the assessment methods to discriminate between painful and non-painful events has been documented (c.f., Craig, Whitfield, Grunau, Linton & Hadjistavropoulos, 1993; Stevens, Johnston & Horton, 1994), researchers in this area point out several contextual variables that influence neonatal responses to painful events. For example, Grunau and Craig (1987) found that the infant's behavioural state (e.g., ranging from quiet/sleep to active/awake) impacts on the intensity of the infant's response to painful events. That is, regardless whether the neonates' were sleeping or awake, they all responded with the same pattern of facial activity to an invasive event. However, those infants who were in one of the waking states responded more vigorously; particularly in terms of displaying a taut tongue

and vertical stretched mouth. Grunau and Craig (1987) also found that neonates in the quiet awake state (i.e., the most prepared to respond to sensory stimuli) responded more vigorously than infants who were in either of the sleep states.

Illness Severity. Another contextual factor hypothesized to affect pain behaviour is the infants' illness severity; with critically ill infants becoming limp, or flaccid, in response to painful stimuli (Stevens, 1996). Stevens, Johnston and Horton (1994) examined the impact of the neonates' severity of illness on facial activity and cry following a heel lance. Although the results of their study did not find a significant effect for illness severity on the facial expression of pain, a nonsignificant trend was noted in the proportion of time that severely ill infants were able to sustain a response. That is, severely ill infants initially presented with a similar configuration of facial action units as the healthy infants, but were unable to hold that facial pattern over the duration of the heelstick procedure.

They did , however, note a significant difference between the severely ill group and healthy or mildly ill neonates on several of the cry variables. Specifically, more severely ill babies presented with a higher peak fundamental frequency, shorter duration of cry, and longer latency to cry. In a second study, examining the effects of illness severity on various physiological parameters, no significant results were noted (Stevens & Johnston,1994). However, a significant interaction was found between severity of illness and behavioural state. Unfortunately, due to the small sample size in this study, the authors did not interpret the univariate effects.

Physical Maturity. The gestational age of the baby has also been identified as an influence on pain behaviour. For example, Craig, Whitfield, Grunau, Linton and Hajistavropolous (1993) found similar patterns among infants of varying gestational ages in the facial expression of pain. However, the relative intensity of the response was diminished in the younger age groups. Comparable findings were noted in the neonates' bodily activity in response to the lance, with older infants displaying more reactivity. Similarly, Johnston, Stevens, Yang and Horton (1994) found that even very premature infants (26-weeks gestational age) were able to respond differentially to a real versus sham (heel squeeze without lancing the foot) heel stick procedure. In addition, although the very premature infants were able to mount a physiological and

behavioural response to a painful event, Johnston, et. al. (1994) also found that they responded less robustly to the procedure. In a more recent study by the same research group, 28 neonates of 28-weeks gestational age were followed over their eight-week stay in the NICU. During that time, the results of the previous study were replicated with the neonates responding more vigorously to the real heelstick. In addition, they found that the intensity of the neonates' responses increased over the course of the study as the babies matured (Johnston, Stevens, Yang & Horton, 1996).

Previous Experience with Pain. In order to examine the effects of experience in the NICU on pain, Johnston & Stevens (1996) compared the responses of neonates with the same post-conceptual age (32 weeks), but who had either a postnatal age of four days or four weeks. The results of their study demonstrated that the earlier born infants presented with a less mature behavioural response, with the number of invasive procedures and Apgar scores accounting for most of the variance.

Franck (1986) compared the responses of newborns during their first and second heelstick procedures. Results of this study demonstrate that during the second procedure, the neonates presented with a shorter latency to cry, and a faster withdrawal reflex. Taddio, et. al. (1995) also found evidence of the persisting effects of previous pain in a study comparing the behavioural pain reactions of infants who had either been circumcised or uncircumsised. Those infants who had been circumcised were found to have a greater pain response and shorter latency to cry during a DPT immunization at 6-months of age.

In addition, Grunau, Whitfield, and Petrie (1994) conducted a 2-year follow up study of Extremely Low Birth Weight (EBLW) preterm infants. Parents were asked to rate their toddlers on a variety of behaviours, and the results of the study indicated that the ELBW infants were relatively inexpressive in response to pain, compared to heavier preterms and full-term babies. These results were attributed to the additional painful and disruptive procedures these infants had undergone during their hospital stay. In a separate 4-year follow up study of another group of EBLW children, Grunau, Whitfield, Petrie and Fryer (1994), found a greater proportion of somatic complaints of unknown origin compared to children born at term.

Fitzgerald and Anand (1993) suggest previous experience with pain will result in an alteration in the experience of pain in both premature and full-term neonates. Specifically, they propose that hypersensitivity will be exhibited at the site of tissue damage following an invasive event, due to the release of prostaglandins and previous activation of neural nociceptive pathways. In addition, they postulate that permanent structural changes occur because such tissue damage in the neonatal period irreversibly destroys cutaneous receptors, leading to the death of afferent inputs attached to those sites. Given the plasticity of the nervous system at this early stage of development, other afferent projections expand into the areas of the dorsal horn that the damaged projections once occupied. This results in the under-representation of somatosensory inputs at the site of repeated tissue damage, and over-representation of the surrounding area; leading to a distorted somatosensory map of the body in the spinal cord and cortex. This alteration in the experience of pain in the neonatal period appears to have different effects depending on the timing of the procedures undergone by the neonate (Andrews & Fitzgerald, 1997). In full-term, healthy infants this previous experience appears to lead to an exaggerated response to pain, while in a preterm, or ill, neonatal population increased experience with pain appears to lead to a flaccid response. This is likely due to the limited physical resources of this particular population to respond to repeated invasive events.

Analgesia. Finally, the previous administration of analgesia is expected to ameliorate the facial expression of pain in subsequent procedures; whether or not the infant is receiving analgesia during the procedure in question. For example, Taddio, et al. (1997) found that EMLA, a topical anaesthetic, diminished the expression of pain during routine vaccinations six months after infants had received the cream for their circumcisions. Neonates who had received EMLA for their circumcisions presented with an intermediate pain response at four to six months during a routine vaccination. Infants who had been in the placebo condition presented with the greatest pain response, while uncircumsised boys presented with the smallest pain response.

Simultaneous Influence of the Contextual Variables

Although all of these variables have been shown to individually impact on the expression of pain, only one study has attempted to examine their concurrent influence on pain behaviour. In a study conducted by Stevens, Johnston and Horton (1994) an attempt was made to describe the

impact of behavioural state, illness severity, gestational age, sex, and weight on facial movements and cry in response to painful events. Although this study only found that behavioural state impacted on the facial action variables, and that illness severity impacted on cry, several limitations of the study are worth noting.

First, unlike previous studies, age was not found to have an influence on pain behaviour. This was likely due to the relatively restricted sample employed in this study (i.e., infants in the study only ranged from 32 to 34-weeks gestational age). Therefore, it is likely that this limited age range did not provide enough variability in the model to allow for significant findings.

Second, the researchers converted scores on a continuous illness severity rating scale into four discrete illness severity groups (e.g., Healthy, Mildly ill, Moderately ill, and Severely ill). Although this approach is appropriate for the statistical analysis they chose, the use of discrete categorical variables results in a reduction of power to notice differences that may exist if continuous variables are used (Howell, 1987; Tabachnick & Fidell, 1989).

Finally, one of the goals of the study was to determine if there would be differences between groups in the pattern of facial action variables (e.g., open lips, taut tongue). Therefore, they analysed each of these variables separately, rather than calculating a summary score of facial movements in response to pain (cf., Craig, et al., 1993). The use of this approach not only reduces power to detect significant differences generally, but may not have been sensitive enough to discriminate reliably between the small differences present in their restricted sample.

Therefore, the purpose of this study will be to extend the results reported by Stevens, et al. (1994), by examining the relative impact of various contextual variables on the expression of pain in neonates ranging in age from 24 to 40-weeks gestational age. Structural equation modeling procedures (using EQS version 4), based on the analysis of covariance structures, will be used to test the postulated causal effect of the specified factors (physical maturity, illness severity, behavioural state, analgesic use, and the number of previous invasive procedures) on pain behaviour.

The hypothesized model that will be tested in the current study is displayed pictorially in Figure 1. Five latent variables are expected to predict the overall intensity of the neonates' behavioural response to a venepuncture (a needle inserted into a vein to draw blood, or deliver

medication, fluids, or nutrition). Facial expression will be used as the measure of pain behaviour as it is the most sensitive and reliable measure of pain in the neonate. In addition, it is also the measure more easily obtained as the neonates' body movements are frequently obstructed from view, and intubated infants are unable to cry.

As illustrated in Figure 1, illness severity is predicted to have an adverse impact on the neonates' ability to express their pain, due to the limited resources sick babies have to mount a pain response. The facial expression of pain is also expected to vary with the neonates' behavioural state prior to the procedure; with increased wakefulness leading to a more intense reaction (Grunau & Craig, 1987). Analgesics given during the neonates' stay in the NICU, is the third variable expected to influence the relative amount of pain behaviour displayed; with those neonates receiving more aggressive pharmacological management of their pain presenting with decreased pain behaviours. Next, previous studies have demonstrated that prior experience with a tissue-damaging event can lead to a heightened pain response in healthy term infants (Franck, 1986; Taddio, et al., 1995). However, in an ill, preterm population, previous experience with pain appears to lead to less robust, or even flaccid response to subsequent pain (Johnston & Stevens, 1996; Stevens, 1996). Therefore, the number of painful procedures received while in hospital is expected to have a negative impact on the ability to express pain in this ill, preterm population. Finally, physical maturity is predicted to be positively related to subsequent pain behaviour; with older and heavier neonates responding more vigorously to the heel lance.

An additional path has also been specified between physical maturity and the neonates' illness severity. This is due to the fact that younger and smaller infants tend to be more ill. However, age effects are not expected to be explained fully by illness severity due to the presence of other developmental changes that are not accounted for by this variable (e.g., the development of facial musculature allowing the neonate to grimace in response to pain).

By outlining which variables have the most influence on the infants' pain behaviour during their stay in the hospital, clinicians are in a better position to read the neonate's cues, and plan their interventions accordingly. Therefore, this approach will delineate a model of the contextual influences on pain behaviour that has both theoretical and practical applications in a clinical setting. This study also addresses the limitations of previous research by using structural

equation modeling procedures that allow for the simultaneous analysis of the contextual variables within a single conceptual framework.

Alternative Models

In addition to the hypothesized model presented in the previous section, two alternative models will be described. These alternative models will be compared later to the hypothesized model, for improvements in overall fit, using the Expected Cross Validation Index (ECVI). In the first alternative model (see Figure 2), the direct paths from behaviour state and number of procedures will be removed. Instead, the neonates' illness severity and physical maturity are expected to account for the infants spending more time in one of the sleep states, and the number of procedures they receive (i.e., younger, more ill infants will require more frequent bloodwork to monitor their physiological status).

The second alternative model (see Figure 3) hypothesizes a single direct path from the infants' physical maturity to subsequent pain behaviour. The variability in the other four contextual variables is, therefore, expected to reflect differences in neonates of varying gestational ages. For example, neonates born closer to term should present with lower illness severity ratings, and spend more time in one of the waking behavioural states. Older infants are also expected to receive higher levels of analgesia, because of reduced fears of respiratory depression in this population. Finally, older neonates are hypothesized to require fewer invasive procedures during their stay in hospital.

Contextual Variables Not Included in the Current Study

In addition to those variables under investigation in the current study, there are several other contextual factors that may influence the subsequent pain behaviour of neonates' in the intensive care nursery. For example, Craig (cf., Craig & Grunau, 1993) found differences between technicians in the amount of pain that is elicited from similar procedures. This variable was not included as there were over 100 nurses who could have completed the venepuncture, making it a variable that would be impossible to analyse in the present study. Another analysis beyond the scope of the current study would be the examination of the way the various contextual factors influence the judgements made by different raters. For example, previous research has found differences between the pain ratings made by nursing staff, physicians, allied

health workers, and parents. Generally, parent ratings more closely approximate child ratings of pain, and allied health care workers infer more pain than nurses or physicians (cf., Korol, Goodman, Hsu & Gayton, 1992; Shapiro, 1989).

Craig and Grunau (1993) suggest that these biases in adult judgements of pain may be related to (1) an active avoidance of recognizing the infant's pain, due to beliefs that pain could not be relieved without significant risk to the child; (2) reduced ability to empathize with the experience of the neonate in the NICU, where attention is primarily focused on the saving of lives; and (3) difficulty in differentiating between pain and agitation in the neonate. The last point is particularly salient, given that recognizing cues from the limited repertoire of newborns is not intuitive, and does require some special interest and training (Craig & Grunau, 1993).

Finally, Craig and Grunau (1993) emphasize the necessity of studying the impact of environmental variables in the NICU (e.g., noise, light, temperature, handling procedures) on pain in future research. Previous studies have found links between higher lighting and sound levels, and increased handling of high risk neonates, with: (1) decreased physiological stability; (2) hearing loss; (3) retinopathy of prematurity; (4) and decreased neurodevelopmental functioning (cf., Buehler, Als, Duffy, McAnulty & Liederman, 1995; Gardner, Garland, Merenstein, Lobchenco, 1993; Mouradian & Als, 1994). Despite these complications, Als and her colleagues (Als, 1990; Als, Lawhon, Brown, Gibes, Duffy, McAnulty & Blickman, 1986; Buehler, Als, Duffy, McAnulty & Liederman, 1995; Mouradian & Als, 1994) have found preliminary support for the efficacy of individualized behavioural and environmental care in improving neonatal outcomes. Basically, Als suggests that caregiving practices (e.g., type and amount of tactile stimulation, visual and auditory inputs) should be based on observations of the individual neonate's ability to cope with the surrounding environment. To date, there are no studies on the impact of these environmental variables and subsequent pain behaviour.

Additional miscellaneous variables that could impact on pain, such as positioning, time of day, type of lancet, length of procedure, heel warming, and time since feeding, were also excluded from the analyses. Although these factors would invariably impact on the facial expression of pain, including too many variables in the analyses would lead to the over-fitting of the model. That is, such a strategy would not lead to a parsimonious representation of the data.

The contextual variables included in the hypothesized model were chosen because they are presumed to have the greatest impact on the facial expression of pain, based on the author's review of the literature and practical experience in the area. Thus, results of the study should be interpreted with this limitation in mind, and future studies may be able to determine the specific impact of these variables on the expression of pain in newborns.

Method

Subjects

Data were obtained for 197 neonates, ranging from 24 to 40 weeks gestational age from the tertiary care NICUs of a children's hospital, and a general hospital with maternity facilities. The neonates were hospitalized for a variety of conditions, such as extreme prematurity, broncho-pulmonary dysplasia, hyperbillirubinemia, or surgery. Eleven neonates were removed because they had pacifiers in their mouths during the venepuncture, resulting in a final sample of 186 neonates. Sample characteristics are presented in Table 1, while the means and standard deviations of variables included in the analyses are presented in Table 2. This sample size approximates the minimum number of 200 subjects recommended for structural equation models by Boomsma (1985). Exclusionary criteria included infants who were: more than three weeks of postnatal age (M=5.99 days, SD=7.91); not either singletons or twins; found to have a grade IV intraventricular haemorrhage, or periventricular leukomalacia; and who received sedatives (e.g., chloral hydrate or phenobarbital) or paralytic agents such as pavulon. In addition, of the infants who were eligible for the study, 134 parents did not give consent for their infants to participate, 298 infants were discharged before bloodwork was performed or consent could be obtained, and 39 babies died before bloodwork was performed. Unfortunately, comparisons could not be made between participants and refusers because the researchers did not have access to the medical records for the neonates whose parents did not allow them to participate.

Measures

Neonatal Facial Coding System (Appendix A). The Neonatal Facial Coding System (NFCS) was developed by Grunau and Craig (1987; 1990), and is based on the Facial Action Coding System (FACS) (Ekman & Freisen, 1977). The NFCS provides a detailed and objective coding system for the description of the facial expressions of infants undergoing painful

procedures. Thus, the coder records the occurrence of: brow bulge, eye squeeze, naso-labial furrow, open lips, vertical stretch mouth, horizontal stretch mouth, and taut tongue. These five 2-second segments were then summed for each facial action unit, producing a total score for that unit. The raters were doctoral students in psychology who received training in the use of NFCS. These raters began coding for the study after they achieved an inter-rater reliability of .80 on practice tapes.

Support for the use of the NFCS as a valid measure of pain has been provided by Craig, Hadjistavropoulos, Grunau and Whitfield (1994) who found that the most frequently occurring facial actions, that occurred in response to pain, loaded on one factor which was interpreted as a pain structure. Inter-rater reliability, measured as the number of agreements relative to the total number of actions coded (cf., Ekman & Friesen, 1978), has ranged from 0.88-0.90 (Craig, Whitfield, Grunau, Linton & Hadjistavropoulos, 1993; Grunau & Craig, 1987; 1990; Grunau, Johnston & Craig, 1990). This particular method of calculating inter-rater agreement is typically used in studies using similar coding systems because it provides a more conservative estimate than traditional calculations of inter-rater reliability that include agreement on occurrence and non-occurrence (Craig, Hadjistavropoulos, Grunau &Whitfield, 1994). Inter-rater reliability (for 25% of the cases) was calculated in a similar manner, in the proposed study, by a second rater also trained in the use of NFCS.

Score for Neonatal Acute Physiology (Appendix B). The SNAP is a 26-item index that rates the severity of pathology in each organ system during the first 24 hours following birth (Richardson, Gray, McCormick, Workman & Goldmann, 1993). Scores are obtained in 5 to 15 minutes from medical charts, and are easily obtained by nonmedical personnel. The SNAP also has demonstrated validity as it is predictive of length of stay, mortality, nursing workload, therapeutic intensity, and physician estimates of mortality risk (Richardson, et al., 1993).

Neonatal Therapeutic Intervention Scoring System (Appendix C). The NTISS is a 62-item index of therapies typically applied in a NICU setting (Gray, Richardson, McCormick, Workman-Daniels, & Goldmann, 1992). Items are weighted on a scale of one to four based on the complexity and intensity of the required intervention. In addition, there are several mutually exclusive items, with the item receiving the highest weighting included in the total score (e.g., a

baby who receives supplemental oxygen, and later required mechanical ventilation would only receive a score for the latter, more intense intervention). Scores were obtained from the neonates' medical records in the 24 hour period following admission by a trained research assistant blind to the purpose of the study. Initial support for the use of the NTISS as a measure of neonatal illness severity has been found with its ability to predict mortality risk and rates, nursing workload, and length of stay (Gray, et al., 1992).

Apgar Scores (Appendix D). Originally developed by Virginia Apgar (1953) as a measure to predict resuscitation in the newborn, the Apgar score currently consists of a five item index where values of 0, 1 or 2 are assigned at one, five and ten minutes following birth. These five items include: heart rate, respiratory effort, muscle tone, reflex irritability, and colour (Letko, 1996). Typically, Apgar scores taken at five and ten minutes are better predictors of outcome than the one minute Apgar (American Academy of Pediatrics, 1986). For this study the one and five minute scores were used because they were available for all the infants who participated in the study, while the ten minute score was rarely available from the infants' medical records.

Behavioural State. Sleep state was scored, using Craig and Grunau's (1993) adaptation of Pretchl's (1974) scoring system, at the neonates' bedside 60 seconds prior to the initiation of the procedure. This scale has been shown to discriminate reliably between the following sleep states: quiet sleep, active sleep, quiet awake, and active awake, and crying. Inter-rater reliability in a previous study was reported as 83% (Grunau & Craig, 1987). Inter-rater reliability ratings were obtained in the present study by having a second judge rate behavioural state from all of the videotapes of the infants. This was done so that the second rater's judgement could be used as a second indicator in the covariance structure analyses.

Analgesia. The doses of actual analgesia administered (not just prescribed) in the 24 hour period preceding the heel lance was obtained from the neonates' bedside charts. Dosages, expressed in terms of milligrams per kilograms, were recorded for the following analgesics: morphine, fentanyl, tylenol.

Number of procedures. A chart review was used to count the number of invasive procedures the infants received during their stay in hospital. These procedures included:

venepuncture, arterial puncture, lumbar puncture, circumcision, heel stick, chest-tube insertion, and long-line insertion.

Apparatus

A colour VHS video camera was used to record the infants' facial movements during the venepuncture, and a research assistant superimposed an audio tone on the videotape to signal the beginning of the procedure. In addition, a digital time display was superimposed upon the videotape in order to accurately identify the segments that were coded. A Super-VHS video recorder, with stop frame and slow motion feedback, was used during the coding of the segments.

Design and Procedure

Informed consent was obtained from parents before videotaping the infants during the venepuncture (see Appendices E and F). Prior to the initiation of the venepuncture, the nurse performing the procedure paged one of the research assistants. Data were collected seven days a week, between the hours of 7:30 am and 9:00 pm in order to obtain the required sample size within a reasonable time frame. The camera was positioned to obtain a full view of the infant's face, although the exact distance varied slightly from infant to infant depending on where the nurse was standing, and the neonate's position. Thus, all of the data for the study were obtained unobtrusively, and did not impact upon the delivery of care to the infant. However, there was the possibility that the awareness of being videotaped while performing the procedure may have impacted upon the behaviour of the medical staff.

Once the camera was positioned the infant was videotaped for 60 seconds prior to the procedure to permit the scoring of the infants' behavioural state. The research assistant signalled the onset of the venepuncture with the tone generator, a device that was directly connected to the audio input of the camcorder, that superimposed an audio signal on the videotape. In order to prepare the video segments for facial coding, the first research assistant superimposed a digital time display accurate to 1/30 of a second (essentially there are 30 frames per second on a standard VHS tape). This allowed for the accurate identification of the precise five - 2 second segments that were to be coded using the NFCS. A second research assistant coded all of the segments for both the neonates' behavioural state and facial expression. In order to ensure

accuracy of the coding, a reliability check was performed after this research assistant coded the first 20 video segments, and was allowed to proceed after it was established that inter-rater reliability exceeded .80. Reliability coding of behaviour state and the NFCS was performed for 25% of the sample by the primary investigator, who has also been trained in the use of NFCS and the Facial Action Coding System (Ekman & Friesen, 1978).

Structural Equation Modeling. For those readers unfamiliar with covariance structure models, a brief description is provided below. When employing structural equation modeling (SEM) procedures, the researcher's goal is to determine whether the hypothesized model fits the data based on statistical criteria, practical criteria, and the meaningfulness of the model. Two submodels, a structural and a measurement model, comprise the full covariance structure model (Byrne, Shavelson & Muthen, 1989). The measurement model, defines the relationships between the observed variables (i.e., the items for each of the measures) and the factors (Byrne, et al., 1995). Consequently, this submodel specifies a priori which items will load on which factor. In Figure 1, this model is depicted by the rectangular boxes, each representing an item on one of the measures. The arrows leading from each of the factors to their respective observed variables are regression paths that represent the factor loadings. The observed measurement error associated with each of the items is depicted in Figure 1 as the arrows pointing to each box (Byrne, 1989).

The structural model consists of the pattern of relationships between the unobserved hypothetical factors, often referred to as latent variables. The structural submodel is usually identified in diagrams as a series of interrelated circles that represent the factors under investigation. The arrows leading from the factors representing the contextual variables to the pain factor represent a regression path demonstrating the causal influence of physical maturity, illness severity, number of previous procedures, behavioural state, and analgesic use, on the facial expressions of the neonates receiving a venepuncture (Byrne, 1989). The angled arrows pointing at each of the factors represent the residual error in the model (i.e., error in the prediction of pain behaviour by the contextual variables). If the proposed model should generate a less than adequate fit, an exploratory-sensitivity analysis was conducted to delineate the source of model misfit. All analyses was based on covariance matrices and listwise deletion of data.

Data Analyses. Data were analysed in two-stages and based on the EQS (version 4) program (Bentler, 1992). First, the measurement model was tested (i.e., all the latent variables were tested for validity of structure in an initial CFA). Second, a causal model based on the pattern of relationships between the factors was specified (Figure 1). Direct paths, impacting on the intensity of neonatal pain behaviour, were hypothesized as follows: (1) physical maturity will have a positive impact on pain behaviour; (2) illness severity was expected to have a negative impact on pain; (3) the number of previous procedures the infants has had to undergo will have a positive impact on subsequent pain behaviour; (4) behavioural state will have a positive impact on pain; and (5) analgesics given 24 hours prior to the venepuncture will have a negative impact on pain behaviour. One indirect path is hypothesized between gestational age and illness severity given that younger infants tend to be more ill.

Assessment of Model Fit. Multiple criteria, based on statistical, practical, and theoretical considerations, were used to assess the fit of the initial and nested models (cf. Byrne, et al., 1989). Researchers have been encouraged not to base their judgement of model fit on the χ^2 statistic alone (Byrne, 1989), additional fit indices included the Bentler (1990) revised normed comparative fit index (CFI), and the root mean square error of approximation (RMSEA). The CFI provides an index based on a comparison of the specified model with a null model (i.e., a model where all items are hypothesized to be uncorrelated). The RMSEA takes into account the complexity of the model, with values ranging between .05 and .08 considered adequate.

Sources of misfit in the initial model were identified through the use of the Lagrange multiplier test (LM test) and by determining the substantive meaningfulness of misspecified parameters. Following an examination of the LM test, a sensitivity analysis was performed to determine whether each newly specified model presented a significant improvement over its predecessor. Constraints on misspecified parameters were only relaxed when it made substantive sense to do so. Next, non-significant parameters were removed following inspection of the Wald test. In this manner, a final model was generated that reflected the most parsimonious, and substantively meaningful best-fitting model (cf. Byrne, 1989). Statistical, practical and the substantive meaningfulness of the solution were used to judge the suitability of the final model.

The latter criterion was based on the author's empirical and theoretical knowledge of the subject area.

Cross-Validation. Cross-validation is one means of assessing the validity of covariance structure models. Initially, a calibration model is used to identify the regression weights. Second, a validation sample is employed in order to calculate a cross-validation index (cf. Cudeck & Browne, 1983). However, given the small sample size obtained in the present study, splitting the sample into two separate calibration and validation samples was infeasible.

Therefore, an alternative method of estimating the cross-validation coefficient was employed. Browne and Cudeck (1989) have outlined a method of obtaining the estimated cross-validation index (ECVI) when researchers are unable to calculate a two-sample index. Use of the ECVI involves comparing values obtained from competing models to determine which model is most likely to cross-validate in future samples.

Browne and Cudeck (1989) compared the values obtained from the ECVI with a two sample index for four competing models. In addition, they compared the accuracy of the indices for three different samples sizes: (1) N=100; (2) N=400; (3) N=800. The results of the study demonstrated that in a sample size of 100, they were able to obtain values that approximated the two sample index. The differences for the larger sample sizes were inconsequential. Although the use of the ECVI is not ideal, given the small sample size to be obtained in this study, it does provide an additional method of assessing the predictive validity of the model in future samples. Therefore, a comparison of the hypothesized model, with the alternative models (see Figures 2 and 3) was conducted to determine which model is most likely to generalize to a second sample.

An alternative method of assessing the validity of the model in future samples is to employ bootstrapping techniques (Bollen & Stine, 1993; Stine, 1989; Thompson, 1995). Bootstrap methods involve treating the original sample as if it was the underlying population. The bootstrap sample is generated by sampling with replacement from the original data.

Although the bootstrap method is an appealing alternative to estimating the predictive validity of a given model, it has been developed only recently (cf. Efron, 1979). Consequently, its applicability to covariance structures has not received substantial investigation (Bollen & Stine, 1993; Yung & Bentler, 1996). In fact, several difficulties in applying the bootstrap in this area

have been noted. For example, Bollen and Stine (1993) demonstrated that, in a sample that displayed multivariate normality, the distribution of the bootstrap sample became skewed.

Although Bollen and Stine (1993) argued that the bootstrap sample could be transformed to correct this problem, Yung and Bentler (1996) argue that these methods are not a "cure-all" for the problems associated with small sample sizes. For example, they point out that there are several studies citing the failure of the bootstrap, and that there are currently no rules to predict when it will fail. Therefore, they suggest that more research be conducted to determine the precision of bootstrap estimates in structural equation modeling before they are performed as a matter of course.

Results

Preliminary Analyses

Preliminary analyses of the data were performed to determine the accuracy of data entry, the presence of missing values or outliers, and to determine that all the assumptions of multivariate normality were achieved.

Reliability of Indicators. The inter-rater reliability of the facial coding data was computed by dividing the total number of agreements by the total number of action units coded (c.f., Ekman & Friesen, 1978) for 25 % of the cases. Using this conservative approach, agreement between raters was calculated at 88.94%. In addition, inter-rater reliability for the coding of the neonates' behavioural state prior to the procedure was also acceptable (κ = .809).

Removal of Infrequent Indicators. A number of the indicators planned for use in the current study were removed from the analyses of the measurement and structural models. This was due to the fact that they occurred too rarely to be useful in subsequent analyses. These included all of the analgesic variables, because fewer than nine percent of the sample received any analgesic medication during their stay in the NICU. Furthermore, of those who participated in the study, none were receiving medication in the 24-hour period preceding the videotaping of their bloodwork.

None of the infants in the study had been circumcised, and less than five percent received a lumbar puncture, chest tube, or had surgery prior to their participation in the study. Therefore, these indicators were removed from the Previous Procedures factor.

Finally, the lip purse, chin quiver and tongue protrusion facial action units were removed because they occurred in less than two percent of the sample. A revised hypothesised model, with these indicators removed can be found in Figure 4.

Missing Data. It was determined that, upon inspection, all values for each indicator fell within their expected ranges. Eleven cases were deleted from the sample because they had pacifiers in their mouths during the venepuncture; leaving a sample size of 186 participants.

Outliers. Casewise residuals were identified to determine the presence of univariate outliers (i.e., cases with $z > 3.0$). Twenty cases were identified (13 had received a high number of invasive procedures while in hospital, 4 had high illness severity ratings, and 3 had low five minute Apgar scores). The initial CFA was run both with and without these cases, with identical results. Therefore, it was decided to keep these outliers in the analyses in the interest of maintaining a satisfactory sample size. In terms of multivariate normality, EQS identified five cases with the largest contribution to multivariate kurtosis. However, upon inspection these cases did not appear to reflect extreme values and were not deleted from the analyses.

Sample Size. Boomsma (1983) recommends a minimal sample size of 200 for small samples. The sample used in this study ($N = 186$), approaches this number.

Normality. Univariate skewness ranged from -1.4948 to 2.7543 and kurtosis ranged from -1.8076 to 9.3327. Mardia's coefficient = 118.4809 with a normalized estimate of 30.1098, indicated a moderate degree of multivariate kurtosis. However, this is to be expected in this particular population as most of the neonates are seriously ill, and receive many invasive procedures during their stay in the NICU. Therefore, maximum likelihood estimation was used requesting the Satorra-Bentler Scaled χ^2 . This statistic was specifically designed to correct for multivariate kurtosis, by adjusting the standard error terms. Typically, multivariate kurtosis has a more deleterious effect on the model than skewness.

Linearity. A review of selected pairwise scatterplots did not show evidence of a marked departure from linearity.

Multicollinearity and Singularity. The determinant of the matrix was .31070E+15, indicating that there was no singularity. Hence, the matrix could be inverted, a necessary function in the analysis of covariance structures.

Factorability of the Covariance Matrix. As a rough guide to the patterns of relations in the covariance matrix, the correlation matrix of the 18 indicators in the model was inspected. Several correlations >.30 were found between items that were not part of the same assessment tool (see Table 2).

Model Estimation

Evaluation of the fit of a model involves the use of multiple criteria based on statistical, theoretical and practical issues due to lack of agreement on a single indicator of model fit. Consequently, the following statistical and non-statistical criteria were employed to determine the adequacy of the hypothesized model: (a) Satorra-Bentler χ^2; (b) the comparative fit index; (c) the root mean square error of approximation; and (d) the expected cross-validation index.. Sources of misfit in the initial model were identified through the use of the Lagrange multiplier test (LM test) and by determining the substantive meaningfulness of misspecified parameters. Following the identification of the misspecified parameters, each model was compared, using the Satorra-Bentler χ^2 to determine whether each newly specified model presented a significant improvement over its predecessor. Constraints on misspecified parameters were only relaxed when it made substantive sense to do so. Next, non-significant parameters were removed following inspection of the Wald test. In this manner, a final model was generated that reflected the most parsimonious, and substantively meaningful best-fitting model (cf. Byrne, 1989).

A confirmatory factor analysis of the measurement model was performed. Although a change in chi-square indicated a significant improvement in fit between the independence model and the measurement model, a less than adequate fit was found for the initial CFA in terms of the Satorra-Bentler χ^2 (130, N = 186) = 237.534 , $p < .001$, the CFI (.854) or the RMSEA = .122. In addition, even though the residuals are symmetrically distributed around zero, they remain large. The largest standardized residual was .505, with several over .30.

Consequently, post hoc model-fitting modifications were employed in order to create a more parsimonious well-fitting model. Using the LM test, and taking into account the substantive meaningfulness of the parameters, two paths were added. Table 3 contains the models with their respective Satorra-Bentler χ^2 values, CFI, RMSEA, and Chi-square change statistics. The final measurement model, included a correlated error between V16 (Vertical Stretch Mouth) and V18

(Taut Tongue), a cross-loading between V8 (Heel Lance) and F1 (Illness Severity), and the removal of V2 (NTISS score) when a corresponding correlated error was noted with V1 (SNAP score). These modifications resulted in a well-fitting measurement model (CFI=.946, RMSEA=.079, Satorra-Bentler χ^2 (112, $\underline{N}$ = 186) = 110.845 , $\underline{p}$ = .513). Although it is not ideal to have correlated errors present in the model, it is less problematic when they appear as part of the same measuring instrument (Byrne, 1989). Hence, the correlated error was allowed between V16 and V18 which are both items of the Neonatal Facial Coding System, but was not permitted between the SNAP and NTISS measures of illness severity because they were separate measurement indicators. The SNAP score was retained in favour of the NTISS, because of its stronger factor loading. Finally, the cross-loading between V8 (Heel Lance) and F1 (Illness Severity) was allowed because it made intuitive sense that those neonates who are more seriously ill are also more likely to receive an increased number of blood tests.

In the next stage of the analysis, the revised structural model was evaluated, with directional arrows from Illness Severity (F1), Physical Maturity (F2), Painful Procedures (F4), and Behaviour State (F3) to Pain Expression (F5), and from Physical Maturity (F2) to Illness Severity (F1). This provided a well-fitting model. Additional parameters were not added because a non-significant χ^2 difference was obtained, Satorra-Bentler χ^2 (113, $\underline{N}$ = 186) = 114.206 , $\underline{p}$ = .451, CFI (.944), RMSEA = .080. In the interest of parsimony, a final model was run after inspection of the Wald test for the removal of non-significant parameters. This resulted in a final model with the deletion of the paths from Physical Maturity (F2) to Pain Expression (F5) and from Painful Procedures (F4) to Pain Expression (F5), Satorra-Bentler χ^2 (115, N = 186) = 115.773 , $\underline{p}$ = .462, CFI (.944), RMSEA = .079. In addition, 27 % of the variance in the facial expression of pain was accounted for by its predictors.

Regarding individual parameters, high illness severity scores were predictive of a diminished response to pain (standardized coefficient = -.280). Behaviour state was also predictive of pain expression (standardized coefficient = .436), with increased wakefulness leading to a stronger pain response. In addition, Physical Maturity was directly predictive of the infants' Illness Severity ratings (standardized coefficient = -.510), and accounted for 24 % of the variance in Illness Severity. Finally, an indirect effect was found between Physical Maturity and

Pain Expression that was mediated by Illness Severity (standardized coefficient for indirect effects = .143). A pictorial diagram of the final model with standardized parameter estimates can be found in Figure 5.

The last phase of the data analyses consisted of the comparison of the two alternative models with the final model. In the first alternative model (see Figure 2) the neonates' illness severity and physical maturity were expected to account for the variability in the other factors (i.e., younger, more ill infants should require more frequent bloodwork to monitor their physiological status, and spend more time sleeping).

The second alternative model (see Figure 3) hypothesized that the variability in the other four contextual variables reflected differences in neonates of varying gestational ages. For example, older neonates should be healthier, more alert, receive higher levels of analgesia, require fewer invasive procedures during their stay in hospital. Using expected cross-validation index (ECVI) it was determined that the final model was the most likely to cross-validate in future samples compared to either of the two alternative models (see Table 5).

Discussion

A well-fitting model of the contextual factors that influence the facial expression of pain was obtained from data collected in a tertiary care NICU. The final model was established post-hoc, by identifying sources of misfit of the initial hypothesized model. Improvement of fit was achieved with the addition of one correlated error, one cross-loading, and the removal of a redundant indicator. Therefore, the model explained 94% of the covariance observed in the data.

Specifically, the facial expression of pain could be predicted by the neonates' illness severity ratings (with more severely ill neonates showing a diminished response to pain) and by behaviour state (with increased wakefulness leading to a stronger pain response). Also interesting was the indirect effect of physical maturity on pain behaviour mediated through illness severity. One possible explanation for failing to find a direct relationship between these two variables may be due to the sample that was employed in the current study. Due to the fact that the data were collected in a tertiary care NICU, few of the neonates in the study were completely healthy (or they would have been discharged or transferred to the well-baby unit). This lack of variability in the sample may have prevented the true relationship between physical maturity and the facial

expression of pain from being described, and future samples should include more healthy infants. Another possibility includes the 10 second time frame from which the data were collected. The response to the procedure may be delayed in younger neonates, and a longer sampling period may have assisted in detecting a direct effect from physical maturity on pain expression (e.g., Johnston & Stevens, 1996).

No relationship was found between number of previous procedures and subsequent pain behaviour. This is in contrast to research conducted by Johnston and Stevens (1996) where infants who had spent four weeks in the NICU had less mature pain responses than infants who had spent only four days in the hospital. In the current study, infants had only spent an average of six days in the NICU. It is possible that the shorter period of time was insufficient to detect the effects of repeated invasive procedures on subsequent pain expression. This conclusion is supported by an examination of the significant negative correlations between the number of heel lances and arterial punctures received by the neonates and the individual NFCS variables (see Table 2). Although the correlations are modest, they are in the expected direction, with those neonates undergoing more invasive procedures presenting with a more subdued facial expression.

Finally, it was also disappointing that not enough neonates received analgesic medication for this factor to be included in the study; although findings from this study appear to be consistent with practice at other NICUs where medication is rarely given for routine invasive procedures (Johnston, Collinge, Henderson & Anand, 1997). Taddio, et al. (1997) found promising results for the use of an analgesic cream, EMLA, in the attenuation of the long-term effects on pain behaviour. In that study, infants who received EMLA for their circumcisions showed a reduction in pain behaviour, during a vaccination at four to six months of age, compared to infants who had received a placebo cream. However, the pain response of the infants in the EMLA condition was still greater than the male infants who had not been circumcised.

Despite these limitations, this study replicated previous research that found relationships between pain behaviour and the neonates' behaviour state (Craig, et al., 1993; Grunau & Craig, 1987), illness severity (Stevens, Johnston, & Horton) and physical maturity (Craig, et al. 1993;

Grunau, et al., 1994; Johnston, et al., 1994). Furthermore, through the use of structural equation modeling procedures, allowing for the simultaneous analysis of these variables, the indirect effect of age on pain could be determined in a tertiary care sample. Researchers have often speculated on how these contextual factors work together to influence pain expression (Craig & Grunau, 1993; Stevens, 1996; Stevens, et al., 1995). Previously, it was difficult to tease out the relative influence of the contextual variables included in this study, because younger infants tend to be more ill, and spend more time in one of the sleep states.

Finally, additional support for the final model was found when it was compared to the two alternative models. In the first alternative model (see Figure 2), the direct paths from behaviour state and number of procedures were removed. Instead, the neonates' illness severity and physical maturity was expected to account for the infants spending more time in one of the sleep states, and the number of procedures they received (i.e., younger, more ill infants will require more frequent bloodwork to monitor their physiological status). The second alternative model (see Figure 3) hypothesized a single direct path from the infants' physical maturity to subsequent pain behaviour. The variability in the other four contextual variables was expected to reflect differences in neonates of varying gestational ages. Of the three models tested, the model proposed for this study was found to be the one most likely to be cross-validated in a second sample. Despite this encouraging result, this approach does not replace the more stringent test of replicating the results in a second cross-validation sample of neonates.

Future Research

This study found a well-fitting model of the contextual variables influencing the facial expression of pain. This model was meaningful from both a substantive and practical point of view. However, several limitations are notable, and should be taken into account in future research. First, it was disappointing that the impact of previous pain experience on subsequent pain behaviour could not be demonstrated. In contrast, Johnston and Stevens (1996) were able to find that preterm infants who had been in the NICU for a month did present with a more flaccid response to pain than neonates who were newly admitted. A future test of this model would likely benefit from including the number of days the infant had spent in hospital, and by making a point of including infants who had stayed a month or longer in the NICU.

Next, the indicators in this study only were able to account for 27% of the variance observed in the facial expression of pain. Although this is meaningful in a clinical sample, there remains a substantial proportion of variance explained by other factors. Craig and Grunau (1993), in their review of the literature, note that the differences in pain expression accounted for by the gestational age of the neonate were modest in comparison to the individual differences between infants, with some infants occasionally not even responding to invasive events.

In fact, there are a myriad of other factors, either hypothesized or demonstrated, that influence a neonate's response to pain. These potential causal factors include environmental, behavioural and physiological variables that would be important to include in any prospective replication of the model examined in the current study (Craig & Grunau, 1993). For example, Grunau, Craig and Drummond (1989) found that obstetric medication, and when the neonate was last fed had a substantial influence on the behavioural pain response.

Future studies also need to delineate the role of environmental variables on the ability of the infant to respond to invasive procedures. Light, sound, and tactile contact have all been shown to impact upon the neonates' behavioural and physiological stability, as well as long-term outcome following discharge from the NICU (Als, 1990; Als, Lawhon, Brown, Gibes, Duffy, McAnulty & Blickman, 1986; Buehler, Als, Duffy, McAnulty & Liederman, 1995; Mouradian & Als, 1994). Several researchers have hypothesized that these environmental factors might play an important role in the behavioural and physiological response of the neonate to pain (Craig & Grunau, 1993, Stevens, 1996).

Because the study of neonatal pain relies on the observation of pain in a naturalistic setting, future studies must also attempt to quantify the difficulty in the performance of the procedure under study. This factor is particularly salient in a preterm population, where clinicians must often draw blood from extremely preterm neonates with veins that are hard to access. Possible methods to include such a variable in future research would be to obtain subjective ratings by clinical staff on the ease with which they were able to perform the procedure, the number of attempts that were made before the blood sample could be obtained, and the total time required to perform the procedure.

Finally, another point not addressed in this study was the impact of these contextual variables on other measures of pain, such as cry, physiological parameters, or body movements. Facial expression was chosen for this study, not only because it is thought to be the most

sensitive and specific measure of pain (Craig & Grunau, 1993), but also because many of the other assessment techniques are not always available in an NICU setting. For example, any infant who had been intubated could not have been included in the study because they would be unable to cry. However, a complete assessment of the neonate's response to pain requires the inclusion of multiple measures of the experience. Furthermore, it would be interesting to determine if cry, body movement, and physiological indicators of pain were differentially affected by the various contextual factors.

Conclusions

Support was found for a practical and meaningful model of the contextual factors influencing the expression of pain. This study replicates the findings of previous research that state the importance of including behavioural state and illness severity when assessing pain in the neonate (Grunau & Craig, 1987; Stevens, Johnston, & Horton, 1994). In addition, it extends that research by uncovering the indirect effect of physical maturity on pain, mediated through the infants' level of illness severity. Furthermore, this indirect effect provides further evidence that even very premature infants experience pain, but are unable to mount a response to an aversive event when they are ill.

In fact, Fitzgerald and colleagues have gathered evidence that neonates may experience elevated levels of pain due to their abundance of afferent projections to the spinal cord, few efferent projections, and densely distributed receptors for NMDA and substance P (Andrews & Fitzgerald, 1994;1997; Fitzgerald & Anand, 1993). They posit that these differences lead to exaggerations in neonatal responses to nociceptive stimuli, in healthy full-term infants, and the flaccid responses noted in exhausted, premature neonates. Given these findings, attempting to quantify the neonatal experience of pain on the basis of behavioural response, is a precarious endeavour. For example, although seriously ill, premature neonates may be more sensitive to nociceptive stimuli, they may be unable to express their pain because of their diminished physical capacity (Andrews & Fitzgerald, 1997; Craig & Grunau, 1993). In this instance, equating the expression of pain with the experience of pain would be inaccurate, and would likely lead to the medical mismanagement of the neonate's pain.

In conclusion, theories of pain that explicate the integration of psychological and physiological components of pain were presented to clarify the existence of infant pain. In this regard, it is of great importance to delineate accurate methods of identifying neonatal pain. This

also speaks to the education of clinicians who may gain a greater appreciation for the variables associated with the expression of pain in neonates.

This study also emphasizes the necessity of clinicians being aware of the many factors that will impact on the expression of pain in this vulnerable population. Craig and Grunau (1993) point out that the ability to assess pain in the neonate is not intuitive, and that a special interest or training may be necessary. In addition to learning about the specific repertoire infants have at their disposal to communicate pain, this study also strengthens the notion that clinicians need to be aware of the external factors that attenuate the neonatal pain response. Most notably, failing to recognize pain when it is present has important humanitarian implications. However, such failures also impact upon decisions about treatment, and the provision of analgesic medication when required. This point is especially salient in seriously ill neonates, who may present with underlying painful conditions, or who require numerous invasive procedures, but who are severely limited in their ability to express pain. Therefore, clinicians working with seriously ill neonates, in particular, may wish to take a proactive stance in the management of their patients' pain. That is, knowing that these infants will have difficulty expressing their pain, steps could be taken to insure the provision of appropriate pharmacologic and non-pharmacologic interventions for all invasive procedures, reducing the number of procedures required, or by modifying the NICU environment so that it is less stressful for the neonate.

Researchers in this area also need to take into account these multiple influences on pain if they are to contribute accurate and meaningful findings to our understanding of the experience and management of pain in the neonatal period. By not including contextual influences in clinical trials of pain interventions, the results of this research will be inaccurate. For example, if behaviour state was not included in a study, and many of the neonates were sleepy during the observation period, the efficacy of potentially useful interventions may be significantly underestimated. Furthermore, this study points to the inherent difficulty in demonstrating the efficacy of different pain relieving interventions in an extremely premature, ill sample of neonates.

Another important consideration for future research is the indirect effect of physical maturity on pain, mediated through illness severity. Depending on the population under study, a researcher may find inconsistent evidence of an age effect on pain behaviour. For example, if a study sample was obtained from an NICU containing "growing" preterms (i.e., premature, but

not necessarily seriously ill) it might be difficult to find an effect for age. However, samples from a tertiary care NICU, where there were are a number of neonates of varying gestational ages and illness severity levels, there would be a greater likelihood of finding a relationship between age and pain behaviour.

In conclusion, researchers and clinicians in the NICU need to ensure that they do not equate the experience of pain, that is thought to be heightened in a neonatal population (cf., Andrews & Fitzgerald, 1994; 1997; Fitzgerald & Anand, 1993), with the neonate's failure to respond. This study represents a major step in accurately delineating the contextual influences on the expression of pain in this particularly vulnerable population. Future studies need to extend this research by examining additional factors that may impact on pain expression, and determine the influence of these factors on other methods of pain assessment in neonates.

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Table 1

Sample Characteristics

Characteristic	
Sex	
Male	88
Female	98
Gestational Age, weeks	
<26	7
26-28	28
29-32	44
33-37	68
>37	36
Birth weight, grams	
<750	7
750-999	12
1000-1499	45
1500-2499	63
>2500	49
Race	
White	176
Black	6
Asian	4

Table 2

Correlations, means and standard deviations of the indicators used in the structural equation model

	SNAP	NTISS	One Minute Apgar	Five Minute Apgar	Gest Age	Vene-puncture	Arterial Puncture	Heel Lance	Weight in grams	Behav State - Rater 1	Behav State - Rater 2	Brow Bulge	Eye Squeeze	Naso-Labio Furrow	Open Lips	Vertical Stretch Mouth	Horiz Stretch Mouth	Taut Tongue
SNAP	1 000	551*	-.434*	-.402*	-.304*	000	.263*	.475*	-.296*	-.164*	-.150*	-.218*	-.227*	-.235*	-.175*	-.288*	-.289*	-.251*
NTISS	551*	1 000	-.307*	-.344*	-.306*	021	.244*	505*	-.267*	-.236*	-.221*	-.239*	-.167*	-.245*	-.221*	-.238*	-.295*	-.184*
One Minute Apgar	-.434*	-.307*	1 000	.730*	399*	.006	-.112	-.377*	.331*	208*	231*	.262*	.301*	.288*	.190*	264*	.289*	.219*
Five Minute Apgar	-.402*	-.344*	.730*	1.000	.408*	075	-.158*	-.327*	.338*	.197*	192*	.270*	273*	.296*	218*	243*	284*	200*
Gestational Age	-.304*	-.306*	399*	.408*	1 000	-.010	-.074	-.412*	854*	065	074	151*	177*	212*	199*	155*	209*	.167*
Venepuncture	000	021	006	075	-.010	1.000	.105	.043	1018	047	074	028	084	090	-.003	104	038	124
Arterial Puncture	263*	244*	-.112	-.158*	-.074	105	1 000	.190*	-.043	-.108	-.098	-.262*	-.153*	-.176*	-.239*	-.256*	-.200*	-.243*
Heel Lance	475*	505*	-.377*	-.327*	-.412*	043	190*	1 000	-.387*	-.137	-.150*	-.185*	-.124	-.176*	-.204*	-.161*	-.213*	-.144*
Weight	-.296*	-.267*	331*	338*	854*	-.018	-.043	-.387*	1 000	074	098	180*	187*	217*	178*	201*	238*	167*
Behaviour State - Rater 1	-.164*	-.236*	208*	197*	065	047	-.108	-.137	074	1 000	944*	415*	389*	380*	330*	597*	421*	600*
Behaviour State - Rater 2	-.150*	-.221*	231*	192*	074	074	-.098	-.150*	098	944*	1 000	451*	423*	416*	333*	601*	456*	615*
Brow Bulge	-.218*	-.239*	262*	270*	151*	028	-.262*	-.185*	180*	415*	451*	1 000	839*	860*	653*	626*	758*	624*
Eye Squeeze	-.227*	-.167*	301*	273*	177*	084	-.153*	-.124	187*	389*	423*	839*	1 000	873*	635*	607*	773*	625*
Naso -Labio Furrow	-.235*	-.245*	288*	296*	212*	090	-.176*	-.176*	217*	380*	416*	860*	873*	1 000	738*	622*	830*	611*
Open Lips	-.175*	-.221*	190*	218*	199*	-.003	-.239*	-.204*	178*	330*	333*	653*	635*	738*	1 000	567*	631*	520*
Vertical Stretch Mouth	-.288*	-.238*	264*	243*	155*	104	-.256*	-.161*	201*	597*	601*	626*	607*	622*	567*	1 000	665*	863*
Horizontal Stretch Mouth	-.289*	-.295*	289*	284*	209*	038	-.200*	-.213*	238*	421*	456*	758*	773*	830*	631*	665*	1 000	703*
Taut Tongue	-.251*	-.184*	219*	200*	167*	124	-.243*	-.144*	167*	600*	615*	624*	625*	611*	520*	863*	703*	1 000

** Correlation is significant at the 0.01 level (2-tailed)

* Correlation is significant at the 0.05 level (2-tailed)

	SNAP	NTISS	One Minute Apgar	Five Minute Apgar	Gest Age	Weight in grams	Vene-puncture	Arterial Puncture	Heel Lance	Behav State - Rater 1	Behav State - Rater 2	Brow Bulge	Eye Squeeze	Naso-Labio Furrow	Open Lips	Vertical Stretch Mouth	Horiz Stretch Mouth	Taut Tongue	Valid N (listwise)
N	186	186	186	186	186	186	186	186	186	186	186	186	186	186	186	186	186	186	186
Mean	6 69	13 32	6 18	8 03	32,92	2077	2 36	2 46	10 94	3 10	3 05	3 24	3 32	3 54	3 81	2 29	3 09	2 09	
Std Deviation	4 81	6 47	2 42	1 51	4 41	924 86	2 12	3 43	12 24	1 61	1 52	2 17	2 10	2 01	1 95	2 23	2 13	2 37	

Table 3

Comparison of the Initial and Final CFA Models

Model	χ^2	d.f.	Satorra - Bentler χ^2	ECVI	CFI	RMSEA	χ^2_{diff}	Δd.f.
Model 1 Hypothesized Model	489.59*	130	237.53*	3.089	0.854	0.122		
Model 2 1. Correlated error added between Vertical Strecth Mouth (E16) and Taut Tongue (E18) 2. Path added from Illness Severity (F1) to Heel Lance (V8) 3. NTISS (V2) removed	240.53*	112	110.84	1.721	0.946	0.079	249.06	18

Note. ECVI = estimated cross-validation index: CFI = comparative fit index; RMSEA = root mean square error of approximation; d.f. = degrees of freedom.

*$p < .05$.

Table 4

Comparison of Nested Models for the Structural Model

Model	χ^2	d.f.	Satorra - Bentler χ^2	ECVI	CFI	RMSEA	χ^2_{diff}	Δd.f.
Model 1 Hypothesized Model	246.19*	113	114.21	1.774	0.944	0.080		
Model 2 1. Path deleted from F2 (Physical Maturity) to F5 (Pain Expression) 2. Path deleted from F4 (Painful Procedures) to F5 (Pain Expression)	247.06*	115	115.77	1.778	0.944	0.079	0.87	2

Note. ECVI = estimated cross-validation index; CFI = comparative fit index; RMSEA = root mean square error of approximation; d.f. = degrees of freedom.

*$p < .05$.

Table 5

Table Comparing the Final Hypothesized Model with the Alternative Models

Model	Satorra - Bentler χ^2	d.f.	ECVI	CFI	RMSEA	χ^2_{diff}	Δd.f.
Final Model	115.77	115	1.778	0.94	0.079		
Alternative Model 1	227.42	127	3.125	0.86	0.123	111.65	12
Alternative Model 2	255.54	130	3.211	0.85	0.124	139.77	15

Note. ECVI = estimated cross-validation index; CFI = comparative fit index; RMSEA = root mean square error of approximation; d.f. = degrees of freedom.

Figure Caption

Figure 1. Hypothesized model of contextual variables predicting the facial expression of pain in neonates. SNAP = Score for Neonatal Acute Physiology; NTISS = Neonatal Therapeutic Intervention Scoring System; Apgar1 = Apgar score at one minute; Apgar5 = Apgar score at 5 minutes.

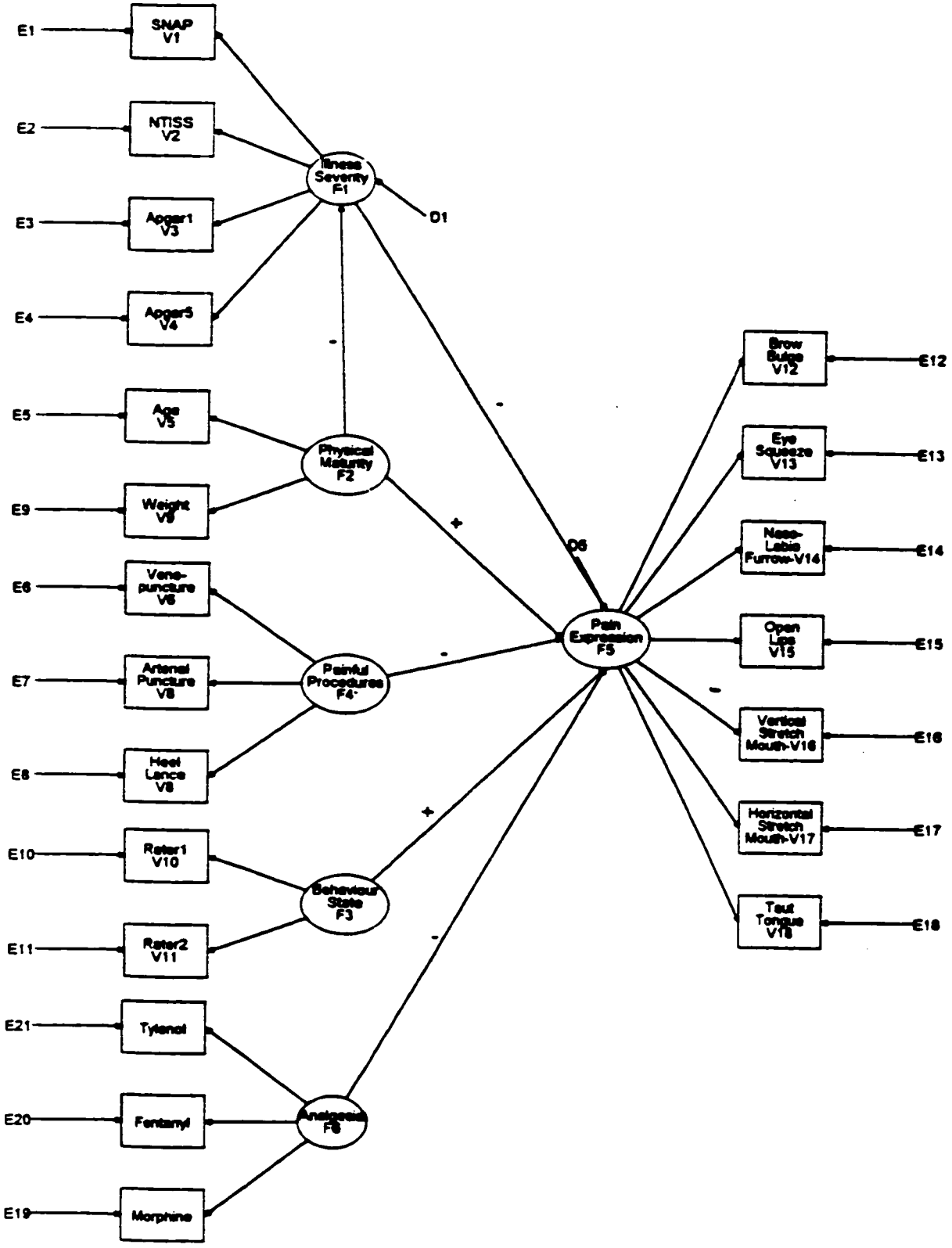

E1
SNAP V1
E2
NTISS V2
E3
Apgar1 V3
E4
Apgar5 V4
Illness Severity F1
D1
E5
Age V5
E9
Weight V9
Physical Maturity F2
E6
Vene-puncture V6
E7
Arterial Puncture V7
E8
Heel Lance V8
Painful Procedures F4
E10
Rater1 V10
E11
Rater2 V11
Behaviour State F3
E21
Tylenol
E20
Fentanyl
E19
Morphine
Analgesia F6
D5
Pain Expression F5
Brow Bulge V12
E12
Eye Squeeze V13
E13
Nasa-Labia Furrow V14
E14
Open Lips V15
E15
Vertical Stretch Mouth V16
E16
Horizontal Stretch Mouth V17
E17
Taut Tongue V18
E18

Figure Caption

Figure 2. First alternative model with Illness Severity and Physical Maturity predicting Pain Expression. SNAP = Score for Neonatal Acute Physiology; NTISS = Neonatal Therapeutic Intervention Scoring System; Apgar1 = Apgar score at one minute; Apgar5 = Apgar score at 5 minutes.

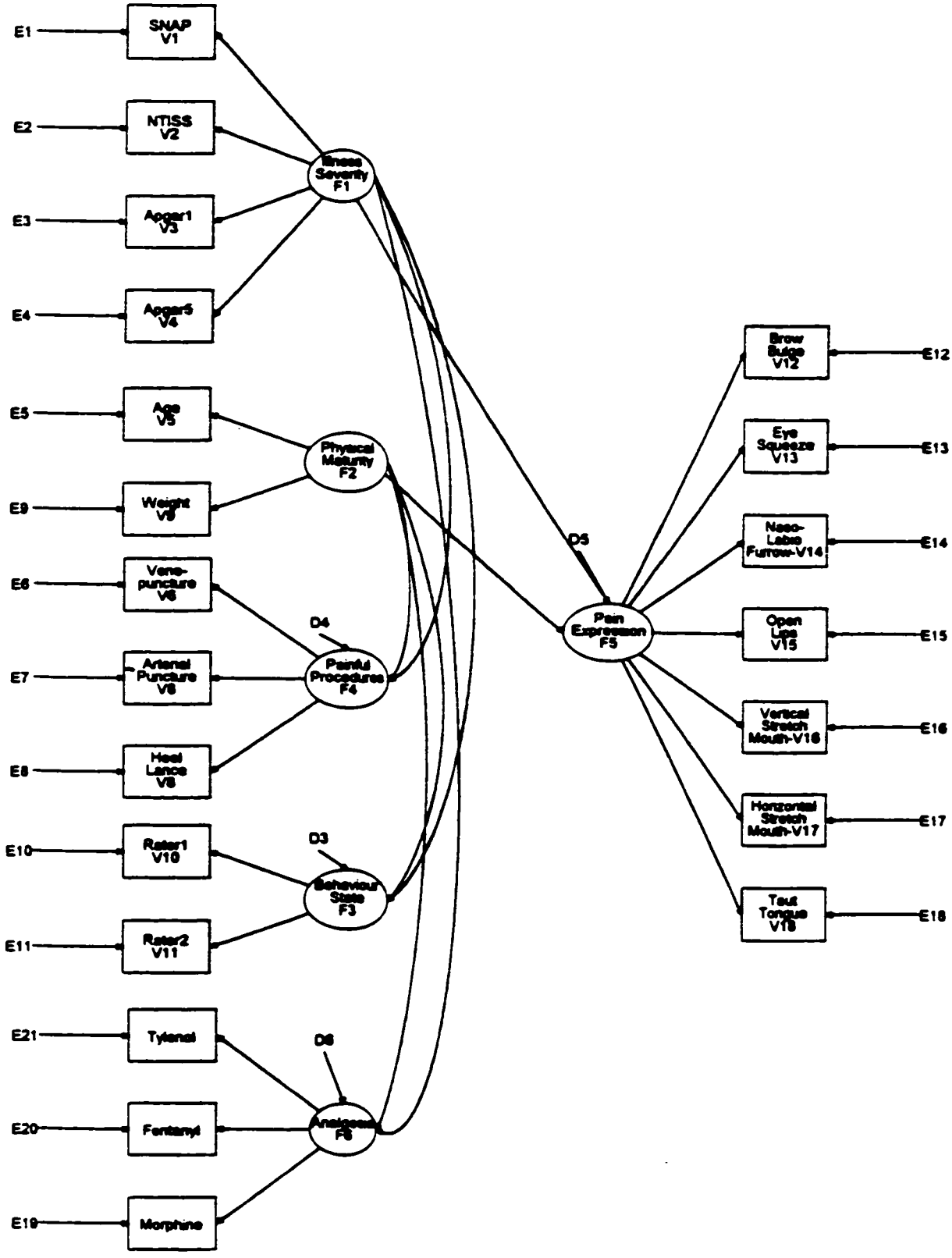

E1
SNAP V1
E2
NTISS V2
E3
Apgar1 V3
E4
Apgar5 V4
E5
Age V5
E9
Weight V9
E6
Vene-puncture V6
E7
Arterial Puncture V7
E8
Heel Lance V8
E10
Rater1 V10
E11
Rater2 V11
E21
Tylenol
E20
Fentanyl
E19
Morphine
Illness Severity F1
Physical Maturity F2
Painful Procedures F4
Behaviour State F3
Analgesia F6
D4
D3
D6
D5
Pain Expression F5
Brow Bulge V12
Eye Squeeze V13
Naso-Labial Furrow-V14
Open Lips V15
Vertical Stretch Mouth-V16
Horizontal Stretch Mouth-V17
Taut Tongue V18
E12
E13
E14
E15
E16
E17
E18

Figure Caption

Figure 3. Second alternative model, predicting a single, direct path from physical maturity to the subsequent facial expression of pain. SNAP = Score for Neonatal Acute Physiology; NTISS = Neonatal Therapeutic Intervention Scoring System; Apgar1 = Apgar score at one minute; Apgar5 = Apgar score at 5 minutes.

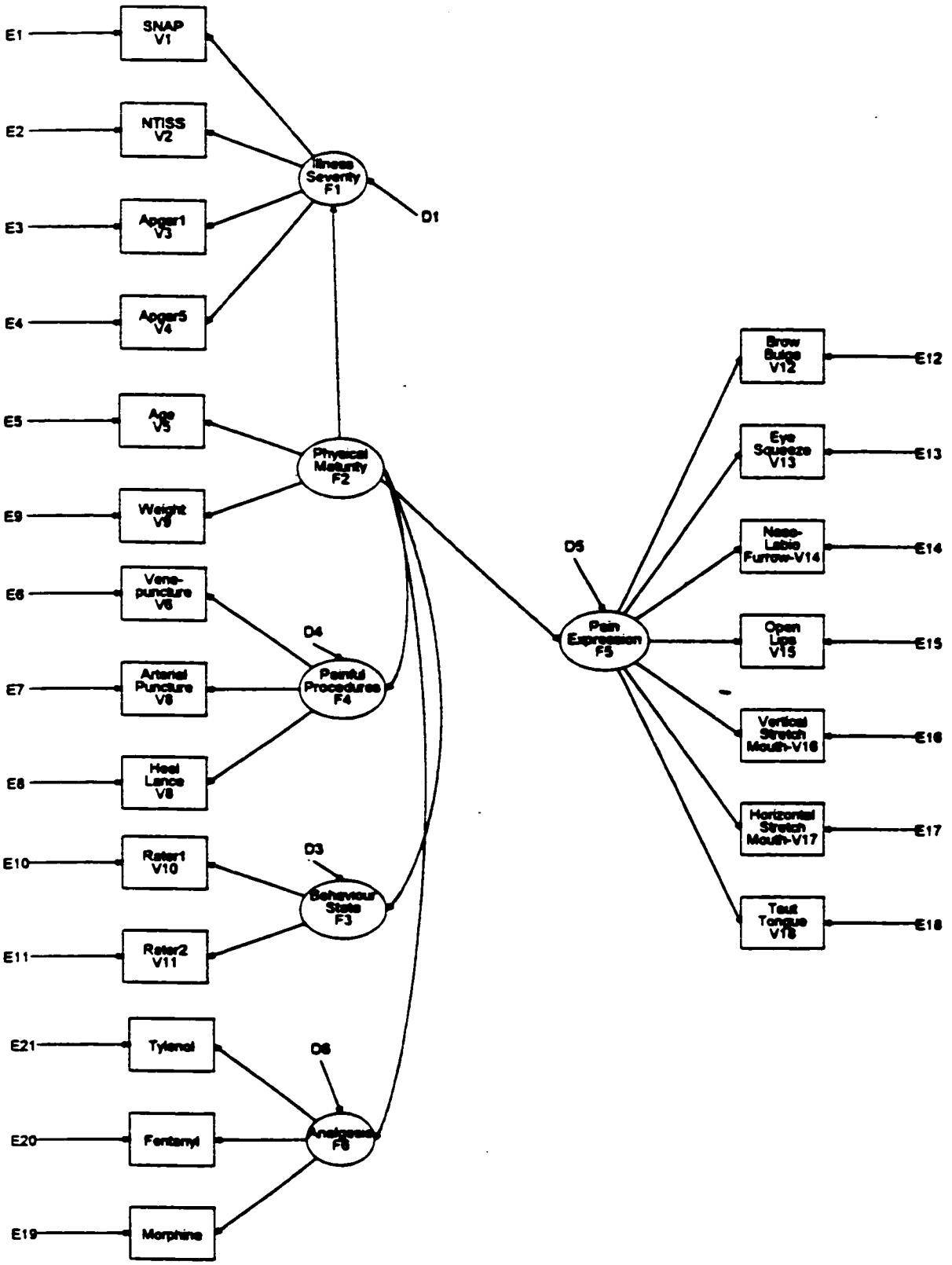

E1
SNAP V1
E2
NTISS V2
E3
Apgar1 V3
E4
Apgar5 V4
Illness Severity F1
D1
E5
Age V5
E9
Weight V9
Physical Maturity F2
E6
Vene-puncture V6
E7
Arterial Puncture V7
E8
Heel Lance V8
D4
Painful Procedures F4
E10
Rater1 V10
E11
Rater2 V11
D3
Behaviour State F3
E21
Tylenol
E20
Fentanyl
E19
Morphine
D6
Analgesia F6
D5
Pain Expression F5
Brow Bulge V12
E12
Eye Squeeze V13
E13
Nase-Labio Furrow-V14
E14
Open Lips V15
E15
Vertical Stretch Mouth-V16
E16
Horizontal Stretch Mouth-V17
E17
Taut Tongue V18
E18

Figure Caption

Figure 4. Revised hypothesized model after the removal of infrequent indicators. SNAP = Score for Neonatal Acute Physiology; NTISS = Neonatal Therapeutic Intervention Scoring System; Apgar1 = Apgar score at one minute; Apgar5 = Apgar score at 5 minutes.

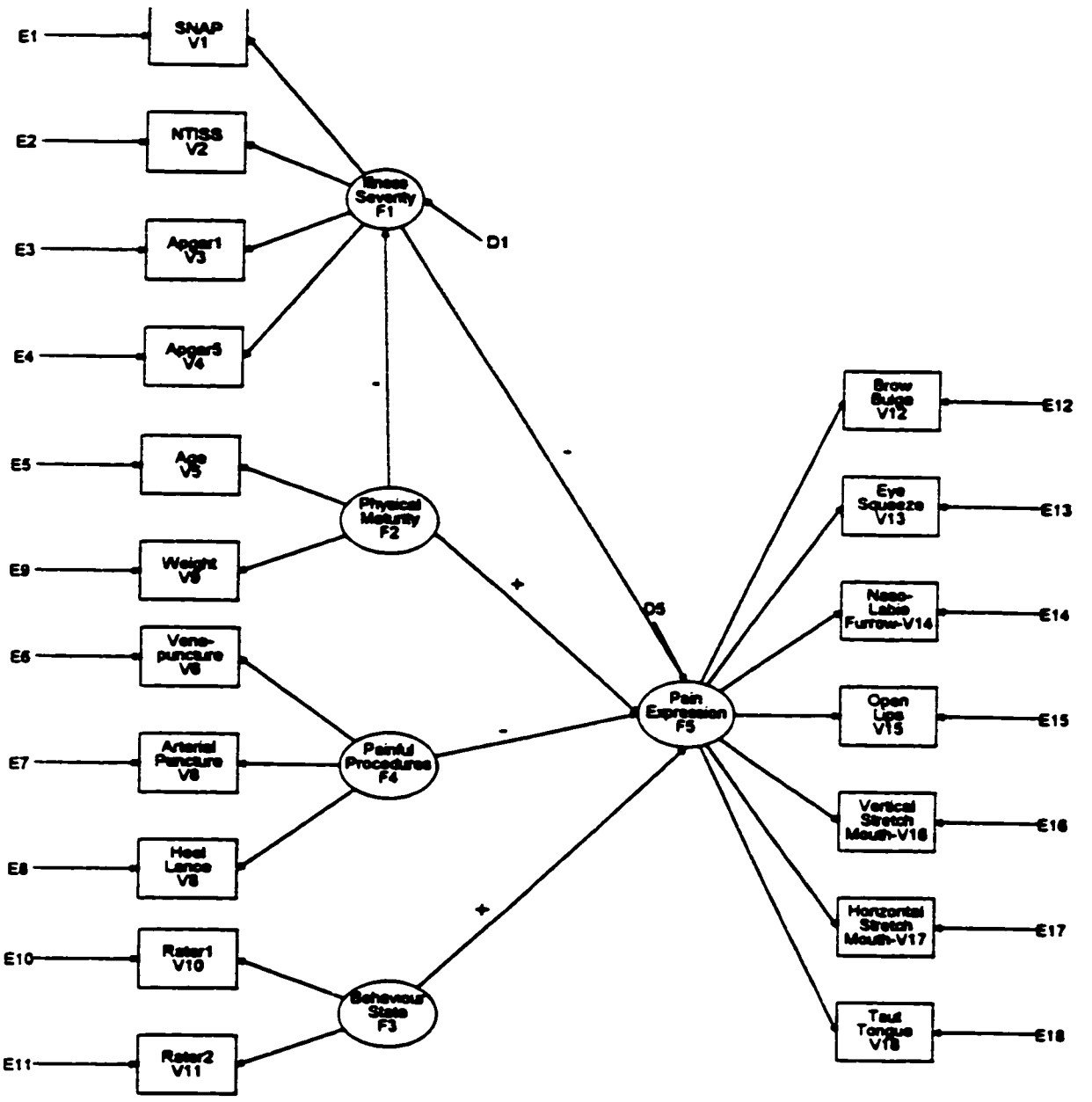
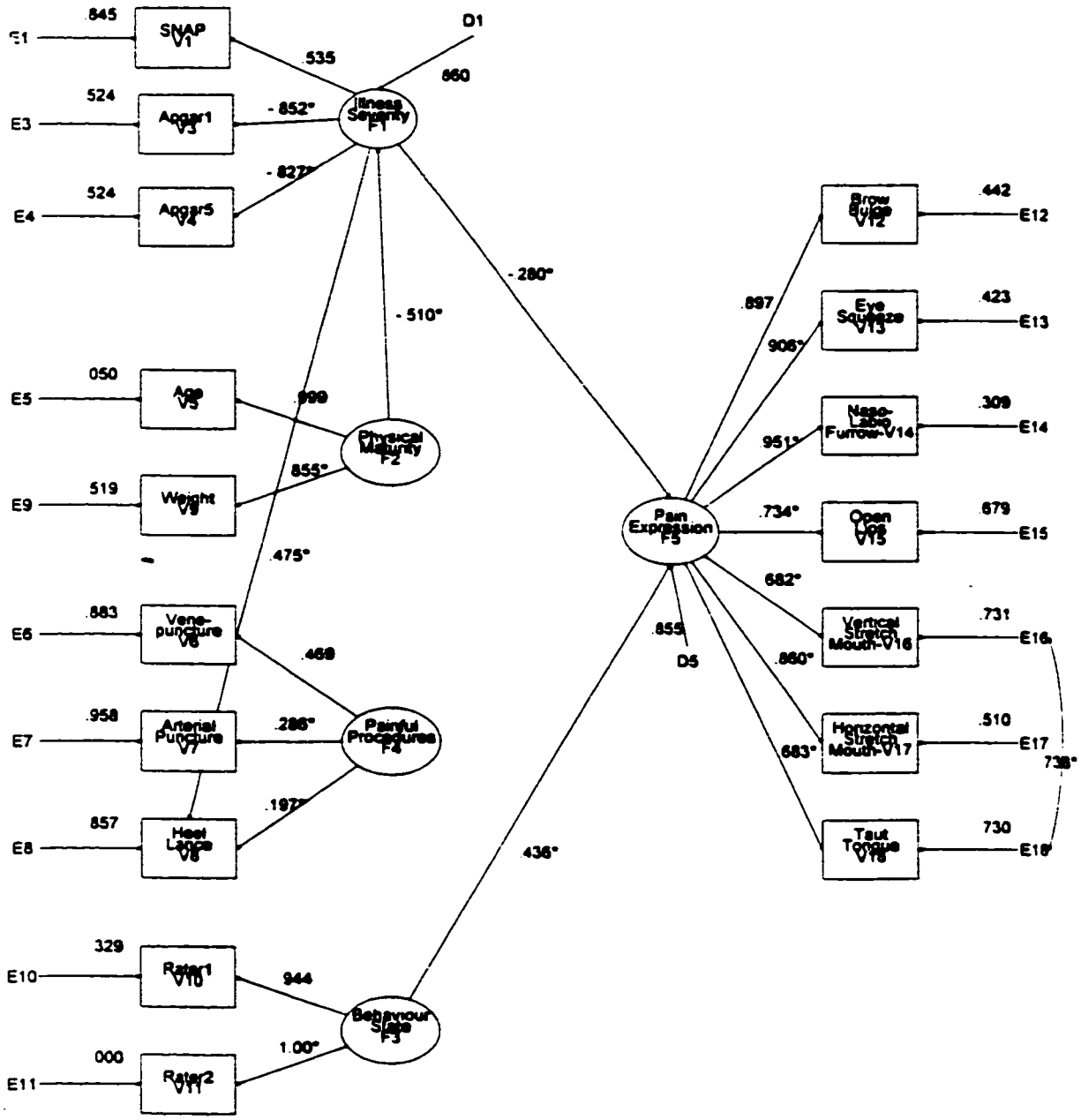

E1
SNAP V1
E2
NTISS V2
E3
Apgar1 V3
E4
Apgar5 V4
E5
Age V5
E9
Weight V9
E6
Vene-puncture V6
E7
Arterial Puncture V7
E8
Heel Lance V8
E10
Rater1 V10
E11
Rater2 V11
Illness Severity F1
Physical Maturity F2
Painful Procedures F4
Behaviour State F3
D1
D5
Pain Expression F5
Brow Bulge V12
E12
Eye Squeeze V13
E13
Naso-Labial Furrow-V14
E14
Open Lips V15
E15
Vertical Stretch Mouth-V16
E16
Horizontal Stretch Mouth-V17
E17
Taut Tongue V18
E18

Figure Caption

Figure 5. Final model with standardized parameter estimates. SNAP = Score for Neonatal Acute Physiology; NTISS = Neonatal Therapeutic Intervention Scoring System; Apgar1 = Apgar score at one minute; Apgar5 = Apgar score at 5 minutes.


.845
SNAP V1
.535
D1
.660
524
Apgar1 V3
- .852*
Illness Severity F1
524
Apgar5 V4
- .827*
E1
E3
E4
- .510*
- .280*
050
Age V5
.999
Physical Maturity F2
519
Weight V9
.855*
E5
E9
.475*
.883
Vene-puncture V6
.468
.958
Arterial Puncture V7
.286*
Painful Procedures F4
.197*
857
Heel Lance V8
E6
E7
E8
329
Rater1 V10
.944
Behaviour State F3
1.00*
000
Rater2 V11
E10
E11
.436*
.855
D5
Pain Expression F5
.897
.906*
.951*
.734*
.682*
.860*
.683*
Brow Bulge V12
Eye Squeeze V13
Naso-Labio Furrow V14
Open Mouth V15
Vertical Stretch Mouth V16
Horizontal Stretch Mouth V17
Taut Tongue V18
.442
.423
.309
.679
.731
.510
.730
E12
E13
E14
E15
E16
E17
E18
.738*

APPENDIX A

Neonatal Facial Coding System

_Action	Description
Brow Bulge	Bulging, creasing and vertical furrows above and between brows occurring as a result of the lowering and drawing together of the eyebrows.
Eye Squeeze	Identified by the squeezing or bulging of the eyelids. Bulging of the fatty pads about the infant's eyes pronounced.
Naso-labial	Primarily manifested by the pulling upwards and furrow deepening of the nasolabial furrow (a line or wrinkle that begins adjacent to the nostril wings and runs down and outward beyond the lip corners).
Open lips	Any separation of the lips.
Ver stretch mouth	Characterized by a tautness at the lip corners (vertical) coupled with a pronounced downward pull of the jaw. Often stretch mouth is seen when an already wide open mouth is opened a fraction further by an extra pull at the jaw.
Hor stretch mouth	Appears as a distinct horizontal pull at the corners of the mouth.
Lip purse	The lips appear as if an "oo" sound is being made.
Taut tongue	Characterized by a raised, cupped tongue with sharp tensed edges. The first occurrence of taut tongue is usually easy to see, often occurring with a wide open mouth. After this first occurrence, the mouth may close slightly. Taut tongue is still scoreable on the basis of the still-visible tongue edges.
Chin quiver	An obvious high-frequency, up-down motion of the lower jaw.
Tongue Prot.	Tongue visible between the lips extending beyond the mouth.

Table originally printed in Grunau and Craig (1990).

APPENDIX B

Score for Neonatal Acute Physiology

Parameter	1-Point Range	3-Point Range	5-Point Range
Blood pressure (mean)			
High	66-80	81-100	>100
Low	30-35	20-29	<20
Heart Rate			
High	180-200	201-250	>250
Low	80-90	40-79	<40
Respiratory Rate	60-100	>100	
Temperature	95-96	92-94.9	<92
Po2, mm Hg	50-65	30-50	<30
Po2 Fio2 ratio	2.5-3.5	0.3-2.49	<0.3
Pco2, mm Hg	50-65	66-90	>90
Oxygenation index	0.07-0.20	0.21-0.40	>0.40
Hematocrit, %			
High	66-70	>70	...
Low	30-35	20-29	<20
White blood cell count (x1000)	2.0-5.0	<2.0	...
Immature total ratio	>0.21	...	...
Absolute neutrophil count	500-999	<500	...
Platelet count (x1000)	30-100	0-29	...
Blood urea nitrogen, mg/dL	40-80	>80	...
Creatinine, mg/dL	1.2-2.4	2.5-4.0	>4.0
Urine output, mL/kg/h	0.5-0.9	0.1-0.49	<0.1
Indirect bilirubin (by birth weight)			
>2 kg: mg/dL	15-20	>20	...
<2 kg: mg/dL/kg	5-10	>10	...
Direct bilirubin, mg/dL	>2.0	...	...
Sodium, mEq/L			
High	150-160	161-180	>180
Low	120-130	<120	...
Potassium, mEq/L			
High	6.6-7.5	7.6-9.0	>9.0
Low	2.0-2.9	<2.0	...
Calcium (ionized), mg/dL			
High	>1.4	...	...
Low	0.8-1.0	<0.8	...
Calcium (total), mg/dL			
High	>12	...	...
Low	5.0-6.9	<5.0	...

Parameter	1-Point Range	3-Point Range	5-Point Range
Glucose			
High	150-250	>250	...
Low	30-40	<30	...
Serum bicarbonate, mEq/L			
High	>33	...	...
Low	11-15	<10	...
Serum pH	7.20-7.30	7.10-7.19	<7.10
Seizure	Single	Multiple	...
Apnea	Responsive to stimulation	Unresponsive to stimulation	Complete apnea
Stool guaiac	Postive	...	...

APPENDIX C

Neonatal Therapeutic Intervention Scoring System

Item	Subscore
Respiratory	
Supplemental oxygen	1
Surfactant administration	1
Tracheostomy care	1
Tracheostomy placement	1
Continuous positive airway pressure administration	2
Endotracheal intubation	2
Mechanical ventilation	3
Mechanical ventilation with muscle relaxation	4
High-frequency ventilation	4
Extracorporeal membrane oxygenation	4
Cardiovascular	
Indomethacin administration	1
Volume expansion (<15 mL/kg)	1
Vasopressor administration (1 agent)	2
Volume expansion (>15 mL/kg)	3
Vasopressor administration (>1 agent)	3
Pacemaker on standby	3
Pacemaker used	4
Cardiopulmonary resuscitation	4
Drug Therapy	
Antibiotic administration (<2 agents)	1
Diuretic administration (enteral)	1
Steroid administration (postnatal)	1
Anticonvulsant administration	1
Aminophylline administration	1
Other unscheduled medication	1
Antibiotic administration (> 2 agents)	2
Diuretic administration (parenteral)	2
Treatment of metabolic acidosis	3
Potassium binding resin administration	3
Monitoring	
Frequent vital signs	1
Cardiorespiratory monitoring	1
Phlebotomy (5-10 blood draws)	1
Thermoregulated environment	1
Noninvasive oxygen monitoring	1
Arterial pressure monitoring	1
Central venous pressure monitoring	1
Urinary catheter	1
Quantitative intake and output	1
Extensive phlebotomy (>10 blood draws)	2
Metabolic Nutrition	
Gavage feeding	1
Intravenous fat emulsion	1
Intravenous amino acid solution	1
Phototherapy	1
Insulin administration	2
Potassium infusion	3

Item	Subscore
Transfusion	
Intravenous gamma globulin	1
Red blood cell transfusion (<15 mL/kg)	2
Partial volume exchange transfusion	2
Red blood cell transfusion (>15 mL/kg)	3
Platelet transfusion	3
White blood cell transfusion	3
Double volume exchange transfusion	3
Procedural	
Transport of patient	2
Single chest tube in place	2
Minor operation	2
Multiple chest tubes in place	3
Thoracentesis	3
Major operation	4
Pericardiocentesis	4
Pericardial tube in place	4
Dialysis	4
Vasucular access	
Peripheral intravenous line	1
Arterial line	2
Central venous line	2

APPENDIX D

Apgar Scoring System

Criteria	Score		
	0	1	2
Colour	Blue: pale	Body pink: extremities blue	All pink
Heart Rate	Absent	<100	>100
Respiration	Absent	Irregular: slow	Good. crying
Reflex response to nose catheter	None	Grimace	Sneeze. cough
Muscle tone	Limp	Some flexion of extremities	Active

APPENDIX E

Parental Consent Form - English Version

Names of researchers: John T. Goodman, Christine Korol, Jocelyn Lawrence

Title: Contextual Influences on the Facial Expression of Pain in Full-term and Preterm Neonates

Purpose: To determine how much influence a baby's illness severity, number of previous procedures, gestational age, and whether they are sleeping has on the expression of pain during routine procedures.

Rationale: Babies are unable to tell their doctors and nurses how much pain they feel while they are in the hospital. Therefore, we need to use other ways to tell when babies are hurting, such as watching their facial expressions. However, facial expressions can be influenced by how drowsy babies are during a procedure, how sick they are, whether they were born prematurely, and their past experience with pain. The results of this study will help us determine how to accurately determine when babies feel pain while they are in the hospital.

Procedure: We will be asking your permission examine your baby's medical chart to find out how many procedures have been performed, and how healthy they are while they are in the hospital, and to videotape your baby when she or he receives a routine heel lance to take a blood sample. All babies have to have this blood test shortly after they are born. Therefore, your baby will not be undergoing an extra procedure as a result of this study, and it will not interfere with your baby's care.

Direct benefits to the subjects: None.

Possible risks: None.

If you have any questions or concerns now or at a later time you can contact Christine Korol (737-2492) or Dr. John Goodman (737-2692), Department of Psychology, CHEO.

I, _____, have read the above information and agree to allow my child, _____, to participate. The procedure and its possible risks have been explained to me by the researcher and I understand them.

I understand that my responses will be kept confidential, and that I am free to withdraw from this study at any time.

_____ _____

Signature Witness

Date_____ Date_____

I have explained the nature of the study to the parent and believe she/he has understood, to the best of his/her knowledge.

_____ _____

Name and signature Date

APPENDIX F

Parental Consent Form - French Version

Noms des chercheurs: John T. Goodman, Christine Korol, Jocelyn Lawrence, Pradeep Merchant

Titre: Influences contextuelles sur l'expression faciale de la douleur chez les nouveau-nés à terme et prématurés.

Objectif: Déterminer l'influence du type de maladie du bébé, de la gravité de la maladie, du nombre d'interventions précédentes, de la quantité d'analgésie donnée, de l'âge de gestation et du fait que le bébé dort ou non, sur l'expression de la douleur lors des interventions de routine.

Raison: Les bébés ne sont pas en mesure de dire au médecin et à l'infirmière combien de douleur ils ressentent, quand ils sont hospitalisés. Nous devons donc avoir d'autres moyens de savoir quand les bébés ont mal, comme en observant leur expression faciale. Cependant, les expressions faciales peuvent être influencées par le degré de somnolence des bébés pendant l'intervention, par le degré de gravité de leur maladie, s'ils sont prématurés, combien de médicament pour la douleur on leur a donné, et leur expérience passée concernant la douleur. Les résultats de cette étude nous aideront à déterminer exactement quand les bébés éprouvent de la douleur pendant leur hospitalisation.

Intervention: On vous demandera votre permission pour étudier le dossier de votre enfant et savoir combien d'interventions il a subies, combien de médicaments on lui a donné pendant son hospitalisation, quel a été son état de santé à l'hôpital, et pour filmer votre bébé en vidéo pendant qu'on lui fera une ponction veineuse. Votre bébé ne devra pas subir d'intervention supplémentaire à cause de cette étude, et ceci ne nuira pas aux soins qu'on lui donnera. De plus, veuillez noter que le vidéo de votre bébé sera gardé de manière strictement confidentielle, et ne sera vu que par le chercheur, et non par l'équipe médicale. De plus, tous les vidéos sont détruits 5 ans après la publication du projet de recherche.

Avantages directs pour le sujet: Aucun

Risques possibles: Aucun

Si vous avez des questions à poser maintenant ou plus tard, vous pouvez contacter Christine Korol (737-2492), Service de psychologie, HEEO.

Je, soussigné(e), _____ ai lu les informations ci-dessus et accepte que mon enfant _____ participe. Le chercheur m'a expliqué l'intervention et les risques possibles, et je les comprends. Je comprends que mes réponses seront gardées confidentielles et que je suis libre de me retirer du projet de recherche à n'importe quel moment.

_____ _____

signature témoin

date: _____ date: _____

J'ai expliqué la nature du projet aux parents et je pense qu'ils l'ont bien compris, au meilleur de leurs connaissances.

_____ _____

nom et signature date

APPENDIX G

Training Procedures for the Neonatal Facial Coding System

The research assistant who completed the NFCS scoring was trained in the following manner. First, she was given a copy of Appendix A, which provides a detailed description of all the facial action units that comprise the NFCS. Next, several video segments that had already been collected for the current study, were reviewed with the primary investigator. While reviewing the tapes, the research assistant was asked to identify the presence or absence of the various facial action units. Once it was felt that the research assistant had a solid understanding of the coding system, she began to code the video segments for the study. After 20 segments had been coded, the primary investigator (who is trained in the use of the Facial Action Coding System and NFCS) did a reliability check of the data. The research assistant was then allowed to proceed with the coding as inter-rater reliability exceeded .90.