AGE RELATED DIFFERENCES IN INFANT PAIN EXPRESSION AND PARENTAL JUDGEMENTS OF PAIN THROUGHOUT THE FIRST YEAR OF LIFE

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Abstract

For over two decades, researchers have studied the expression of pain in young infants to unlock the nature of this powerful experience early in life, with these studies resulting in the discrediting of numerous myths about infant pain (e.g., infants are insensitive to pain). The more useful measures of infant pain to emerge from this research examine facial activity, body movement and cry characteristics. To date, however, there has been little effort to examine the developmental progression of these pain behaviours throughout early infancy. This work has great relevance for caregivers of pre-verbal infants who often are asked to assess the presence or absence and severity of pain an infant may be experiencing. This can be a challenging task, as they must extract information specific to pain from apparent generalized distress reactions, substantial variability in response among children, and similarities in response to noxious and non-noxious aversive events, among other influences on their judgments. The extent to which parental assessment accommodates changes in the nature of pain (and its expression) with infant development has received little study and is not well understood at present.

The purposes of the present study were to: a) Describe how, and if, pain expression differs throughout the first year of life; b) Illustrate how parent perceptions and assessment of pain change with the development of the infant; and c) Explore the relationship between parental assessments and behavioural indices of infant pain.

The study used the sociocommunications model of pain as a theoretical framework from which to describe the interplay between infant behaviour and caregiver response. Participants in this cross-sectional study were 160 infants (40 infants in each of four age groups: 2-, 4-, 6- and 12-months) receiving routine immunization injections and their parents. Following immunization procedures, parents provided judgments of the amount of pain their infants experienced and rated the importance of various cues in making their judgments. Infant pain experiences were assessed using measures of facial activity, body movement and cry characteristics.

Results indicated almost no age related differences in pain expression, with only minor differences in body movement profile. However, significant differences in parental assessments of pain were observed, with parents attributing greater pain to younger infants compared to older infants. These findings were in contrast to the findings that behavioral cues (cry, facial activity and body movement) were reported by all parents to be the most important factors in making their pain judgments, yet these changed minimally. Thus, systematic variations in parental judgements of pain across this age span were influenced to a greater extent by other factors and were not solely dependent on the behavioural display of the infants. These findings suggest that variations in caregiver attributions of pain across the first year of life may result from caregiver characteristics (cognitive biases, sensitivity, knowledge and emotional availability to the infant). Further research is required to examine age related differences in infant recovery from painful events and factors influencing parental judgments of infant pain.

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Introduction

Assessment of infant pain throughout the first year of life for research or clinical purposes is often a difficult and challenging task. In older children and adults, pain is primarily assessed using verbal self-report, sometimes referred to as the "gold standard" for pain assessment (Anand & Craig, 1996). However, the standard is not so golden when applied to young infants who are incapable of verbal self-report. The result of the failure to look beyond self-report for alternative measures of infant pain or to engage in detailed study of how infants respond when in pain was discounting and ignoring of pain in infants (Anand & Hickey, 1987; Field, 1995; Puchalski & Hummel, 2002). Infants came to be viewed as insensitive to pain and suffering (Chignell, 2001; Derbyshire, 1999, 2001), neurologically incapable of experiencing pain (McGraw, 1945; Vertosick, 2000), and not able to remember or interpret pain (Chignell, 2001; Levy, 1960). The result was that pain in infants was often construed as inconsequential (American Academy of Pediatrics, 2001) and there was mismanagement and undertreatment of pain in this very vulnerable population (Puchalski, & Hummel, 2002; Schechter, Berde, & Yaster, 1993).

During the past two decades, considerable changes have been seen in many of these assumptions about infant pain, resulting in a fast growing body of research exploring infant pain assessment and transformations in clinical practice. Until recently, research and practice were based upon global, intuitive judgment, informed only through personal experience, rather than by clear evidence as to how infants behave while in pain or by standardized measures. However, as the research area has expanded, researchers and clinicians have begun to better understand and appreciate the many sources of information available to assist in infant pain assessment and measures reflecting good psychometric standards are emerging. This has been supported by an increase in research examining the ways infants can communicate pain to caregivers. Rather than ignoring nonverbal expression of pain, infants now are viewed as having a rich and multifaceted repertoire of behaviours that can be used for assessing pain and multidimensional approaches to neonatal and infant pain assessment have been recommended and explored recently (Duhn & Medves, 2004).

The present study uses a sociocommunications model of pain (Craig, Lilley, & Gilbert, 1996; Craig, Korol, & Pillai, 2002) to better understand pain assessment in young infants. The sociocommunications model proposes that understanding pain in infants necessitates not only an understanding of infant pain expression, but also requires appreciation of the complex social interactions among children in pain and their caregivers. An inclusive understanding of pain views pain as more than a private, internal event. The encoded behavioural pain expression of the child and the interpretation of the encoded displays by caregivers must also be considered. Although infants are unable to verbally communicate distress, they usually very effectively express pain and distress using a variety of salient communication channels including facial activity, body movement and cry. Therefore, pain assessment in infants should utilize the multidimensional sources of information provided by infants in pain. The tasks researchers and clinicians now confront entail establishing the details of how infants communicate painful distress and maximizing the skills of caregivers in using this information.

Complicating the challenge of assessment is the reality that, as infants develop throughout the first year of life, there are dramatic changes in almost all areas of functioning, reflecting ontogenetic maturation, confrontation with the physical world and family socialization practices. Pain expression is likely to change as infants develop greater cognitive and motor skills, acquire life experiences and develop a better understanding of the pain experience through social interactions. If infant pain expression does change with age, different indices may be of greater or lesser utility in assessing infant pain at different developmental stages. Yet little is known about whether, and how, infant pain expression changes throughout the first year of life. It is conceivable that an adaptation well conserved in the course of evolution would be associated with a relatively invariant pattern of display. For example, it has been noted that the stereotypic facial display of pain can be observed in infants, children, adults and the elderly (Craig, 1998; Hadjistavropoulos, LaChapelle, MacLeod et al., 1998, 2000).

The sociocommunications model also necessitates that an understanding of pain includes an appreciation of caregiver factors in the pain assessment process. Parents are often called upon to determine the presence and severity of pain in their infants. Presumably, parents base their judgments primarily on the behavioural expression of pain by the infants, however, this process has not been well studied in the context of infant developmental changes throughout the first year of life. In addition, the sociocommunications model proposes that factors independent of the behavioural display of the infant (e.g. caregiver and contextual factors) may influence pain assessment. How parental assessments of pain in infants change throughout the first year of life and what factors most strongly contribute to those judgments have not been well studied.

Therefore, the primary purpose of this study was to determine if and how pain expression differs with infant age throughout the first year of life. The study examines facial activity, body movement and cry in infants 2-, 4-, 6- and 12-months-old receiving routine immunization injections. In addition, the study seeks to gain a better understanding of how parent perceptions and assessment of pain changes with the development of the infant and how their assessments relate to infant behavioural indices of pain and contextual factors.

Literature Review

The Definition of Pain Applied to Infants

The International Association for the Study of Pain (IASP) defines pain as, "An unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such tissue damage . . . pain is always subjective. Each individual learns the application of the word to experiences related to injury in early life" (IASP Task Force on Taxonomy, 2001). This widely endorsed definition of pain is multifaceted in that it includes criteria related to physical stimulation, subjective experience and it allows for pain in situations where there is not any apparent tissue damage (Owens, 1984).

The criterion of tissue damage is usually easy to satisfy by direct observation or considering contextual factors (i.e. medical procedures such as venepuncture, surgery, or circumcision, or tissue damage resulting from an accident). Note, however, that the definition provides for pain when tissue damage or stress is not evident. The central feature of subjective distress is more complicated in that it requires inference from the behaviour of the individual or organism in pain (Owens, 1984). In verbal populations, this appears to be a relatively simple task as self-report is used to assess the degree of subjective distress. The subjective world of pain in verbal populations is accessed primarily through self-report, thereby providing the basis for referring to this as the "gold standard" of pain assessment (Abu-Saad, Bours, Stevens et al., 1998; Anand & Craig, 1996). However, this leads to generous claims that pain is whatever the patient says it is (McCaffery, 1972). This emphasis on verbal report has resulted in the underutilization of nonverbal expression (Barr, 1992).

The underutilization of nonverbal behaviours and over-emphasis on self-report has led to questions about the generalizability of the definition of pain to non-verbal populations. In terms of pain assessment, this definition becomes problematic when dealing with infants and other populations with limited ability to communicate verbally (Anand & Craig, 1996). Hadjistavropoulos, von Baeyer, and Craig (2001) summarize the problem, stating,

> "It is often assumed that because the experience of pain is a subjective state, the only means whereby it can be tapped is through the suffering person's verbalizations. . . . The current definition of pain, which emphasizes the use of self-description, can only be taken to imply that states of pain and suffering cannot be understood in nonverbal persons. This position limits attention to the availability and usefulness of nonverbal expression." (pp. 137)

Recently, IASP has taken steps to rectify limitations of the definition by adding the statement, "The inability to communicate verbally in no way negates the possibility that an individual is experiencing pain and is in need of appropriate pain relieving treatment" (IASP Task Force on Taxonomy, 2001).

Misperceptions of Infant Pain

These recent shifts in thinking about pain assessment in infants have resulted from numerous observations of a long history of neglecting, discounting or under-treating the distress experienced by infants experiencing tissue damage (Abu-Saad et al., 1998; American Academy of Pediatrics, 2001; Anand & Hickey, 1987; Anand & Carr, 1989;

Anand & Craig, 1996; Benini, Johnston, Faucher et al., 1993; Craig, McMahon, Morrison et al., 1984; Lawrence, Alcock, McGrath et al., 1993; Puchalski, & Hummel, 2002; Stevens, Johnston, & Grunau, 1995). Many misperceptions have resulted from the inability of prelingual infants to verbally describe their pain (Levine & Gordon, 1982). Some common misperceptions and myths regarding pain experience in infants have been: infants are insensitive to pain (Chignell, 2001; Derbyshire, 1999, 2001); they have higher pain thresholds and recover more quickly from pain than adults (Eland & Anderson, 1977); and they do not have memories of painful experiences and therefore do not interpret pain in a similar way to adults (Chignell, 2001; Levy, 1960; Vertosick, 2000).

The result of these assertions was that infants were at risk for inadequate pain management. Until recently, infants were seldom given analgesic medications prior to medical procedures such as circumcision and the clinical practice of using minimal or no analgesia in newborns requiring surgery was widespread (Eland & Anderson, 1977; Hatch, 1987; Purcell-Jones, Dorman & Sumner, 1987; Shearer, 1986; Swafford, & Allan, 1968). Concerns about using analgesics (in particular, opiates) reflected unsubstantiated beliefs about the potential for adverse side effects and addiction (Craig & Grunau, 1993; Lawrence et al., 1993; Marchette, Main, Rednick et al., 1991; Pigeon et al., 1989). However, side effects (e.g., respiratory depression) are readily controlled through careful monitoring and it is well documented that when dependencies on opioids are generated, there are many regimens for withdrawal that can be readily applied (Suresh & Anand, 2001). Nevertheless, these misperceptions persisted despite evidence that from the moment of birth, infants responded to noxious stimuli with both vocal and nonvocal displays (Craig et al., 1984; Grunau & Craig, 1987) and that infants experienced pain with significant short-term (Benini et al., 1993) and long-term (Grunau, Whitfield, Petrie et al., 1994; Taddio, Katz, Ilersich, et al., 1997) adverse sequelae.

A number of hypotheses have been posed to try to explain the unwillingness of caregivers, health professionals and researchers to attribute pain to infants. As discussed above, many health care professionals are hesitant to treat pain in infants and neonates for fear of the potential negative side effects. It has also been suggested that adults have a limited ability to empathize with neonatal and infant distress (Craig & Grunau, 1993). It has been hypothesized that health professionals who routinely perform noxious procedures on infants (i.e. circumcision, venepuncture) reduce their own sympathetic distress through a process of cognitive restructuring; the infant is believed to not be suffering and as a result, less emphasis is placed on the use of analgesics (Owens, 1984). In medical settings, it may be adaptive to suspend sensitivity to a child's distress in order to deliver care (Craig, Grunau, & Branson, 1988; Fuller, Thompson, Conner et al., 1996; Ruddick, 1997). Even when infants display pain responses, Craig et al. (1988) argue, "The adult's capacity for comprehension and empathy probably does not grasp the qualities of the experience and there are risks of insensitivity and neglect" (p. 317). McGrath and McAlpine (1993) refer to this as a process of denial, explaining, "Denial traditionally refers to the unconscious motivated refusal to believe something that is true. Denial is a defence mechanism that protects against facing a reality that is unacceptable" (p. s6). The unacceptable reality was that infants were suffering pain, but with poor assessment tools, caregivers were failing to recognize it and few treatment options became available. Ruddick (1997) described a process of psychological "forgetting" of pain, whereby physicians tend to forestall, discount, or minimize observations of pain in others for primarily self-protective reasons. Therefore, when presented with infants displaying signs of pain, health professionals would misinterpret those signals as emotional states different from pain (McGrath & McAlpine, 1993).

As a result of many of these misconceptions about pain in infants, neurological mechanisms have been proposed to account for altered pain sensations in infants. Specifically, infants were assumed insensitive to pain because they were too neurologically immature and developmentally incapable of experiencing pain (Abu-Saad et al., 1998; Howard & Thurber, 1998; Porter, Miller, Cole et al., 1991; Weatherstone, Rasmussen, Erenberg et al., 1993). Theoretically, insensitivity was thought to be adaptive in protecting infants from pain during childbirth (Anand & Hickey, 1987), although there is a lack of research to support such an assumption. "This assumption has been convenient for everyone, except perhaps, the infant" (Owens, 1986, p. 29). It has also been argued that infants have reduced sensitivity to pain because of a lack of pain receptors, underdeveloped nervous system and lack of myelinization of the peripheral nerves (Abu-Saad et al., 1998; Anand & Carr, 1989). Neonates and young infants were thought to be incapable of pain based on early studies of neurological development that suggested that neonatal responses to pain were "decorticate in nature", the result being that infants were unable to perceive or localize pain (Anand & Hickey, 1987).

Despite these hypotheses aimed at explaining reduced pain sensitivity in neonates and infants, there was little empirical evidence to support such assertions. While the immature state of development of newborns and infants may limit their ability to signal painful distress, they still require a system to signal physical danger and pain to adult caregivers (Grunau & Craig, 1990). The nociceptive system fulfils basic biological functions and is required at the time of birth (and immediately thereafter) to warn the neonate of tissue damage and to signal painful distress to others (Craig & Grunau, 1993). Anand and Hickey (1987) demonstrated that, from the perspective of neurological maturation, infants are developmentally capable of perceiving pain as early as 24-28 weeks of gestation. The pain pathways and subcortical areas necessary for nociception are well developed and the associated neurochemical systems for pain transmission and modulation are functional, even in the preterm infant (Anand & Carr, 1989). As well, the density of nociceptive nerve endings in newborn skin is similar or greater to that in adult skin (Anand & Hickey, 1987). Although incomplete myelinization of the peripheral nerves in the newborn infant suggests slower conduction and altered pain sensation, this is offset by shorter neuromuscular distances and interneuronal spaces (Anand & Hickey, 1987; Anand & Carr, 1989).

In addition, there is evidence that young infants may experience pain even more intensely than older infants and adults (Schellinck & Anand, 1999). Young infants in the first 8 months of life have "synaptic excess" in the frontal lobes where inhibitory processes are located (Hamilton & Zeltzer, 1994). As the infant gets older, there is greater descending inhibition of nociceptive neurons in the dorsal horn and spinal cord, which can help inhibit the pain experience (Anand & Carr, 1989). Hamilton and Zeltzer explain, "Pain, representing discrepant information, may overload the infant who cannot inhibit the transmission of the pain sensation" (p. s98). Fitzgerald and Beggs (2001) provide an account of the anatomical basis for this, showing that the descending inhibitory tracts are not present, particularly in preterm infants.

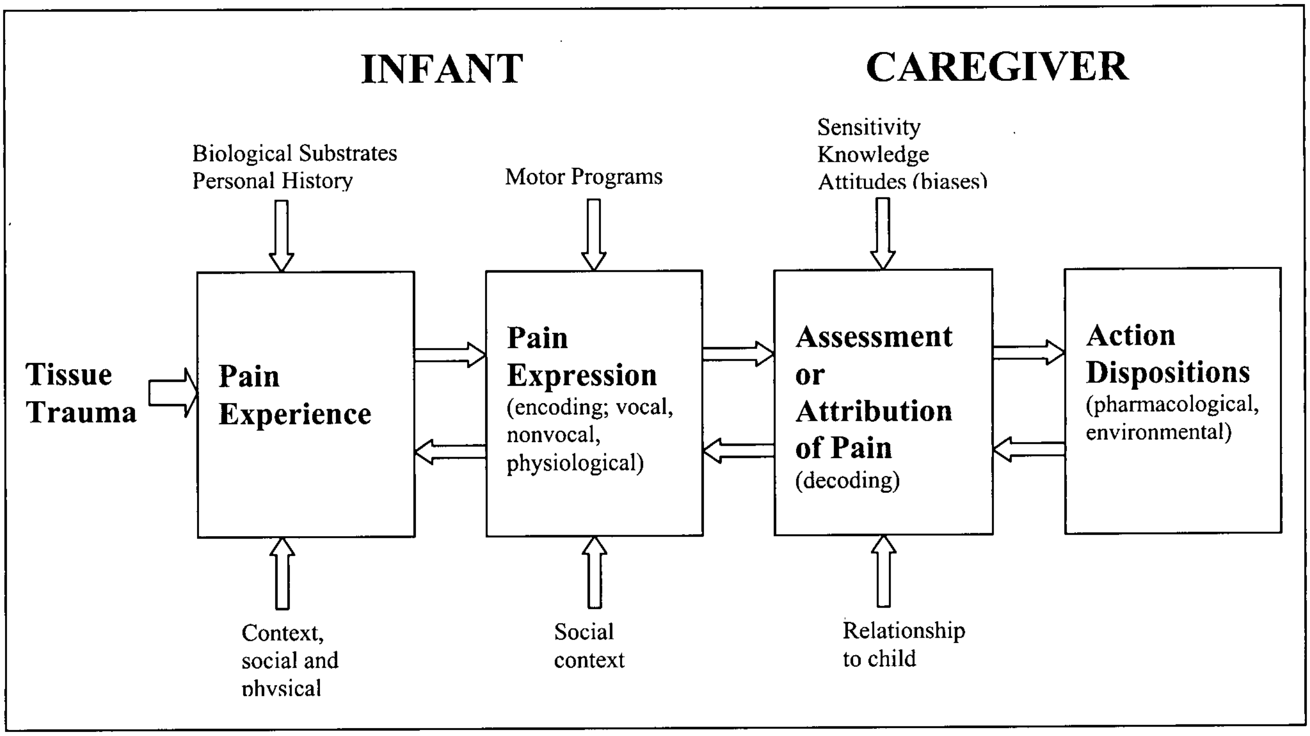
The Sociocommunications Model of Pain

From an evolutionary perspective, both the experience and expression of pain provide for adaptive responses to tissue damage for both adults and young infants. The adaptations most necessary for survival are the first to appear in development, and therefore, the ability to signal tissue damage is a necessity for infant survival (Anand & Craig, 1996). The behavioural reactions of infants to noxious events have tremendous survival value in terms of being able to communicate needs and states to caregivers (Craig et al., 1988; Craig, Gilbert-MacLeod, & Lilley, 2000; Grunau & Craig, 1987). It would be maladaptive for newborn infants to be insensitive to pain, as they would be unaware of tissue damage and therefore would not signal distress to adults who could take care of them (Craig et al., 1988).

Therefore, survival of the infant depends not only on the newborn's ability to experience pain, but also the ability to communicate pain to a caregiver. The challenge for the adult caregiver is to be able to decipher the child's behaviour as a means of determining the presence of pain (Craig et al., 1988). In order for adults to be able to distinguish pain from other emotional states in the infant, there should be consistency in the pattern of pain displays between infants with only minor variations relative to the consistencies. There could be variation contingent upon stages of development, but again, consistent variation should be evident. For example, neonates in pain tightly close their eyes in response to painful stimuli, while older infants squint. Since visual information is of little value to a newborn, tightly closing the eyes protects them, whereas older children can use visual information to protect themselves (Craig, 1998).

It was from this perspective that Craig and colleagues developed the sociocommunications model of pain (Figure 1; Craig et al., 1996, 2002), which takes into account the complex social interactions among children in pain and their caregivers. The model is useful not only for understanding pain in infants, but has been applied also to older, healthy children (Craig, 1998), children with autism (Nader & Craig, 2003), and other populations with limited ability to communicate (Hadjistavropoulos et al., 2001). The sociocommunications model was a reaction to the biomedical model of pain, which neglected the social factors contributing to the pain experience and the role of caregivers in providing relief from suffering.

Figure 1. The Sociocommunications Model of Pain (Craig et al., 2002).



According to the model, in order to understand pain in infants, focus needs to move beyond just the pain experience of the infant and must examine the expression of pain. In addition, the model takes into consideration the skills of caregivers and cues used in assessing pain in infants, as well as their disposition to act on what they believe is happening to the child (Craig et al., 1996). The great strengths of the model are that it gives perspective on how pain is encoded (including context), how adults can improve strategies for decoding pain expressions, and the role of social and psychological mechanisms for the control of pain (Craig, 1998).

According to the sociocommunications model, the sequence of events associated with pain begins with tissue damage, stress or other physiological events that are noxious to the child or infant. What the child experiences as a result of the event is determined by a number of factors including perception, maturation, affective mechanisms, setting and psychological capabilities of the infant (Craig et al., 1996). However, until perhaps 15 years ago, this was where much of the research on pain in infants stopped. The result was a large body of literature examining and describing the internal biological correlates of pain in an attempt to either prove or disprove the notion of altered pain sensations in infants.

The sociocommunications model of pain takes the study and understanding of pain in infants beyond the private experience and views pain as a defensive system designed to avoid tissue damage (or escape when it occurs) and motivate recovery and healing that necessitates social interaction with caregivers. Human infants are born helpless and depend on adult care for a long time; therefore, the ability to communicate distress is a basic survival need. Craig (1998) explains, "Infants have, in effect, a protolanguage that says, 'Help! I am in great need!' that ordinarily allows caretakers to attend to and begin to understand the nature of needs for care" (p. 104). Infants express this protolanguage in their response to noxious events in a number of ways including cry, facial expression, body movement and, for older children, in increasingly linguistic terms (Craig et al., 1996). However, given the developmental limitations of young infants, the encoded behaviours are often ambiguous with respect to the triggering event.

The ambiguous nature of the infant's encoded behaviours makes pain assessment a challenging task for caregivers who must "decode" the behaviours to determine the presence or absence of pain. The difficulty of the task is evidenced by the fact that there is often a lack of concordance between child experiences and adult perceptions of pain (Craig, 1998). The decoding process requires skills of observation and interpretation on the part of the caregiver. This is a complex process, as the caregiver has to pay attention to the infant's behaviours, then detect, and discriminate pain signals from "noise". The caregiver must not only attend to pain cues, but pain assessment also depends on the interpretation and meaning given to the encoded behaviours. The sociocommunications model recognizes that characteristics of the decoder such as cognitive biases, sensitivity, knowledge and relationship to the infant can influence pain assessment. In addition, beliefs that infants are incapable of experiencing or remembering pain likely play a role in biasing caregiver judgments of pain (Craig et al., 1996).

The final part of the model concerns the actions that result from the caregiver's perception and interpretation of the infant's behavioural response to the noxious stimulus. If the caregiver concludes that the infant is experiencing unnecessary pain, a pharmacological or behavioural intervention may be used (Larsson, 1999; Zempsky & Schechter, 2003). However, if the caregiver concludes that the infant is not experiencing pain, or that an intervention may result in greater harm, or that the pain is of benefit to the infant, withholding of care will likely result (Craig et al., 1996). This helps explain the reluctance of health professionals to use narcotic analgesics to treat or prevent pain in infants (Marchette et al., 1991). Hadjistavropoulos et al. (2001) conclude, "Unsubstantiated beliefs concerning the nature of pain in particular populations [infants], rather than evidence-based knowledge, often dictate care; as a result, care is frequently inadequate" (p. 143).

While the sociocommunications model expands the understanding of infant pain, it does have some limitations. In particular, the model focuses primarily on a sequential and serial process rather than a more dynamic, interactive process. Although it acknowledges the potential for reciprocal actions between steps (e.g. assessment influencing pain expression or action dispositions influencing assessment), these reciprocal processes are not well developed or described. In addition, the model begins with the presence of some form of tissue trauma, which is not always necessary for experiencing pain. As discussed earlier, pain is associated with actual or potential tissue damage and the absence of tissue damage does not dismiss the possibility of pain. Therefore, the sociocommunications model may not adequately explain chronic pain conditions, where observable tissue damage is not always present. The model appears to be more applicable to acute pain conditions.

In summary, the sociocommunications model of pain highlights the difficulties and complexities of pain in infants. Assessing pain in infants requires not only an understanding of the internal biological correlates of pain, but also an appreciation for the expression and interpretation of pain behaviours by infants and caregivers, respectively. Therefore, pain assessment in infants should examine both the encoded pain displays of the infant and the factors involved in the decoding process of the caregiver.

Challenges in Assessing Infant Pain

Assessing pain in infants is a difficult process complicated by a number of factors, many of which have already been discussed. One of the most obvious difficulties is the subjective nature of pain and need to infer its nature and severity in the absence of sensitive and specific measures. The inability of infants to verbalize their pain is often cited as a problem (Abu-Saad et al., 1998; Franck & Miaskowski, 1997; Johnston & Strada, 1986;). The most direct measure of pain would appear to be verbal self-report; it is often declared that verbal report is the only way to communicate pain, as pain has been described as, "whatever the person says it is, existing whenever the person says it does" (McCaffery, 1968, p. 95). These assertions appear to ignore the limitations of verbal report, as verbal competence is necessary (Hadjistavropoulos et al., 2001) and is subject to a variety of personal and situational biases. Verbal self-report is not a viable measure of pain in infants and many other nonverbal populations, despite their ability to express painful distress quite clearly. Therefore, pain assessment must conform to their limited communication capabilities (Anand & Craig, 1996) and rely more on non-verbal channels of communication (Craig, Grunau, & Aquan-Assee, 1988; Craig et al., 1988).

The necessity to rely on non-verbal expressions leads to its own set of problems and challenges. Infants are born in a high state of sensory preparedness while their motor capabilities are poorly coordinated and developed (Lamb, Bornstein, & Teti, 2002). The result is that infants may respond to both painful and non-pain stimuli with similar stereotypic behaviours (Franck & Miaskowski, 1997), although not necessarily in an identical manner. The challenge for caregivers then is to discern the cues that would discriminate among pain, hunger, fatigue and other negative states within the context of the infant responding in similar ways to each of these states. Discriminating pain from other states, or pain signals from surrounding noise, is often an uncertain task for caregivers. If the distinction could be made, it requires them to rely on specific cues to determine the presence or absence of pain. The difficulty with this is that there is disagreement as to which indicators are the most useful and important to detecting pain (Craig, Hadjistavropoulos, Grunau et al., 1994). There also is a criterion challenge in research differentiating noxious from various aversive states; unambiguous measures of these states also are not available and it is possible that these so-called aversive states could also be painful. For example, hunger and fatigue could instigate qualities of pain. Nevertheless, evidence indicating one could differentiate among them would confirm their difference as psychological states.

A number of different indicators have been suggested as indices of pain for the purposes of assessment. Some of the most important indicators are the contextual cues concerning situational events likely to have had an impact on the child (Owens, 1986). For example, it is easier to attribute pain to an infant who is crying when that infant has just experienced a noxious event (i.e. venepuncture). However, it is not unusual for babies to display minimal reactivity even to invasive procedures. Individual differences in reactivity are evident early in life. It is clear that pain assessment is more difficult when the context provides little indication as to what may be causing the behavioural reaction. Evidence of tissue damage is a source of information, but there can be excessive dependence on evidence of tissue damage, as there is with adults.

Physiological Measures

Physiological measures also have been proposed as possible indicators of pain in infants and have received considerable attention and research in the study of pre-verbal infants for a number of reasons. Some of the physiological and biological indices that have been proposed as indicators of pain are cortisol assays (Gunnar, Connors, Isensee et al., 1988), skin blood flow (McCulloch, Ji & Raju, 1995; Porter et al., 1991), skin temperature (Chapman, Casey, Dubner et al., 1985; Weatherstone et al., 1993), blood pressure (Weatherstone et al., 1993) and skin conductance (Chapman et al., 1985). Brain imaging approaches have not yet been systematically studied, although they offer potential. The problems with many of these physiological indicators are that they have not been well studied, are not routinely measured and are relatively impractical as clinical tools (Sweet & McGrath, 1998). The much more widely used and studied physiological measures are heart rate, respiratory rate and oxygen saturation (Chapman et al., 1985; Franck & Miaskowski, 1997; Johnston, Stevens, Yang et al., 1995; McGrath, 1996; Porter et al., 1991; Stevens & Johnston, 1994; Weatherstone et al., 1993).

The most obvious advantage that physiological measures have is that they can provide precise, objective, quantifiable information about an infant's response to a noxious stimulus (Chapman et al., 1985; Stevens et al., 1995, 1996). In circumstances when verbal self-report is unavailable, or for infants who do not cry or show much change in facial expression, heart rate, respiration rate and oxygen saturation are especially useful (Gonsalves & Mercer, 1993). In addition, the physiological measures are widely used and easy to record and interpret. This makes them clinically relevant as opposed to being abstract and academic (Chapman et al., 1985; Sweet & McGrath, 1998).

Despite the clinical and objective advantages of using physiological measures, there are numerous disadvantages to relying solely on physiological measures of pain.

The greatest drawback of physiological measures of pain is that they are not specific to pain (Lilley, Craig & Grunau, 1997; Stevens & Johnston, 1994; Sweet & McGrath, 1998). Physiological events are multidetermined, so they do not provide a direct measure of subjective states, like pain. Rather, the physiological changes that are observed during painful procedures or tissue damage are more clearly associated with a general stress response rather than pain (Craig et al., 1993, 1994; Stevens et al., 1995). Autonomic reactivity may change in response to noxious stimuli, but it can also respond to stress and non-noxious situations as well; while all pain is stressful, not all stress is painful (Craig et al., 1993; Hadjistavropoulos et al., 2001; Owens, 1986; Stevens & Johnston, 1994). Therefore, physiological measures, by themselves, are not enough to discriminate between painful and non-painful responses (Franck & Miaskowski, 1997; McGrath, 1996). Obrist, Light and Hastrup (1982) summarized the problem stating, "Might it not be placing too much responsibility on the cardiovascular system [and other physiological systems], which must supply the tissues with oxygen and nutrients, remove metabolic waste products, maintain kidney function and keep the body temperature within narrow limits to require that system also to be particularly sensitive to behavioral states?" (p. 313).

Physiological measures have a number of other shortcomings that make them unlikely as isolated measures of pain. In general, physiological measures are likely to be unreliable because of background activity and the tendency of the responses to habituate to stimulation (Pigeon et al., 1989). Therefore, these measures are only useful in situations involving short, sharp pain. Finally, most of the studies that have used physiological measures have only examined the presence or absence of pain and provide little information about the magnitude of the pain (Sweet & McGrath, 1998). In sum, while physiological measures may provide objective and quantifiable data, they need to be considered in the context of other behavioral measures of pain.

Behavioural Measures

In terms of behavioural indicators of infant pain, they can be viewed as global (e.g. general integrative judgments made by an observer), behaviourally focused (e.g. an observer rating the intensity of a cry), or fine grained (e.g. specific facial actions) (Hadjistavropoulos et al., 2001). While routine measurement by caregiver rating is often used and certainly can be of benefit (McGrath, 1996), the previously discussed biases and misperceptions regarding infant pain may lead to failure to identify pain and underestimating or overestimating pain in infants. As a result, evidence-based, behavioural responses to pain, and in particular, fine grained measures, are likely the best objective indicators of pain in infants. A number of investigators have suggested that the most useful indices of pain in infants are behavioural; facial expression, crying and body movements have often been cited as important sources of information regarding pain in infants (Craig et al., 2000; Fuller, 1991; Lilley et al., 1997; Stevens & Johnston, 1994).

Pain assessment in infants is further complicated by the fact that different indices are not always concordant with one another. Behavioural and physiological measures of pain have been shown to be only weakly correlated (Johnston, Stevens, Yang et al., 1995) and not always in agreement (Abu-Saad et al., 1998; Stevens et al., 1995). Field and Goldson (1984) reported that facial expression appeared to be independent of heart rate in infants. In a study examining physiological indices of pain in preterm and full term neonates, Craig, Whitfield, Grunau et al. (1993) found that physiological measures such as heart rate, respiration rate and oxygen saturation were not always in agreement. Studies have also demonstrated no correlation between facial pain expressions and cry acoustics (Grunau & Craig, 1987; Grunau, Johnston, & Craig, 1990). These studies demonstrate the complex and multidimensional nature of pain. The limited relationships between different indices of pain suggest that each index may represent a distinct dimension of the pain experience or different response system (Franck & Miaskowski, 1997; Grunau et al., 1990). The different indices could be involved in related, but not identical components of the pain response. For example, crying might be designed to attract caregiver care; body movement might be related to reflexive withdrawal or other adaptive escape behaviours; and facial activity might be involved in the communication of specific states.

As a result, no single measure of pain is likely to be an adequate indicator of pain in infants; no single measure of pain is reliable, valid, specific and practical for identifying the existence, intensity and impact of pain in infants (Stevens, 1998). The quest for a unidimensional measure of pain in older children and adults is now recognized as problematic, as scales of this type obscure the complexities of the experience (Williams, Davies, & Chadury, 2000). However, this does not rule out the search for more sensitive and specific indices of pain in infants or other populations. It does seem reasonable to conclude that pain in infants should be viewed as a multidimensional phenomenon requiring multivariate pain assessment. Since the 1980s, a number of investigators have identified the value of assessing infant pain using a multidimensional approach (Craig & Grunau, 1993; Fuller, 1991; Owens, 1984; Stevens, 1998; Sweet & McGrath, 1998). Craig and Grunau (1993) suggest, "The gestalt of information available through multiple sources should provide a better understanding than any single measure would afford" (p. 75). Behavioural measures of pain provide different, but complementary information about the pain experience of the infant (Abu-Saad et al., 1998; Craig et al., 2000) and, therefore, a combination of multiple assessment indices is logical and may lead to more sensitive and specific pain assessment (Pigeon et al., 1989; Stevens et al., 1995). The key is the ability to identify valid indicators that are not redundant. It seems probable that multidimensional measures already available will include indices that are not valid and it would be important that the individual indicators were shown to be sensitive and valid.

Multidimensional Scales

With developing appreciation for the necessity of multiple indices for assessing pain in infants, a number of multidimensional infant pain scales were developed in the 1990s. Many of the scales included physiological, behavioural, and contextual indicators that appeared to be associated with pain. The first of these composite measures was the Neonatal Infant Pain Scale (NIPS; Lawrence et al., 1993), designed to assess pain associated with medical procedures in infants. The NIPS consists of five behavioural indicators of pain (facial expression, crying, arm and leg movement, and state of arousal) and one physiologic indicator (breathing pattern). The indicators were designed to tap categories that nurses had reported as being useful in pain assessment (Pigeon et al., 1989). The NIPS indicators are scored on two- or three-point scales, before during and following the procedure and require a global assessment on the part of a caregiver observing the infant (Lawrence et al., 1993).

The CRIES (Kretchel & Bildner, 1995) was designed to assess neonatal postoperative pain. The measure consists of five behavioural and physiological indicators and CRIES is an acronym designed to prompt health care professionals to the indicators (Stevens, 1998): crying, requires O2 for saturation above 95, increased vital signs, expression and sleeplessness. Each indicator is rated on a three-point scale and, like the NIPS, requires global observer judgments.

The Premature Infant Pain Profile (PIPP; Stevens et al., 1996) was developed to assess acute pain in full term and pre-term infants. In the development of the PIPP, 15 indicators of pain in infants were identified from a literature review and clinical practice. After a principal components analysis, the seven indicators chosen were three facial actions (brow bulge, squeezing of the eyes and nasolabial furrow), two physiological (heart rate and oxygen saturation) and the behavioural state of the infant. Each indicator is rated on a four-point scale. Interestingly, the scale assumes developmental changes in pain expression, including a correction for gestational age and assigns higher pain scores for infants less than 36 weeks, citing studies demonstrating decreased reactivity in pre-term compared to full term neonates (Craig et al., 1993; Johnston et al., 1996). There is no correction factor for full-term infants.

The FLACC (Merkel, Voepel-Lewis, Shayevitz et al., 1997) is a behavioural-based scale for assessing post-operative pain in infants and young children. The FLACC codes for five categories of behaviour that had been identified in previous studies: facial expression, leg movement, activity, cry and consolability. Each category is scored from 0-2 and requires observer global ratings. While the FLACC was designed for ease of use in a clinical setting, it assumes that each of the five behaviours are equally important in indicating the presence of pain, although this is not supported empirically.

The development of composite measures of pain such as the NIPS, CRIES, PIPP and FLACC aid in infant pain assessment and have demonstrated validity in discriminating painful from non-noxious medical procedures (Lawrence et al., 1993; Stevens et al., 1996) and response to analgesics (Kretchel & Bildner, 1995; Merkel et al., 1997). However, they do have important limitations; in particular, it has not been empirically demonstrated that all of the indices included in the scales are sensitive and specific to pain, nor are they necessarily the best, or most utilized, cues. In addition, the scales are based on the assumption that the indicators of pain remain constant with infant development. While the indicators are based on prior research and clinical practice, there is relatively little known about if and how these indicators change with the development of the infant throughout the first year of life. It is possible that with the great psychological and physical changes that accompany development in the first year of life, there will also likely be changes in behavioural responses of the infant to a painful stimulus. There needs to be a greater understanding of the changes in behavioural responses of infants to noxious events throughout the first year of life.

Infant Facial Expression and Pain

Facial expression has emerged as one of the most consistent, reliable and useful indicators of pain in young infants. Facial activity has been cited as the most promising approach to pain assessment in infants (McIntosh, Van Veen, & Brameyer, 1993). It has also demonstrated the highest specificity to pain of any cues available (Craig & Grunau, 1993; Craig et al., 1993; McGrath, 1996) and appears to be the most distinctive of all the behavioural signs in terms of signalling pain (Craig et al., 2000). Facial expression has also been described as the most consistent indicator of pain across infants (Johnston &

Strada, 1986; Stevens, 1998).

In order to appreciate why facial activity is such a good indicator of pain, one must consider the evolutionary benefits of communicating pain via facial expression. Infants require a method of communicating subjective states to caregivers who can then respond appropriately to assist the infant. In newborns and young infants, the facial musculature is well developed, probably primarily to accommodate feeding, but it has also been postulated as a primary mechanism to communicate subjective states to caregivers (McGrath, 1996; Rinn, 1984). Faces can assume a remarkable number of different configurations, allowing for great amounts of information to be conveyed with considerable speed (Ekman, 1993). Facial expressions have been theorized as being universally expressed and recognized, regardless of cultural differences and particular facial configurations are connected to specific emotions (Ekman, 1999). Six facial expressions have been identified as having universal meaning (happiness, anger, disgust, sadness, fear and surprise; Ekman, 1999) and these can be distinguished from facial expression associated with pain (Axia & Bonichini, 1998; Izard et al., 1983). Craig (1998) reports, "No other visible area of the body conveys the same level of detailed and differentiated information about psychological states" (p. 106). Given the amount of information that can be conveyed through facial activity, it makes logical sense that facial activity should have a primary and powerful role in interpersonal communication, particularly for pre-verbal infants.

Darwin (1872/1998) postulated that facial expressions of emotion represent innate patterns of action. In neonates and young infants, these innate patterns of facial activity appear to be involuntary and involve activity in subcortical brain systems. In comparison, voluntary face movements derive from activity in the cortex, which is not as highly developed in young infants (Rinn, 1984). Therefore, in young infants, facial expressions are relatively independent of conscious control and appear to reflect predominantly sensory and affective qualities of pain (Grunau, Johnston & Craig, 1990). This is likely independent of cognitive interpretation that assists adults and older children cope with painful events. Therefore, facial activity appears to be a relatively "pure" measure of pain in young infants.

A number of studies have demonstrated that facial expression changes in response to a variety of pain stimuli across a variety of infant populations. In early studies, Franck (1986) and Grunau and Craig (1987) reported that newborn infants receiving a heel lance for the purposes of blood collection responded with a distinctive facial grimace. In a later study of preterm neonates receiving a heel lance, facial activity consistently differentiated the response to the lance from the preparatory phases (Craig et al., 1993). Very low birth-weight, premature neonates also demonstrated a differential facial response between sham (preparing the area on the heel for the stick, but no stick) and actual heel stick procedures (Johnston et al., 1995). For intramuscular injections, Grunau et al. (1990) found that healthy newborns responded to immunizations with increased facial activity. Johnston and Strada (1986) found similar results with 2- and 4-month-old infants receiving immunizations. In response to circumcision, healthy newborns demonstrated more facial actions indicative of pain as compared with baseline (Benini et al., 1993).

Facial activity has also been shown to systematically vary with the use of analgesics, further suggesting its usefulness as a measure of pain in infants (Craig, 1998). Benini et al. (1993) and Taddio, Stevens, Craig et al. (1997) examined the effectiveness of the topical anaesthetics in reducing pain during circumcision. They found that newborn infants receiving anaesthetic showed less facial activity in response to a circumcision procedure compared to infants who did not receive any anaesthetic.

In addition, as previously mentioned, facial activity response to pain is remarkably consistent across infants. A number of authors have reported and identified distinct facial characteristics associated with response to noxious stimuli in infants. The first was Darwin (1872/1998) who described the pain face of infants: "Whilst thus screaming their eyes are firmly closed, so that the skin round them is wrinkled, and the forehead contracted into a frown. The mouth is widely opened with the lips retracted in a peculiar manner, which causes it to assume a squarish form: the gums or teeth being more or less exposed" (pp. 146-147). Darwin's impressions were based on personal observations, but he employed relatively little systematic, standardized study. In recent years, much more detailed, fine-grained analyses have sought to describe the facial features associated with an infant's response to pain. A number of studies have identified a relatively consistent pattern of facial activity in response to painful events. The pain face in infants is characterized by a lowering and bulging of the brows, eyes squeezed shut, deepening of the nasolabial furrow, opening of the lips, vertically stretched mouth and a taut, dished tongue (Craig & Grunau, 1993; Craig, 1998; Craig et al., 2000; Grunau & Craig, 1987).

This clustering of facial activity has been demonstrated in studies examining healthy newborns receiving immunization injections (Grunau et al., 1990), venepuncture (Larsson, Tannfeldt, Lagercrantz et al., 1998a,b), intravascular injections (Johnston, Stevens, Craig, et al., 1993), 2- and 4-month-old infants receiving immunization injections (Johnston et al., 1993), preterm and full-term neonates receiving a heel lance (Craig et al., 1993; Grunau, Oberlander, Holsti et al., 1998; Johnston et al., 1993; Larsson et al., 1998b) and postoperative pain in infants (Peters, 2001).

These studies demonstrate that the pattern of facial activity in response to different painful procedures appears consistent across early infant development. However, it also appears that the pattern of facial activity in response to pain in infants is generally similar to the facial grimace of adults in pain, thereby providing further construct validity that the face communicates painful distress in infants and adults (Craig et al., 1994). Indeed, the expression is also evident in aging seniors suffering from dementia (Hadjistavropoulos et al., 1998, 2000), people with intellectual disabilities (LaChapelle, Hadjistavropoulos, & Craig, 1999) and children with developmental delays (Nader, Oberlander, Chambers et al., 2004), supporting the argument that noncortical brain systems are central to the expression. The features that are common to both the adult and the infant pain grimace are brow lowering, tension and narrowing of the eyes, deepening of the nasolabial furrow, opening of the mouth and raising of the upper lip (Grunau & Craig, 1990). There are some noticeable differences, however; adults display horizontal stretching of the lips (a feature not seen in infants) and the taut tongue seen in the infant in pain is not seen in adults (Grunau & Craig, 1990). In addition, infants tightly close their eyes while adults' eyes are narrowed, but still open. As discussed earlier, post hoc reasoning suggests an evolutionary explanation for the differing configuration of the eyes as it would be more adaptive for infants to close and protect their eyes during a painful assault (Grunau et al., 1990). However, for adults, keeping the eyes open would allow them the opportunity to examine the environment for information that would be meaningful or useful to reducing the painful experience.

Infant Body Movement and Pain

Compared to facial activity, relatively little research has been done on infant body and limb movement as a behavioural response to pain. Body and limb movement can be conceptualized largely as reflecting an attempt on the part of a young infant to escape or avoid physical harm (Hadjistavropoulos et al., 2001). However, given the developmental immaturity of young infants, body and limb movements appear to be diffuse, undifferentiated responses to distress that are not as discriminating as other behavioural indices, such as facial activity (Hadjistavropoulos, Craig, Grunau et al., 1997). Early descriptions suggested that young infants display vigorous gross body movements and withdrawal from a painful stimulus (Franck, 1986; Levine & Gordon, 1982). Johnston and Strada (1986) describe the temporal sequence of body movement in infants receiving intramuscular injections. They found that there was an initial rigidity in the torso and the limbs of the infants, followed by less body rigidity and occasional thrashing. In response to heel lance and other invasive procedures, young infants display vigorous movements of the hands, feet, arms, legs, head and torso (Craig et al., 1993; Craig et al., 2000; Franck & Miaskowski, 1997).

Given the diffuse nature of infant body movement in response to pain, early research suggested that the withdrawal of affected and unaffected limbs in response to pain was a reflex action on the part of the infant. However, a few studies have provided evidence that this behavioural response of the infant is more than just a reflex response (Anand & Hickey, 1987). While infants do withdraw both the affected and unaffected limbs in response to heel lance, they also use the unaffected leg to "swipe" at the site of the heel lance (Craig & Grunau, 1993; Franck, 1986). Craig and Grunau (1993) suggested that this swiping motion by the unaffected leg serves as an active, defence behaviour indicating more than just a simple reflex response. Fine-grain behavioural coding indicates that in the second year of life, limb and body movements become more coordinated and affective (Craig et al., 1984).

Infant Cry and Pain

A considerable amount of theory and research has been generated in an effort to understand the relationship between infant crying and pain. Green, Gustafson, Irwin et al. (1995) describe crying as, "a complex behavioural, motivational, anatomical, physiological and social event that is present at birth and continues through infancy" (p. 161). From an evolutionary point of view, infant crying is a species-typical behaviour that signals particular states (including pain) for the purposes of eliciting responses from caregivers (Gustafson & Deconti, 1990). Some form of communication is critically important for young infants because they are vulnerable and dependent upon adult caregivers for a lengthy period after birth (Craig et al., 2000). The cry of an infant in pain would ideally have distinctive characteristics; it should be arousing, urgent and different from other forms of basic cry, in order to immediately attract the attention of caregivers and provide specific information concerning the status of the child (Grunau et al., 1990). Other investigators have suggested that the basic cry and the pain cry of an infant represent ends of a continuum based on the intensity of the noxious stimulus; the more aversive the stimulus, the more the cry will suggest it is a "pain cry" (Zeskind & Lester, 1978). Lester (1984) described infant crying as serving a biosocial function; it is a form of affective communication between an infant and caregiver, signalling distress in the infant.

However, while the cry of an infant in pain may have powerful communicative value, it does not appear to be specific to pain. Crying in a young infant is often an ambiguous stimulus, contributing to the caregiver being unable to discern the source of the distress (Craig & Grunau, 1993; Craig et al., 2000; Grunau & Craig, 1990). Therefore, crying has been referred to as a "biological siren" (Zeskind & Marshall, 1988) and a "distant early warning signal" (Craig et al., 2000) that is designed to attract the caregiver's attention to the subjective distress of the infant. The caregiver then acts by attending to the infant and determining what is wrong by using additional behavioural, environmental and contextual cues (Craig et al., 1996; Muller, Hollien & Murry, 1974).

Murray (1979) viewed crying as a distress signal that evolved with attachment behaviour to promote closeness between the infant and caregiver. Murray theorized that infants may be genetically programmed to cry during distress and this is associated with a reciprocal mechanism in caregivers that ensures they respond to the crying infant. When a caregiver meets the needs expressed by a crying infant, crying stops and an enjoyable interaction between caregiver and infant occurs; the result is closer attachment of caregivers to infants and vice versa (Lester, 1984; Owens, 1984).

While the purpose of cry, for the infant, may be to determine the caregiving environment, it can serve other functions for observers. There has been much reported on the utility of infant cry as a neurophysiological measure of biological status. Lester's (1984) biosocial model of infant crying suggested that the cry of an infant provides information regarding the infant's biological status. Crying can be triggered by a complex series of neurophysiological mechanisms, thereby providing anatomical and physiological information about the infant (Fuller, Conner & Horii, 1990; Lester, 1984). Specifically, some authors have hypothesized that the acoustical features of infant cry can be used in the clinical diagnosis of infants with central nervous system abnormalities (Golub & Corwin, 1982; Gustafson & Green, 1989; Wasz-Hockert, Michelsson & Lind, 1985). Lester (1984) suggested two potential uses of cry: a diagnostic early sign of brain damage; and to identify infants at risk for developing later abnormalities.

An understanding of the physical properties of sound production and cry is necessary before one can begin to understand how cries can reflect physiological and anatomical characteristics of infants. Human vocalizations consist of multiple simple sound waves, each having their own frequency and amplitude. The amplitude of a simple sound wave is the amount of sound energy in the waveform while the frequency is the number of wave cycles per second (Fuller, 1991). The complex waveform that results from the combination of multiple simple sound waves has a number of acoustical attributes reflecting anatomical and physical changes in the infant during the cry. An infant cry results from specific configurations of the larynx, the length and mass of the vocal cords, the interaction between air pressure and vocal cord tension and the resonance in the cavities of the chest, throat and mouth (Craig et al., 2000). These anatomical and physical changes in the infant during the cry produce the pitch, phonation and melody patterns of the cry.

Golub and Corwin's (1985) physioacoustic model of infant cry explains that an infant cry involves both acoustic and anatomical/physiological components. The acoustical component is how sound is generated at the larynx and in the airway above the larynx. The anatomical/physiological component involves the movement and configuration of the respiratory, laryngeal and supralaryngeal structures (Golub & Corwin, 1985). The resulting sound that is generated is a function of the source (the vibrating vocal cords) and the filters of that sound source (modifications caused by the vocal tract and radiation characteristics from the lips) (Golub & Corwin, 1982; Green, Irwin, & Gustafson, 2000).

The resulting cry sound can provide information about the physiological capabilities of the infant. The muscles of the larynx are controlled partially by the vagal system, which is also involved in heart rate and respiration. Therefore, the cry of the infant is likely to be closely related to autonomic functioning of the infant (Green et al., 2000). Out of this arose the idea of using cry as a diagnostic tool for assessing central nervous system functioning; a lack of neurological integrity would affect vagal control of the larynx and result in abnormalities in the infant cry (Green et al., 2000). Grunau et al. (1990) related this to pain suggesting that infants in pain may experience enough stress that a normal infant would temporarily become physiologically disorganized and produce a distinctive pain cry. Evidence for this can be observed in the pitch of the infant cry. The pitch of the cry appears to be indicative of the central nervous system capacity for response modulation. Disorganization, or difficulty in modulating responses to stimulation is reflected by higher pitched cries (Grunau & Craig, 1987; Lester, 1984; Wasz-Hockert et al., 1985). Nevertheless, it remains uncertain whether other sources of extreme stress would yield cries with similar acoustic attributes.

The exploration of cry as an indicator of pain has led researchers to examine a number of different features of crying including temporal, spectral and intensity domains.

Temporal Features of Cry

Cry Latency

The most frequently studied temporal features of cry examined in relation to pain are cry latency and duration of the crying. The latency period is the time between onset of the pain stimulus and onset of the initial cry sound (Grunau & Craig, 1987; Thoden & Koivisto, 1980; Wasz-Hockert et al., 1985). The first cry is defined as the first phonation lasting more than 0.5 seconds (Golub & Corwin, 1985). Cry latency has served as a useful outcome measure for infant pain in some studies. Pain cries have been described as characterized by a sudden onset of vocalizations as opposed to a gradual build up (Murray, 1979). Grunau et al. (1990) reported that a shorter latency from stimulus was indicative of pain cry compared to other cries. Cry latency appears less variable among infants and tends to be consistent across stimulus intensity and postnatal age (Franck & Miaskowski, 1997).

Cry Duration

The duration of crying has also received attention as a potential outcome measure for infant pain. The duration of the cry consists of all of the vocalizations occurring during a single expiration or inspiration (Golub & Corwin, 1985). The cry unit that is considered has usually been the first cry expiration after the painful stimulus (Grunau & Craig, 1987). The first cry after a painful stimulus is characterized as having a longer duration (Craig & Grunau, 1993; Johnston & Strada, 1986), up to 4 seconds compared to 1 second for the basic cry (Murray, 1979). Grunau et al. (1990) found that newborn infants receiving intramuscular injections responded with cries that were of greater duration in their first cry cycle. In a study of infant circumcision, the most invasive part of the circumcision procedure elicited longer crying bouts than the other parts of the procedure (Porter, Miller, & Marshall, 1986).

Other researchers have also considered cry duration as the total crying time after a noxious stimulus. Franck and Miaskowski (1997) report that, in general, pain is associated with increased crying time. Infants receiving intramuscular injection demonstrated longer crying bouts compared to rubbing their thighs with alcohol (Grunau et al., 1990). In studies of newborn infants receiving circumcision, infants who received anaesthesia before the procedure demonstrated a shorter total crying time compared to newborns who received placebo (Benini et al., 1993; Taddio et al., 1997). However, most of the research examining cry duration has focused on the duration of a single cry unit, likely due to the relative ease of defining the start and finish of a single cry unit versus a period of crying.

Spectral Features of Cry

Fundamental Frequency

Much of the research on cry as a measure of pain in infants has focused on the frequency characteristics of the cry. The fundamental frequency (F0) has received a considerable amount of attention as a potential index of pain in infants. It is the number of times a complex sound waveform repeats itself per second (Grunau et al., 1990). The F0 is the first harmonic in a complex, periodic sound wave (Golub & Corwin, 1982; Grunau & Craig, 1987). It is the number of glottal openings per second determined by the frequency of vocal cord vibrations (Gustafson & Green, 1989; Hadjistavropoulos, Craig, Grunau et al., 1994; Lester, 1984). The F0 is perceived as the pitch, which is not a physical property of the sound, but rather a human judgement or perception (Golub &

Corwin, 1985). The relationship between pitch and F0 is linear below 1000 Hz, but above that, larger changes in frequency are required to lead to a change in pitch (Lester, 1984).

The rationale for using F0 as an indicator of pain in infants relates to features of the stress response in the infant. The mechanism underlying alterations in the F0 during a pain cry is associated with the stress-arousal response of the infant. In response to stress, the tension in the striated muscles of the body (including the larynx, vocal folds and abdominal respiratory muscle) increases (Fuller et al., 1990; Lester, 1984; Scherer, 1986). The cry is generated at the larynx by air passing through, causing the laryngeal vocal folds to vibrate, interacting with laryngeal muscle tension to produce the F0 (Porter, Porges, & Marshall, 1988). The F0 will rise whenever the vocal folds are changed in a way that increases their rate of vibration. As the tension in the laryngeal muscles increases, the vocal folds are stretched and increase in length. This stretching leads to the vocal folds becoming thinner, with their mass decreasing and their rate of vibration increasing (Lester, 1984). This leads to the increase in the F0 of an infant who is experiencing stress.

There have been numerous studies that have examined how the F0 of infant cry changes in response to painful stimuli. The typical cry response to pain is characterized by a higher F0 compared to other cries (Craig & Grunau, 1993; Craig et al., 2000; Franck & Miaskowski, 1997). In an early study examining pain response of infants to an elastic band being snapped against the heel, a high pitch was the most striking feature of the resulting cry (Zeskind & Lester, 1978). Porter et al. (1986) found that a high F0 was the most dominant feature of infants receiving circumcisions. In a later study of pain during circumcision, they found that the F0 was greatest during the most invasive parts of the circumcision procedure (Porter et al., 1988). A number of studies of healthy newborns and infants receiving intramuscular injections have identified a high F0 as characterizing the pain cry (Fuller & Horii, 1988; Fuller, Horii, & Conner, 1989; Fuller, 1991; Grunau et al., 1990; Johnston & Strada, 1986; Johnston et al., 1993). A high F0 has also been demonstrated to be associated with the pain cries of premature infants receiving heel sticks and newborn infants receiving intravascular injections (Johnston et al., 1993).

Harmonic Structure

Researchers have also examined the harmonic structure of infant cries as a possible index of pain. A harmonic is a multiple of the F0 (Golub & Corwin, 1985). For example, if the F0 is 200 Hz, the first harmonic is 400 Hz, the second harmonic is 600 Hz, and so on. The cry of an infant is a complex tone, the shape of which is determined by the F0 and the relative amplitude of its harmonics (Golub & Corwin, 1985). The harmonic structure of the vocalization represents the regularity of the vibration of the vocal cords; irregular vibration of the vocal cords results in dysphonation in the cry, characterized by blurring of the harmonic structure or unvoiced cries (i.e. the infant is exhaling during the cry, but no sound is being produced) (Grunau et al., 1990; Johnston et al., 1993). An infant producing a greatly dysphonated cry can be viewed as being in a highly disorganized state that could be indicative of pain. In stressful or painful states, the harmonies of the cry may be obscured or absent as a result of an overloading of the larynx (Craig et al., 2000; McGrath, 1996).

There is some evidence for the utility of dysphonation of the infant cry as an index of pain. The harmonics of the cry of an infant undergoing circumcision appear less distinct and more blurred (Porter et al., 1986). Grunau et al. (1990) reported that newborn pain cries in response to intramuscular injections were characterized by dysphonation, which they defined as at least 0.5 seconds of blurring of the harmonics within the first two cry expirations following the injection. Finally, premature infants, newborns and 2- and 4-month-old infants all show irregularity in the harmonic structures of their cries in response to a variety of different painful procedures (Johnston et al., 1993). It should be noted that all of the studies cited above examined cries instigated by painful procedures. Further investigations comparing the dysphonation of cries instigated by painful events and cries instigated by other sources of distress need to be done to determine the specificity of cry dysphonation to pain.

Intensity Features of Cry

The intensity of cry has also been used as an indicator of pain in young infants. The intensity of the cry is the amplitude of the waveform measured in decibels (dB) and reflects the energy at various frequency ranges (Grunau et al., 1990). The intensity of the cry is related to the infant's respiratory capacity (Lester, 1984). The difficult with using a basic measure of volume of the cry as an indicator of intensity is that it requires the source to be the same distance from the microphone and that is a difficult task in a clinical setting. As a result, researchers have focused on the "tenseness" in the cry as an indicator of intensity. A "tense" cry is characterized by greater energy in the higher frequencies of the sound spectrum (Fuller & Horii, 1988; Fuller et al., 1989).

The tension in the cry is related to the impact of stress and arousal on the vocal folds discussed previously. As such, the relation between the tenseness of cries and pain has been explored. In studies of infant response to a variety of painful procedures, infant cries had greater intensity in the higher frequencies compared to lower frequencies (Grunau et al., 1990; Johnston et al., 1993). Fuller & Horii (1988) found that crying associated with pain had more sound energy in the higher frequencies than crying associated with hunger or fussiness. A couple of follow up studies found that tenseness was an important feature, along with F0, in discriminating between pain cries and other types of cries (Fuller et al., 1989; Fuller, 1991).

Cry as an Index of Pain

Crying has some clear benefits and utility as a measure of pain in pre-verbal infants. Without verbal language, infants have fewer ways of signalling distress to caregivers than do verbal children. Therefore, the cry of an infant can be viewed as a type of communication intended to attract caregivers who can attend to the infant in distress. In this sense, crying has strong face validity as an index of pain in infants (Owens & Todt, 1984). In addition, cry not only serves as a distress signal to draw the attention of caregivers, but it also involves complex neurological mechanisms that can provide information about the infant's biological status (Fuller et al., 1989). For these reasons, it has been suggested that crying is the best dependant variable for studying pain in pre-verbal infants (Owens & Todt, 1984).

However, cry has a number of important disadvantages that limit its ability to act as an isolated index of pain. The most serious limitation of cry as a measure of pain is its relative lack of specificity. Cry did not develop solely as a signal of pain, but rather as a general distress call (McGrath, 1998). While the studies examining sensitivity and specificity largely remain to be done, it seems likely that crying represents a continuum of infant distress rather than signalling qualitatively different internal aversive states such as pain or hunger (Fuller, 1991; Grunau & Craig, 1987). This explains the large individual differences and why no defining features of a prototypic pain cry have been reliably identified (Craig & Grunau, 1993; Johnston & Strada, 1986; McGrath, 1996). While some studies suggest that pain cries may be differentiated from other types of cries, the cry literature is inconclusive and these claims must be interpreted with caution (Fuller, 1991; Lilley et al., 1997; Stevens et al., 1995). In addition, many infants do not cry when experiencing seemingly painful events (Grunau & Craig, 1990; McGrath, 1998). Finally, acoustic cry analysis requires expensive equipment, expertise and is time consuming, all features which limit its usefulness as a clinical tool (Craig et al., 2000). Therefore, cry should not be viewed as a sole index of pain, but should be considered in the context of other behavioural and physiological measures.

Adult Assessment of Infant Pain

The preceding sections on behavioural indices of pain in infants focused primarily on expressive qualities of infant pain. However, as pointed out in the sociocommunications model of pain, a more complete understanding of infant pain requires consideration of observer decoding of infant pain expressions. Parents and health care practitioners are often required to interpret behaviours of children to determine if they are experiencing pain or discomfort. While the sensory systems associated with pain are well developed in young infants, motoric expression is diffuse (an important exception being facial activity), leading to a general display of distress (Craig et al., 1988). The general expressions provide little in terms of differentiating between distress states. An example of this is observed in the cries of a newborn infant. Adults having little experience with particular infants have difficulty distinguishing cries of hunger, fatigue and pain from cry alone (Craig et al., 1988). However, experience with the given infant appears to play a role in this, as experienced caregivers and parents are more accurate in differentiating among different types of cries (Craig et al., 1988; Owens, 1984). Similarly, it appears that as infants get older, mothers are better able to interpret behavioural cues of the infant in order to discriminate between affective states (Johnston et al., 1993). Cues may become more specific as infants mature, acquire experience and adults acquire experience with specific infants.

Not surprisingly, a body of research has developed examining cues that caregivers use in judgments about pain in infants and other non-verbal populations. Most of these studies have relied on nurses' judgments of pain in infants undergoing painful medical procedures. One of the earliest studies examined the perceptions of infant pain in neonatal intensive care unit (NICU) nurses (Pigeon et al., 1989). They found seven categories of behaviours that NICU nurses believed indicated pain in infants: facial expression, facial color, limb movement, torso movement, respirations, cry and behavioural state. A later study by Shapiro (1993) examined nurses' judgments of pain in full-term and pre-term infants receiving a heel lance and found similar results; the indicators reported to be associated with pain response in infants were cry, body movement, facial expressions and physiological changes.

The most cited work on this topic comes from studies by Fuller and colleagues. In the first study, Fuller and Conner (1996) asked nurses to identify and report cues they used to determine the presence and absence of pain in infants. They reported that nurses believed that grimacing, wrinkling of the face and continuous crying were the most useful pain indicators across a range of infant development. In a follow-up study, nurses were asked to assess pain severity in infants and explain the cues they used in their judgments (Fuller, Thompson, Conner, et al., 1996). The nurses reported the frequency of cue use from highest to lowest as follows: vocalizations, infant's response to others, other-than-pain evaluations, general body language, facial expressions, judgments about pain associated with diagnosis, movement of limbs and head, consolability, nature of diagnosis, affect, state and physiological measures (heart rate). However, the cues with moderate to strong statistical associations with assessed pain were not given the same priority and appeared in the order: vocalizations, body movements, facial expressions, physiological signs and contextual cues (consolability and infant's responses to others). Therefore, while there are a number of cues that nurses endorse when making judgments about pain, only context, vocalizations, facial activity and body movement were frequently used and significantly associated with pain ratings (Fuller et al., 1996).

A subsequent study of nurses' judgments of infant pain revealed relatively similar results. Howard and Thurber (1998) found that 10 indicators were identified by more than 50% of nurses surveyed to assess pain in infants. The cues (in order of most frequent to least frequent), were: fussiness, restlessness, grimacing, crying, increased heart rate, increased respirations, wiggling, rapid state changes, wrinkling of the forehead and clenching of the fists. Therefore, it appears that cues believed to be useful by nurses in making their judgments fall into a number of broad categories including facial activity, vocalizations, body movement, physiological, infant characteristics (fussiness, consolability, response to others) and contextual cues (nature of the procedure or diagnosis). The validity of these assertions remains to be determined.

Many of the cues used by caregivers to assess pain appear to be consistent across different non-verbal populations. Smith, Pillai, Nader et al. (2002) found that judges (undergraduate university students) reported using similar cues to judge pain in videos of 2-month-old infants and children with autism. Among the top five most important cues identified for both groups were facial expression, body movements, vocalizations and context (the infant or child was experiencing a painful procedure). In addition, facial expression was rated as the most important cue for judging pain in both the infants and children with autism. Despite variability among judges (Fuller et al., 1996), the fact that facial expression was rated as the most important cue and that four of the top five cues were useful for each of the two non-verbal populations suggests that there exists a set of factors on which observers base their judgments when verbal report is unavailable. It can be inferred that diverse, non-verbal populations use similar ways to communicate pain and distress and observers report using specific and relatively consistent cues in making their judgments.

The several studies described examined the frequency and reported importance of self-reported cues used, but other than the Fuller et al. (1996) study, they did not explore the strength of the relationship between cues and assessed pain levels. Earlier studies did explore the relationship between reported cues used in judgments and observer pain ratings. Craig et al. (1988) had parents watch videotapes of infants other than their own receiving heel lances and rate the sensory and affective qualities of the pain they believed the infants were experiencing. It was hypothesized that both facial activity and cry characteristics would be associated with parent ratings of pain. For ratings of sensation, 43% of the variance in the pain ratings was accounted for by the facial activity of the infants. For ratings of affect, 49% of the variance was accounted for by facial activity of the infant with an additional 2% from the fundamental frequency. Craig et al. concluded that while cry may serve as an arousing feature to attract the attention of caregivers, facial activity of the infant is the greater contributor to pain ratings.

A later study produced very similar results. Hadjistavropoulos et al. (1994) had adults view and rate videotaped reactions of newborn infants receiving intramuscular injections. Cry characteristics accounted for 38% of the variance in observer pain ratings. Facial activity of the infants accounted for 49% of the variance in pain ratings. When facial activity and cry characteristics were considered together, they accounted for 54% of the pain rating variance. Hadjistavropoulos et al. concluded that cry was mostly redundant to facial activity, and that facial activity was the more important determinant in adult judgments of pain. However, in both this and the Craig et al. (1988) study, observers were watching videos of the infant's face (not the whole body), which may have led to greater attention focused on the face than would be the case in natural settings (Craig & Grunau, 1993).

Another study by Hadjistavropoulos et al. (1997) examined the contributions of a number of variables to observer pain ratings; the variables included facial activity, body movement, gestational age and contextual information. They had observers view videotapes of infants receiving heel lances and then had the observers rate the pain they believed the infants experienced. They found that all but contextual information contributed to the judgments of pain, with facial activity accounting for most of the variance in the ratings. Facial expression accounted for 35%, body activity accounted for 3% and gestational age accounted for 1% of the unique variance in the pain ratings.

Hadjistavropoulos et al. concluded that behavioural reactions of the infants were most important in assessing judgments of pain and that contextual information provided no unique information above and beyond the behavioural reaction.

In summary, self-reported importance of various cues appear to be related to the actual use of the cues when making pain judgements in infants. Judges self-report that behavioural cues (facial activity, body movement and cry) are highly important in making pain judgements in non-verbal populations. These findings are supported by studies demonstrating that infant facial activity, cry and body movement account for significant variability in observer reports of pain.

Age Related Differences in Infant Pain

The first year of life is characterized by major cognitive, social, perceptual and physical developmental changes in infants. The nervous system increases in complexity, the body grows and changes shape, sensory and perceptual capacity evolve, a greater ability to make sense of and understand the world develops and characteristic personality and social styles emerge (Lamb et al., 2002). The brain of a 2-month-old infant is approximately 30% of the adult brain weight, while at 12 months, it is 60% the weight of the adult brain (Schickedanz, Schickedanz, Forsyth et al., 2001). At 2 months, infants can lift themselves up from a prone position by their arms and roll from side to back; at 12 months, they are standing and walking. At 2 months, infants display simple motor habits and limited anticipation of events; by 12 months, they demonstrate goal directed behaviour and improved anticipation of events. At 2 months, infants coo; at 12 months they begin to use preverbal gestures and say their first recognizable words. At 2 months, infants respond to adult facial expressions in kind and engage in social smiling; at 12 months, infants begin to develop a meaningful understanding of perceived facial expressions. At 2 months, infants prefer complex, stylized faces to equally complex patterns; at 12 months, infants display fine-grained discrimination and perception of emotional expressions in others (Berk, 2002). Between the ages of 2 and 12 months, infants develop a number of emotions including wariness, joy, anger, sadness, surprise and fear (Seifert & Hoffnung, 2000).

These changes would be expected to have an impact on an infant's ability to understand, cope with, and respond to painful stimulation. Very young infants do not have the developmental capability or neurological maturity to understand or remember the meaning of pain events in the same way that older children and adults do (Rovee-Collier, Hartshorn, & DiRubbo, 1999). It would seem likely that personal experiences and socialization influences help older children and adults put the experience of pain into context, thereby helping them to cope (McGrath & Craig, 1989). This inability to place pain in the context of past experiences results in the young infant being unable to anticipate relief. Craig et al. (2000) explain, "While painful injuries and diseases are often not life-threatening, the distinction is not available to the infant. One would expect relatively vigorous displays of distress to events deemed of lesser significance to the adult observer" (p. 24). Therefore, developmental differences in pain reactivity may relate to the infant's capacity to modulate the pain response with younger infants being less effective due to immature memory systems. Between 6 months and a year, a more sophisticated form of explicit memory develops, drawing upon cortical structures for semantic memory and hippocampal structures for episodic memory (Papalia, Olds, & Feldman, 2002). The development of more sophisticated explicit memory potentially allows for the interpretation of pain in the context of general knowledge and experiences.

There has been some exploration of developmental changes in infant understanding and memory of pain. Memory for pain is likely, even in infants under 3 months of age (McGrath & Craig, 1989; McGrath & McAlpine, 1993). A recent study demonstrated that newborn infants exposed to repeated heel lances anticipate pain and display more intense pain response than infants who do not experience multiple heel lances (Taddio, Shah, Gilbert-Macleod et al., 2002). Between the ages of 3 and 6 months, the pain response begins to be supplemented by an anger response in the infant (Izard, Hembree & Huebner, 1987; McGrath & Craig, 1989). The anger expression could be due to the infant's increased cognitive capacity and could function to reduce arousal, although this has not yet been demonstrated (Izard et al., 1987; Mangelsdorf, Shapiro, & Marzolf, 1995). From 6 to 18 months, children begin to develop a fear of painful situations, anticipate that events signal imminent pain (e.g., physician's offices) and become able to localize pain (McGrath & McAlpine, 1993). Therefore, as the infant develops, the pain response appears to shift from being almost completely perceptually dominated and reflexive to being modulated more by affective states and cognition.

Evidence for the developing emotional regulation strategies of infants comes from a study by Mangelsdorf and colleagues (1995). The study explored the differences in strategies for emotional regulation in infants between the ages of 6 and 18 months. Mangelsdorf et al. (1995) argued that, with development, infants gain an increasingly complex range of coping strategies to deal with arousing situations. They hypothesized that infants would shift from a more passive form of regulatory behaviour (e.g. fussing) to more active forms (e.g. self-distraction and soothing). The results of the study supported this hypothesis, as 6-month-old infants used self-distraction less frequently than older infants did. Therefore, they concluded that older infants acquire more sophisticated coping mechanisms to help deal more effectively with aversive states. However, the study relied on observer judgments of infant behaviour, but no fine-grained behavioural or physiological correlates of arousal. In addition, the study examined regulatory behaviour of infants interacting with strangers, which is likely a very different type of aversive state than pain.

As mentioned earlier, in addition to cognitive development, there are significant neuromuscular changes that take place in young infants. Developmental maturation of biological systems in the first year of life also could contribute to differential pain responses in younger and older infants. Age differences reflect developing neuromuscular integration whereby infants are able to not only remember and anticipate experiences, but also perform motor actions and goal-directed behaviours (Fuller & Conner, 1996). Developmental changes in the infant neurological system are towards greater organization and specificity of responses (Johnston et al., 1993). In 2-month-old infants, there is a delay between the onset of crying and the infant first looking at the caregiver; in 7 to 9-month-old infants, there is no delay, as infants look at caregivers while starting to cry and elaborate with gestures such as pointing to a desired object or reaching for a caregiver (Graham, 1978). In addition, older infants have more highly developed muscle strength and the coordination necessary to perform particular actions and pain behaviours, while younger infants cannot (Fuller & Conner, 1996; Hadjistavropoulos et al., 1997).

Age Related Differences in Facial Expression

As previously mentioned, facial activity is the most consistent response across infants at all developmental stages, including premature infants (Stevens et al., 1995). However, developmental differences in facial reaction to painful stimuli are evident. Izard et al. (1983) reported that the facial response to immunization injections in infants changes with age; pain expression, as an immediate response, decreases in prominence, while anger expression increases in prominence with age. However, they examined global facial pain response and not fine-grained facial responses associated with pain. In a study comparing pain reactions in premature infants and full-term newborns, Craig et al. (1993) reported that premature infants demonstrated decreased facial activity compared to full-term infants. Johnston et al. (1993) found similar results but reported greater detail in terms of how the facial responsiveness differed between premature and full-term infants. They reported that premature infants demonstrated greater horizontal stretching of the mouth, but less tautness in the tongue compared to full term newborns. Therefore, while premature infants are able to communicate pain and distress via facial activity, it is not as well developed as in newborn infants (Johnston et al., 1993). It is unclear if decreased pain responsiveness or neuromuscular immaturity was underlying the different facial pain responsiveness of the premature infants.

Other studies have examined how facial responsiveness differs in healthy, full term infants of different ages. Full term newborns receiving intramuscular injections displayed greater horizontal mouth stretch and more taut tongue compared to 2- and 4-month-old infants. The facial reactivity of the 2- and 4-month-old infants did not differ from each other (Johnston et al., 1993). In a study of 2- to 18-month-old infants receiving immunizations, Lilley et al. (1997) found a relative absence of large developmental differences in the individual facial actions; the pain face associated with infant pain was relatively consistent across age ranges. Consistent with the notion of developmental increases in inhibitory control, they found that 2-month-old infants had the greatest facial activity compared to older infants. They explained the drop in the degree of facial activity between 2-month-old infants and older infants as due to greater behavioural organization of the older infants, resulting in more self-soothing and lesser need to elicit caregiver aid. That being said, the overall conclusion from the study was that there were surprisingly few changes in the patterns of facial pain display from 2- to 18-months. Other manifestations of painful experience, including cry and limb and body movements were not examined.

Age Related Differences in Body Movement

The first investigator to document age related differences in body movement was McGraw (1945) who reported that infants responded to a pinprick with diffuse body movement, which increased in intensity during the first month of life. However, during the second month, the reaction declined and between the ages of 6 and 12 months, infants demonstrated purposeful withdrawal of the stimulated limb (Owens, 1984). Since then, a number of authors have reported findings similar to McGraw's original descriptions. There appears to be a progressive change in behavioural expressions with younger infants displaying a more global, spontaneous, undifferentiated reaction (Craig et al., 1984; McGrath & Craig, 1989). The diffuse reaction could represent the young infant's limited capacity to self-soothe and eliminate sources of pain and discomfort (Craig et al., 2000). As the infant gets older, the reaction becomes more sophisticated, displaying anticipatory responses and goal-directed movements. At 7 or 8 months, infants begin to learn that certain settings (e.g. hospitals) and people (e.g. nurses) signal pain to come and the result is greater anticipatory distress and movement compared to younger infants (Craig et al., 1988; Craig et al., 1996).

Age Related Differences in Cry

In contrast to facial activity, crying is more developmentally specific and has been demonstrated to change as the infant gets older. As language emerges in the developing infant, crying transforms to permit more specific expressions of distress (Craig et al., 2000). This transformation is partly a result of ontogenetic, neuromuscular maturation (Fisichelli, Karelitz, Fisichelli et al., 1974). Neuroregulatory constraints prevent facial activity from being as subject to conscious control as vocalizations (Craig et al., 2000). In addition, as infants get older, they are able to associate cry with external events, internalize display rules for crying and have greater ability to self-soothe and problem solve (Craig et al., 2000). Therefore, crying appears more greatly influenced and modified by social learning in contrast to facial activity. Craig et al. (2000) explained, "Toddlers are frequently told not to cry, but less often told not to make expressive faces. Young children quickly learn the negative consequences of being labelled a cry-baby, but there is no equivalent term for a child who expresses distress through facial expression" (p. 34). However, this does not rule out the possibility that social learning impacts facial activity as well. Given the social learning factors and neurodevelopmental maturation of infants, there will likely be a modification in vocalizations reflecting the changes.

However, there have been very few studies examining how cries differ developmentally, leading to calls for more developmental studies of crying (Green et al., 1995, 2000). An early study examining cry in response to a rubber band snapping against the heels of infants found general trends of reduction and suppression of cry reactions as infants got older (Fisichelli et al., 1974). However, the study only considered durational features of the cries and if there was a cry reaction or not. A later study by Thoden and Koivisto (1980) explored pain cries in newborn infants, 3-month, and 6-month-olds reacting to an arm pinch. They found few changes in cry characteristics between the age groups other than a trend towards shorter cry latency with increasing infant age and that the cries of the 3-month-olds had greater dysphonation. They concluded that there were few changes in cry characteristics from birth to 6 months.

These early studies, while beneficial in terms of attempting to examine age related differences in cry, suffered from methodological problems that limit their generalizability. The cry characteristics on which they focused were primarily durational and lacked the sophistication of more complex, computer-driven, spectral analyses possible today. In addition, the pain stimuli (rubber band snap on the heel and arm pinch) were crude, nonstandardized, and lacked clinical validity. More recent studies examining clinically painful procedures have identified age related differences in infant cry. The fundamental frequency of the cries of preterm infants is greater than that found in 2-month-old infants (Johnston et al., 1993). As infants get older, the fundamental frequency of the cry decreases while the duration of the cry increases (Craig et al., 2000). In addition, as infants get older, the mean spectral energy and tenseness of the cries decreases (Fuller & Horii, 1988). The result of these changes is that infant vocalizations become less ambiguous as the infant develops and provide more information about the subjective state of the infant (Craig et al., 2000). While this conclusion is likely, empirical support is still lacking.

Age Related Differences in Pain Cues

Given the lack of understanding about age related differences in pain expression in infants, there is relatively little information available about differences in cues used by observers to identify pain across infants of differing ages. A study by Fuller et al. (1996) found that there were no differences in the pain indicators reported to be used by nurses to identify pain in 1- to 12-month-old infants. The authors were quick to point out, however, that the lack of difference did not mean that all of the cues were useful indicators of pain for infants of all ages. Fuller et al. (1996) concluded, "The lack of differences in the frequency with which . . . cues were used across the four infant age categories suggests that some study participants were basing their assessments on some developmentally inappropriate cues" (p. 59). However, this conclusion requires a better understanding of age related differences in infant pain expression. Only this information would allow specification as to whether the cues identified by the nurses were the cues they used.

Other research has demonstrated a shift in the importance of auditory versus visual cues with increasing infant age as determinants of observer judgements. As infants become older, vocalizations appear to make a greater contribution to pain judgments. Fuller et al. (1996) found that pain cry was more often reported to be used as an indicator for pain in infants between the ages of 7 and 12 months compared to infants 1- to 6-months-old. A study by Green et al. (1995) found that recognition of pain cries improved with older infants and that addition of visual information to acoustic information was least helpful for older infants. In other words, the cry of older infants appeared to communicate more about pain states compared to younger infants. For younger infants, they found that observers put more emphasis on facial activity than on cry characteristics when making pain judgments. As discussed earlier, the pain cry of young infants is an ambiguous stimulus other than in the respect that it is a "siren" able to attract the attention of caregivers to the needs of the infant. Given the ambiguous nature of the cry, the facial activity of the infant can help disambiguate the source of the infant's distress (Green et al., 1995). However, no work has demonstrated the impact of age related differences in infant pain expression on observer judgments of pain.

Overview of the Current Study

The first purpose of the present study was to explore how, and if, pain expression differs with infant age throughout the first year of life. While a few studies have explored how facial expression and cry differ with infant age, little is known about multidimensional changes in pain expression. Many studies in this area have been unidimensional, focused on limited age ranges and/or used inadequate or convenience measures. Researchers have also expressed the great need for replication and further developmental studies of changes in infant pain expression (Green et al., 2000; Lilley et al., 1997). The current study was designed to explore and describe how facial activity, cry and body movement reactions to an invasive procedure differ with infant age throughout the first year of life. In addition, little is known about how parent assessments of pain differ as infants become older. For the most part, studies have not considered the sensitivity of parents to infant cues at different ages. Since parents are often required to identify or notice pain in their infants, understanding if and how parental assessments differ with infant development is important. Therefore, the current study aimed to describe and identify age related differences in pain expression in infants, as a primary objective, and pain decoding of their caregivers, as a further objective.

The study examined infants 2-, 4-, 6- and 12-months-old receiving routine immunization injections. According to the Canadian Medical Association (2002) and the British Columbia Ministry of Health Services (2003), infants should receive subcutaneous injections of diphtheria, tetanus, pertussis (DTaP), inactivated poliovirus (IPV), *Haemophilius influenzae* type b conjugate (Hib), hepatitis B (Hep B) and pneumococcal conjugate vaccines at 2, 4 and 6 months. At 12 months, infants should receive measles, mumps, rubella (MMR) and meningococcal conjugate vaccines. The DTaP, IPV and Hib vaccines are combined into one injection, resulting in three injections for 2-, 4- and 6-month-old infants and two injections for 12-month-old infants. Routine immunization vaccinations are the most common cause of iatrogenic pain in infants and children (Taddio, Nulman, Goldbach et al., 1994) and they occur at relatively constant ages throughout infancy, allowing for grouping infants into 2-, 4-, 6- and 12-month age groups. Since almost all infants are immunized, this source of procedural pain provided accessible samples from which to collect information. While the sample was a convenience sample, as it comprised eligible consecutive infants seen at the observation site, universal requirements for immunization indicate that the sample would be reasonably representative of children in this community. The pain response of infants undergoing immunization was assessed using a number of different measures of pain, including facial activity, cry, body movement and parental reports.

The second purpose of the study was to explore the decoding process used by parents in making judgments of pain in their infants. While there have been studies examining cues used by nurses in judging pain in young infants, little research has explored cues used by parents in judging pain in their own children. Given that parents are the caregivers most often called upon to determine if young infants are in pain, this is an important area of study. In addition, little is known about how (or if) cues used by parents in making their judgments of pain are perceived by them as differing as infants develop. Therefore, the current study had parents report on the importance of various cues (vocalizations, facial expression, body movement), in making their judgments of pain in their infants during the immunization procedure.

The final purpose of the study was to examine, objectively, the factors that contributed to parental assessments of pain in their infants. As noted, parents were asked to subjectively report the importance of various observable cues but it was unknown if the cues they reported as being important in their judgments were, in fact, the cues used in making their judgments. As described earlier, there are a number of unsubstantiated beliefs and myths about infant pain that contribute to misinterpretations and underestimations of infant pain (McGrath, 1996). It is plausible that these misinterpretations also govern the cues that parents report as being important in making their pain judgments. Therefore, the current study sought to uncover the relationships between the objectively coded data for cry, body movement, facial expression and parental assessments of pain. In this way, it could be determined if the cues parents report as being important in making their pain judgments were predictive of their pain ratings.

Hypotheses

As few studies using detailed coding systems have examined multidimensional differences with age in infant pain expression, the current study was primarily descriptive. However, the following hypotheses were tentatively formulated based on the following premises that have already been discussed. As infants develop within the first year of life, their capacity to modulate and cope with pain increases (Craig & Grunau, 1993). Age related differences in pain expression are towards greater organization and specificity of responses (Johnston et al., 1993). In other words, the pain responses of younger infants can be interpreted as being more diffuse and disorganized relative to older infants. Finally, infants aged approximately 6-months demonstrate greater anxiety and increased stress in response to being in settings associated with past painful experiences (McGrath & McAlpine, 1993). The hypotheses of the study were:

1. All of the infants would demonstrate an increase in facial activity in response to an immunization injection relative to baseline. Since facial expression appears to be one of the most stable and consistent indicators of pain across age groups, there would likely be small age related differences in the magnitude of the increase in facial activity. Specifically, the older infants would demonstrate smaller increases in facial activity in response to the immunization injection.
2. All of the infants would display an increase in body movement in response to the immunization relative to baseline. In comparison to facial activity, there would be large age related differences in global body movement in response to the immunization injection reflecting the older infants' greater capacity for neuromuscular control. Hence, younger infants would display a greater increase in body movement compared to older infants.
3. Similar to body movement, there would be greater age related differences in the acoustic and temporal features of the infant cries. The vocalizations of the younger

infants would have greater latency, duration, fundamental frequency, dysphonation and tenseness than the vocalizations of older infants.

4. Given the expected differences in pain expression in infants, differences in the assessments of pain by the parents were expected. However, it was unclear how these differences would relate to the developmental age of the infants. It is possible that the likely more global, non-differentiated pain response of younger infants could be ambiguous to parents who could then assign either greater or lesser pain to the ambiguous response. It was expected that as parents observed greater responses to the immunization, they would attribute greater pain to those responses.
5. Given that the pain response of younger infants was expected to be more disorganized and non-specific, it was hypothesized that parents would report greater importance on contextual cues versus behavioural cues in making their pain assessments. With older infants, who were expected to demonstrate more specific pain displays and vocalizations, the contextual cues would play a lesser role and the behavioural cues would play a greater role in parent pain judgments.
6. If parents were actually cognizant of the information determining their judgments and using the behavioural displays of their infants in making their judgements, the predictive ability of the objectively coded behavioural cues would correspond to the importance placed on those cues by the parents. In other words, the behavioural cues identified by parents as being most important to pain judgments would be the objectively coded cues that most strongly predicted parent ratings of pain.

Methods

Participants

A convenience sample of 160 healthy infants receiving routine immunization injections was recruited from two sites: a family practice clinic at a local children's hospital and a private practice clinic of five family physicians. The sample consisted of equal numbers of 2-, 4-, 6- and 12-month-old infants. Sampling was conducted between August 2003 and November 2004, until data from 40 infants had been collected for each age group. The inclusion criteria for participation in the study were: the infants were receiving an immunization within 31 days of the median age for the injection; a parent or caregiver who could speak and read English accompanied the infant; the parent or caregiver had not previously participated in the study; and the parent or caregiver consented to have the infant participate in the study. During the study period, 217 eligible parents were approached to participate in the study. Fifty-seven (26%) declined the opportunity. Although reasons for refusal were not formally requested, the most commonly identified reasons reported by the parents were: the parent was not interested (45%), the parent was in a rush (27%), the infant was sick or tired (13%), the parent was unsure how the baby would react (3%) and concerns about confidentiality (3%).

Procedure

The study received ethical approval from both the University of British Columbia Behavioural Research Ethics Board and the Children's and Women's Health Centre of British Columbia Research Review Committee. The study was conducted in as similar manner as possible across the two clinic sites. Upon arrival at the clinic, parents interested in participating were identified by a staff member of the clinic and then approached by a research assistant who described the study objectives and procedures. Parents who agreed to participate were given an informed consent form to sign (Appendix A).

When it came time for the immunization, the parent and infant were invited into the procedure room by a nurse or physician who then gave the infant a short medical examination. After the examination, the research assistant entered the room and videotaped the infant's face and body using a hand-held digital video (DV) camera during the entire immunization procedure. During the immunization injection, the infants typically sat in their parents' laps, with the parents holding the infants during the injection. Depending on the age of the infant, either two or three immunization injections were given (the 2-, 4- and 6-month-old infants received three injections and the 12-month-old infants received two injections). For later coding purposes, the nurse or physician giving the immunization injection indicated when the injection took place by saying, "poke". The immunization injections were given in the thigh to 151 (94.4%) infants, while the remaining nine (5.6%) infants received the injections in the upper arm. Of the nine infants who received the injections in the upper arm, eight were 12-months-old and one was 6-months-old.

Upon completion of the immunization procedure, parents returned to the waiting room with their infants. While there, parents completed an information form asking about general demographics and the health status of the infant (Appendix B). The parents were then instructed and asked to complete a pain rating form consisting of a visual analogue scale (VAS) and two verbal descriptor scales (Appendix C), requiring the parents to assess the amount of pain experienced by the infants during the first immunization injection. Finally, the parents were asked to complete a questionnaire assessing the importance of various cues they may have used in making their pain ratings (Appendix D).

The digital video of the immunization procedure was converted to VHS and time-stamped to allow for frame-by-frame and second-by-second coding. The audio from the procedure was digitally sampled from the DV tape and directly inputted into a computer for analysis by Kayelemetrics, Multi-Speech 3700 software.

Measures

Infant Behavioral State

The behavioural state of the infants in the 15 seconds prior to the immunization injection was coded using Grunau and Craig's (1987) behavioural state rating system adapted from Prechtl's (1974) observational rating system. The system codes for four behavioural sleep/waking states: quiet sleep (eyes closed, no facial movement), active sleep (eyes closed, facial movement), quiet awake (eyes open, no facial movement), and active awake (eyes open, facial movement) (Grunau & Craig, 1987). This rating system has been used to assess baseline behavioural state in a number of infant pain studies (Grunau & Craig, 1987; Johnston et al., 1996; Stevens & Johnston, 1994). Trained coders who used real time and still motion, frame-by-frame examination of the video prior to the injection coded the behavioural state for each infant. To establish reliability, 20% of the videos were coded for behavioural state by a second trained coder. Inter-rater reliability was calculated using proportion of absolute agreement and was found to be 0.94.

Behavioral state has been identified as factor that may modify the pain response of infants (Craig & Grunau, 1993; Stevens et al., 1996). Franck and Miaskowski (1997) emphasized the importance of assessing behavioural state, explaining, "Behavioural state must be considered in all measurements of neonatal responses to painful stimuli because of the potential influence of baseline behavioural state level on the neonate's responsiveness to these stimuli" (p. 370). Awake, alert but quiet infants display greater pain responsiveness than awake and active infants (Grunau & Craig, 1987), suggesting that the activity could serve as a distraction during noxious events or moderate the experience in some other manner (Craig & Grunau, 1993). Infants in a state of quiet sleep demonstrate the least behavioural response to noxious events (Grunau & Craig, 1987). However, the impact of behavioural state appears to influence facial activity and latency to cry more so than the fundamental frequency of the cry (Grunau & Craig, 1987; Wasz-Hockert et al., 1985).

Facial activity

Facial activity of the infants during the immunization procedure was coded using the Neonatal Facial Coding System (NFCS; Grunau & Craig, 1987). NFCS is a facial coding system specifically designed to assess the pain experience in young infants. The system codes for ten facial actions: brow bulge, eye squeeze, nasolabial fold, open lips, vertical mouth stretch, horizontal mouth stretch, taut tongue, lip purse, chin quiver, and tongue protrusion (Craig & Grunau, 1993). However, only the first seven facial actions have been consistently associated with pain in infants (Benini et al., 1993; Craig, 1998). NFCS was adapted from the Facial Action Coding System (FACS; Ekman & Friesen, 1978), which is an atheoretical, anatomically based coding system developed to study emotional states by providing objective, reliable and comprehensive descriptions of all possible facial movements (Craig et al., 1994). However, it is not specific to infant facial activity or pain, whereas NFCS was developed specifically for the study of pain in infancy.

There are a number of advantages to using NFCS over FACS in the study of pain in infancy. In terms of practicality, NFCS is an efficient coding system, providing a simpler description of some facial activity (especially around the eyes) and codes for only 10 facial actions compared to 46 in FACS (McGrath, 1996). However, NFCS is a slightly more comprehensive system for infants because it codes for tongue activity, which is not coded in FACS (Craig et al., 1994). As mentioned earlier, the NFCS items were selected to be specific to pain, while FACS codes for all forms of facial activity. NFCS has been demonstrated to be comprehensive of all of the facial actions coded on FACS to be observed during infant pain (Craig et al., 1994; Lilley et al., 1997). Finally, given the greater complexity of the FACS system, it requires much longer training of coders, again, making it less practical and useful for studying pain in infants compared to NFCS (Craig et al., 1994). Therefore, for reasons of practicality and specificity, NFCS was the facial coding system used in this study.

A number of studies have demonstrated that NFCS is a valid and reliable indicator of pain in infants. NFCS has been demonstrated to distinguish between painful and non-noxious phases of medical procedures (Johnston et al., 1995; Porter, Wolf, & Miller, 1998; Taddio et al., 2002) and NFCS scores systematically vary with the use of analgesics (Benini et al., 1993; Kaur, Gupta, & Kumar, 2003; Scott, Riggs, Ling et al., 1999). These studies provide evidence for the construct validity of NFCS, but it has also demonstrated convergent validity (Craig et al., 1994; Craig, 1998), sensitivity to changes in pain intensity (Stevens et al., 1995) and high inter and intra-rater reliability (Abu-Saad et al., 1998).

Two segments from the video of the immunization procedure were coded using NFCS: a pre-needle and needle segment. The major behavioural reaction to a physical insult in infants occurs within approximately 10 seconds after the event (Craig et al., 1993, 1994; Johnston et al., 1993). Therefore, the time segments that were analyzed for behavioural coding were a 10-second pre-needle phase and a 10-second needle, pain response phase. Similar coding phases have been used in other infant immunization studies (Craig et al., 1993, 1994; Johnston et al., 1993; Lilley et al., 1997). The pre-needle segment was the 10 seconds immediately before the first injection took place. This segment consisted of the nurse or physician swabbing the injection site with an alcohol swab and served as a non-noxious contrast to the needle phase, which was the 10 seconds immediately after the first injection.

Each of the NFCS facial actions was scored as present or absent during five 2-second segments comprising both the 10-second pre-needle and 10-second needle segments. This resulted in five scores for each NFCS action unit per coding segment. The five scores for each NFCS action unit were averaged for both the pre-needle and needle 10-second segments, resulting in one score for each action unit for each segment. As with previous studies (Craig et al., 1994; Lilley et al., 1997), facial action units that rarely occurred were not included in the analyses. Only facial action units that occurred more than 10% of the time were analyzed. This resulted in chin quiver, tongue protrusion and lip purse being dropped from the analyses (see Appendix E for frequency of facial action units). An overall facial action score (ranging from 0 – 7) for each segment was generated by summing the average scores for each of the remaining action units (brow bulge, eye squeeze, nasolabial fold, open lips, vertical mouth stretch, horizontal mouth stretch, taut tongue) occurring during each segment.

A primary coder, trained to a high level of intercoder reliability in the NFCS, coded all of the video segments. In order to determine reliability, 20% of segments were coded by a second trained NFCS coder. Inter-rater coding reliability was calculated using the formula recommended by Ekman and Friesen (1978) which assesses the proportion of agreement on actions recorded by two coders relative to the total number of actions coded as occurring by each coder. Inter-rater reliability was very good at 0.90.

Body movement

The body movements made by the infant during the immunization procedure were coded using the Infant Body Coding System (IBCS; Craig et al., 1993). The IBCS scores body movements as either present or absent in a number of regions of the body including the hands, feet, arms, legs, head and torso. The IBCS has been shown to discriminate between painful and nonpainful events in infants and demonstrates very good inter-rater reliability (Craig et al., 1993).

Body movement was coded on the same segments as NFCS. Scores for the individual body movements and overall body movement score for each segment were calculated in a fashion identical to the NFCS data. Since IBCS codes for five body movements, the overall body movement score for each segment could range between zero and five. As with NFCS, 20% of the segments were coded by a secondary coder to determine reliability and inter-rater reliability was 0.87.

Cry

There generally have been two approaches used to study pain vocalizations in infants. The first is the use of computer-based acoustic and temporal analyses focusing on the acoustic characteristics of the cry. The second approach has been to use the subjective judgments of adult listeners to interpret and characterize the significance and meaning of infant cries (Craig et al., 2000). The approach used in this study was the former as it provided more quantifiable and objective indicators of pain. The first full cry expiration, lasting greater than one second after the immunization, was examined. The first cry signal is the one most commonly analyzed in research studies, as it is different from subsequent signals and appears to contain the most pain specific information (Johnston et al., 1993). The first cry is generally the longest duration (Franck, 1986; Thoden & Koivisto, 1980) and demonstrates the greatest variability in pitch, suggesting greater initial response differences (Johnston & Strada, 1986).

The infant cries were analyzed using Kayelemetrics, Multi-Speech 3700 software. Cry latency and duration were determined using the cry waveform display generated by the software. The tenseness of the cry was measured by examining the frequency of peak spectral energy in the cry, with an index readily available from the software.

Determining maximum fundamental frequency and dysphonation required examination of the spectrograph of the cry. For the fundamental frequency, a coder trained in acoustic analysis analyzed all of the spectrographs and determined the maximum fundamental frequency for each cry. The coder determined the highest frequency in the first harmonic on the spectrograph. To calculate interrater reliability, a second trained coder examined 20% of the spectrographs and determined the fundamental frequencies of each cry. Reliability was calculated using both Pearson's r and absolute agreement intraclass correlation coefficients (ICC) between the two coders. Inter-rater reliability was high, with $r = 0.985$ and ICC = 0.984.

Dysphonation also required coder judgment to determine what percentage of the cry demonstrated blurred or unvoiced harmonics. To obtain this, the spectrographs of each cry were examined to identify the duration of time the harmonic structure was blurred or not observable during the cry. This was then divided by the total duration of the cry to establish the percentage of time cry was dysphonated. Again, reliability was very good, $r = 0.948$ and ICC = 0.939.

<u>Parent Ratings of Pain</u>

Parents were asked to complete a Visual Analogue Scale (VAS) (Appendix C) to provide their judgments of the pain intensity their infants experienced. This assessment took place immediately after the procedure was completed. The VAS has been demonstrated to be a sensitive and reliable measure of pain intensity and is one of the most widely used pain assessment tools in clinical and research settings (Abu-Saad et al., 1998). The VAS consists of a 100-millimeter horizontal line anchored by, "No Pain" and "The Worst Pain Possible". Parents rated the severity of pain in their infants by placing a vertical mark on the VAS to indicate the level of pain they felt their infants experienced. The greatest strengths of the VAS are that it does not require a sophisticated vocabulary and can allow for fine distinctions among pain states (Duncan, Bushnell, & Lavigne, 1989). One of the key drawbacks of the VAS is that it requires the person to imagine pain in terms of a quantifiable dimension (Duncan et al., 1989). While this may be difficult for some people and different age groups (e.g. young children, cognitively impaired elders), it was not an apparent difficulty for the parents recruited for this study.

Pain intensity is only one characteristic of the pain experience. Therefore, the study also included measures tapping parent judgments of the sensory and affective aspects of pain as well. Parents were asked to complete two verbal descriptor scales (Gracely, Dubner & McGrath, 1979) (Appendix C). The scales consist of 13 pain descriptors each and assess pain intensity (DDS-I) and pain affect or unpleasantness (DDS-U). The verbal descriptor scales were developed to have ratio scale properties (Gracely, McGrath & Dubner, 1978a) and have been demonstrated to be reliable, valid and sensitive measures of pain intensity and affect (Gracely, McGrath & Dubner, 1978b). The primary advantages to using verbal descriptor scales is that they aid in pain evaluation by providing judges with words in their passive vocabulary and they appear to be very sensitive in separating intensity and unpleasantness of the pain experience (Duncan et al., 1989). The main disadvantages of using verbal descriptor scales are that they require fluency in English, understanding of the meaning of the descriptors, and may not contain a word that precisely describes the judge's assessment of pain, requiring a choice of a close approximation (Duncan et al., 1989).

Cues Used in Parent Judgments

Parents also were asked to rate the importance of various cues in their pain assessments using an importance of cues questionnaire (Pillai Riddell, 2003) (Appendix D). The questionnaire consists of 12 cues commonly described in the literature to be important in judgments of infant pain. The cues are: the infants' age, sounds, capacity to understand pain, capacity to remember pain, size, the infant was in a medical setting, facial expressions, the infant was receiving a needle, mood, body movements, the infant was healthy, and capacity to focus on his/her surroundings. Parents were asked to rate the importance of each cue on a scale from zero (not at all important) to 10 (extremely important), in terms of how important each was for their pain judgments. The importance of cues questionnaire has been used in previous infant pain judgement studies as an indicator of cues involved in pain judgments (Pillai, Hoe Yan Ho, & Craig, 2002; Smith et al., 2002).

Results

Demographics

Table 1 summarizes descriptive data about the infants and caregivers who participated in the study. Of the 160 infants who participated in the study, 80 (50%) were male and 80 (50%) were female. Eighty-one (50.6%) of the infants were first born, 62 (38.8%) were second born, 14 (8.8%) third born and one (0.6%) fourth born. Twelve (7.5%) of the infants in the study were born premature, with the number of weeks premature ranging between 1 to 7 weeks ($M = 3.1$, $SD = 1.9$). All parents answered "yes" to the question, "Is your baby generally healthy?" Thirty (18.8%) parents gave their infants Tylenol before the shot to prevent fever resulting from the immunization. One hundred twenty two (76.3%) infants were accompanied by their mothers, 33 (20.6%) by fathers and five (3.1%) by other caregivers (three grandmothers, one aunt, one nanny).

The relationships among background characteristics and the age groups were examined using chi-square tests for categorical variables and ANOVAs for continuous variables. The only variable on which any of the four groups differed was the time the infant had been awake prior to the immunization, $F(3, 156) = 5.65$, $p < 0.05$. The 2-month-old infants were awake for a shorter period prior to the immunization procedure

Table 1

Demographic Characteristics of Infants and Caregivers

	2-months	4-months	6-months	12-months
Infant's Age (days)	M = 64.5 SD = 8.4	M = 128.9 SD = 10.2	M = 199.7 SD = 17.5	M = 386.8 SD = 18.0
Infant's Gender	Male = 20 Female = 20	Male = 20 Female = 20	Male = 18 Female = 22	Male = 22 Female = 18
Infant's Birth Weight (grams)	M = 3555 SD = 536	M = 3503 SD = 578	M = 3574 SD = 529	M = 3443 SD = 516
First Born Infant in Family?	Yes = 21 No = 19	Yes = 23 No = 17	Yes = 21 No = 19	Yes = 16 No = 24
Infant born Premature?	Yes = 4 No = 36	Yes = 2 No = 38	Yes = 1 No = 39	Yes = 5 No = 35
Time Since Infant Last Fed (hours)	M = 1.66 SD = 1.02	M = 1.55 SD = 0.81	M = 1.55 SD = 1.05	M = 1.44 SD = 1.30
Time Since Infant Awoke (hours)	M = 1.28 SD = 1.29	M = 2.41 SD = 1.73	M = 2.12 SD = 1.47	M = 2.70 SD = 1.96
Tylenol Given to Infant Prior to Immunization?	Yes = 8 No = 32	Yes = 7 No = 33	Yes = 9 No = 31	Yes = 6 No = 34
Caregiver Relationship to Infant	Mother = 29 Father = 9 Other = 2 (grandmother, aunt)	Mother = 31 Father = 9	Mother = 28 Father = 11 Other = 1 (grandmother)	Mother = 34 Father = 4 Other = 2 (grandmother, nanny)
Caregiver Age (years)	M = 33.6 SD = 6.0	M = 33.6 SD = 4.8	M = 34.0 SD = 7.7	M = 35.5 SD = 6.9

than any of the other groups.

Infant Behavioral State

Table 2 summarizes the behavioural states of the infants prior to immunization. All of the infants were either active awake or quiet awake. No significant differences in frequency of behavioural states were observed between the four infant age groups (χ^2_3 = 4.56, $p > 0.05$).

Age Related Differences in Facial Expression

Tables 3 and 4 summarize the overall facial action scores and the individual facial action unit scores of infants in each age group during the pre-needle and needle segments. A four (age group: 2-, 4-, 6-, 12-month) by two (segment: pre-needle, needle) repeated measures ANOVA was conducted to determine if there were differences in overall facial activity among the four age groups during the immunization procedure. A significant main effect was found for the coding segment, $F(1, 156) = 630.66$, $p < 0.05$, with the infants displaying greater facial activity during the needle segment, compared to the pre-needle segment. There was no significant main effect between the groups, $F(3, 156) = 1.70$, $p > 0.05$ and no significant interaction between the segments and the groups, $F(3, 156) = 0.24$, $p > 0.05$.

To determine if there were between group differences in the profile of facial activity, a four (age group) by two (segment) repeated measures MANOVA was conducted, with the individual facial actions as dependant variables. Again, there was no significant main effect for group, $F(21, 456) = 1.01$, $p > 0.05$, and no significant interaction between segment and group, $F(21, 456) = 0.89$, $p > 0.05$. As with the overall facial action score, there was a significant multivariate main effect for segment,

Table 2

Frequency of Behavioral State of Infants in Each Age Group Prior to Immunization Injection

Behavioral State	2-months	4-months	6-months	12-months
Quiet Awake	15	10	7	9
Active Awake	25	30	33	31

Table 3

Overall NFCS Mean Scores (and Standard Deviations) During the Pre-Needle and Needle Segments for Each Group

	Pre-Needle NFCS Score	Needle NFCS Score
2 months	2.26 (1.86)	5.73 (1.22)
4 months	1.94 (1.46)	5.23 (1.61)
6 months	1.63 (1.63)	5.22 (1.41)
12 months	2.13 (2.04)	5.69 (1.11)

Table 4

Individual Mean NFCS Facial Action Scores (and Standard Deviations) During the Pre-Needle and Needle Segments for Each Group

NFCS Action Unit	Segment	Age Group			
		2-months	4-months	6-months	12-months
Brow Bulge	Pre-Needle	0.29 (0.41)	0.22 (0.37)	0.21 (0.37)	0.31 (0.40)
	Needle	0.92 (0.15)	0.81 (0.27)	0.80 (0.31)	0.89 (0.17)
Eye Squeeze	Pre-Needle	0.22 (0.37)	0.10 (0.25)	0.11 (0.30)	0.22 (0.35)
	Needle	0.89 (0.17)	0.79 (0.28)	0.76 (0.29)	0.86 (0.18)
Nasolabial Fold	Pre-Needle	0.39 (0.42)	0.40 (0.45)	0.24 (0.37)	0.40 (0.44)
	Needle	0.91 (0.14)	0.82 (0.26)	0.84 (0.25)	0.92 (0.17)
Open Lips	Pre-Needle	0.77 (0.33)	0.83 (0.30)	0.71 (0.43)	0.67 (0.43)
	Needle	0.96 (0.12)	0.94 (0.18)	0.97 (0.09)	0.95 (0.11)
Vertical Mouth Stretch	Pre-Needle	0.20 (0.31)	0.10 (0.22)	0.09 (0.24)	0.13 (0.28)
	Needle	0.62 (0.35)	0.53 (0.34)	0.47 (0.38)	0.53 (0.35)
Horizontal Mouth Stretch	Pre-Needle	0.28 (0.38)	0.24 (0.36)	0.21 (0.35)	0.32 (0.40)
	Needle	0.83 (0.24)	0.77 (0.32)	0.84 (0.22)	0.89 (0.20)
Taut Tongue	Pre-Needle	0.11 (0.27)	0.07 (0.21)	0.07 (0.23)	0.08 (0.25)
	Needle	0.70 (0.30)	0.58 (0.37)	0.55 (0.37)	0.64 (0.29)

$\underline{F}(7, 150) = 99.12$, $\underline{p} < 0.05$. Follow-up analyses were seven paired sample t-tests (with α dropped to 0.007 using a Bonferroni correction for multiple comparisons), indicating that the means for all of the facial actions were greater during the needle than the pre-needle segments (see Table 5).

Age Related Differences in Body Movement

Tables 6 and 7 summarize the overall body movement scores and the individual body movement scores of the infants in each age group during the pre-needle and needle segments. As with facial activity, a four (group) by two (segment) repeated measures ANOVA was conducted to determine if there were differences in overall body movement between the four age groups during the immunization procedure. A significant main effect was found for the coding segment, $\underline{F}(1, 156) = 28.44$, $\underline{p} < 0.05$, with the infants displaying greater body movement during the needle segment, compared to the pre-needle segment, $\underline{t}(159) = 5.18$, $\underline{p} < 0.05$. There was no significant main effect between the groups, $\underline{F}(3, 156) = 2.11$, $\underline{p} > 0.05$ and no significant interaction (although approaching significance) between segments and groups, $\underline{F}(3, 156) = 2.65$, $\underline{p} > 0.05$.

As with facial activity, to determine if there were between group differences in the profile of body movement, a four (age group) by two (segment) repeated measures MANOVA was conducted, with the individual body movements as dependant variables. Similar to the results of the individual facial action units, there was no significant interaction between segment and group, $\underline{F}(15, 462) = 1.01$, $\underline{p} > 0.05$ and there was a significant multivariate main effect for segment, $\underline{F}(5, 152) = 9.56$, $\underline{p} < 0.05$. Follow-up analyses in the form of five paired sample t-tests (with α dropped to 0.01 using a Bonferroni correction for multiple comparisons) indicated that movements of the hands

Table 5

Follow-up Paired Samples t-tests for each NFCS Facial Action Unit by Segment

NFCS Action Unit	t value (DF = 159)	p value
Brow Bulge	19.78	$p < 0.007$
Eye Squeeze	24.60	$p < 0.007$
Nasolabial Fold	16.17	$p < 0.007$
Open Lips	7.91	$p < 0.007$
Vertical Mouth Stretch	15.07	$p < 0.007$
Horizontal Mouth Stretch	18.93	$p < 0.007$
Taut Tongue	20.00	$p < 0.007$

Table 6

Overall IBCS Mean Scores (and Standard Deviations) During the Pre-Needle and Needle Segments for Each Group

	Pre-Needle IBCS Score	Needle IBCS Score
2 months	2.97 (1.12)	3.22 (1.08)
4 months	2.49 (1.02)	3.08 (1.19)
6 months	2.76 (1.19)	3.17 (0.98)
12 months	2.09 (1.23)	3.14 (1.22)

Table 7

Individual Mean IBCS Scores (and Standard Deviations) During the Pre-Needle and Needle Segments for Each Group

IBCS Body Movement Unit	Segment	Age Group			
		2-months	4-months	6-months	12-months
Hands/Feet	Pre-Needle	0.83 (0.27)	0.73 (0.30)	0.74 (0.34)	0.52 (0.38)
	Needle	0.88 (0.28)	0.78 (0.33)	0.88 (0.22)	0.70 (0.35)
Arms	Pre-Needle	0.69 (0.37)	0.54 (0.38)	0.56 (0.40)	0.42 (0.33)
	Needle	0.66 (0.40)	0.61 (0.38)	0.54 (0.39)	0.63 (0.32)
Legs	Pre-Needle	0.76 (0.33)	0.54 (0.36)	0.65 (0.37)	0.34 (0.36)
	Needle	0.90 (0.22)	0.77 (0.31)	0.85 (0.21)	0.63 (0.38)
Head	Pre-Needle	0.51 (0.40)	0.60 (0.36)	0.62 (0.32)	0.64 (0.31)
	Needle	0.57 (0.36)	0.69 (0.33)	0.64 (0.32)	0.78 (0.29)
Torso	Pre-Needle	0.18 (0.31)	0.08 (0.20)	0.20 (0.30)	0.19 (0.26)
	Needle	0.21 (0.26)	0.23 (0.30)	0.26 (0.35)	0.40 (0.34)

and feet, legs and torso were all greater during the needle segment compared to the pre-needle segment. Arm and head movement did not differ significantly between the segments (see Table 8).

Unlike the individual facial action units, there was a significant multivariate main effect for group, $F(15, 462) = 4.41$, $p < 0.05$. Follow-up analyses were five ANOVAs with α dropped to 0.01 using a Bonferroni correction to adjust for multiple comparisons. The results are summarized in Table 9. The analyses indicate a significant effect of age for movement of the hands and feet and legs of the infants. None of the analyses of the other body movements were significant (although head and torso movement approached significance). Post hoc Tukey tests indicated that the 12-month-old infants displayed less movement of the hands and feet compared to 2-month ($p < 0.05$), 4-month ($p < 0.05$) and 6-month ($p < 0.05$) infants. The 12-month-old infants also displayed less leg movements than the 2-month ($p < 0.05$), 4-month ($p < 0.05$) and 6-month ($p < 0.05$) infants.

Age Related Differences in Cry

Table 10 summarizes the number of infants producing one cry phonation lasting greater than one second after the first immunization injection. Ninety-one percent of the infants reacted to the immunization injection with a cry and there was no significant difference among the age groups in terms of what percentage of infants cried ($\chi^2_3 = 6.58$, $p > 0.05$).

To determine if there were between group differences in infant cry in response to the immunization injection, a one-way MANOVA was conducted with cry latency, duration, dysphonation percentage, frequency of peak spectral energy and maximum fundamental frequency (F0) as dependent variables. Table 11 summarizes the means and

Table 8

Follow-up Paired Sample t-tests for each IBCS Body Movement by Segment

IBCS Body Movement	t value (DF = 159)	p value
Hands/Feet	3.61	$p < 0.01$
Arms	1.75	$p > 0.01$
Legs	6.66	$p < 0.01$
Head	2.34	$p > 0.01$
Torso	3.83	$p < 0.01$

Table 9

Follow-up ANOVAs for each IBCS Body Movement by Age Group

IBCS Body Movement	F (3, 156)	p value
Hands/Feet	7.00	$p < 0.01$
Arms	1.91	$p > 0.01$
Legs	14.51	$p < 0.01$
Head	2.56	$p > 0.01$
Torso	2.61	$p > 0.01$

Table 10

Number of Infants in Each Group Producing One Cry Phonation Lasting More than One Second after the Immunization Injection

Infant Respond with a Cry?	2-months	4-months	6-months	12-months
Yes	39	33	36	38
No	1	7	4	2

Table 11

Means (and Standard Deviations) of the Cry Variables for Each Group

	2-months	4-months	6-months	12-months
Latency (seconds)	3.36 (3.11)	4.41 (2.97)	3.54 (2.93)	3.14 (2.49)
Duration (seconds)	5.15 (3.31)	5.73 (3.86)	6.18 (4.07)	7.15 (4.24)
Dysphonation %	38.1 (29.7)	49.8 (33.6)	47.9 (28.4)	57.3 (23.2)
Frequency of Peak Spectral Energy (Hz)	1429 (671)	1419 (709)	1148 (570)	1386 (784)
Maximum F0 (Hz)	653 (284)	636 (279)	855 (569)	877 (551)
	n = 39	n = 33	n = 36	n = 38

standard deviations for the cry variables.

The omnibus F was significant ($\underline{F}(15, 420) = 1.94$, $\underline{p} < 0.05$) indicating that there were group differences among the four groups in at least one of the cry variables. As observed in Table 11, there were some apparent differences with increasing age, including increased cry duration, dysphonation percentage and maximum fundamental frequency. Follow-up analyses were five ANOVAs with α dropped to 0.01 using a Bonferroni correction to adjust for multiple comparisons. The results are summarized in Table 12. With the alpha level reduced to adjust for multiple comparisons, there were no significant differences among the groups on any of the cry variables, although dysphonation percentage and maximum fundamental frequency approached significance, likely accounting for the significant omnibus F.

Age Related Differences in Parent Ratings of Pain

The means (and standard deviations) of the three pain rating scales (used to provide parental pain ratings: VAS, DDS-I and DDS-U) for each group are presented in Table 13. To assess the degree of overlap between the three pain rating scales used, correlational analyses were run for the entire sample. The correlations between the VAS and DDS-I ($\underline{r} = 0.69$), between the VAS and DDS-U ($\underline{r} = 0.56$) and between the DDS-I and DDS-U ($\underline{r} = 0.60$) were all significant ($\underline{p} < 0.05$).

As a result of the high intercorrelations among the pain rating scales, and the resulting likelihood of multicollinearity (Tabachnick & Fidell, 2001), a principal components analysis was conducted on the entire sample to combine the pain rating scales into a single, composite pain score, as has been done in previous research (Pillai Riddell, 2003). A single factor with an eigenvalue of 2.24 was identified (and inspection

Table 12

Follow-up ANOVAs for each Cry Variable by Age Group

	F (3, 142)	p value
Latency	1.28	p > 0.01
Duration	1.80	p > 0.01
Dysphonation %	2.91	p > 0.01
Frequency of Peak Spectral Energy	1.35	p > 0.01
Fundamental Frequency	3.02	p > 0.01

Table 13

Means (and Standard Deviations) of Parental Pain Ratings and Composite Pain Score for Each Group

	2-months	4-months	6-months	12-months
VAS[a]	67.8 (16.8)	57.8 (20.5)	48.0 (21.2)	55.1 (19.7)
DDS-I[b]	32.8 (14.1)	39.5 (12.1)	22.5 (12.5)	22.4 (11.9)
DDS-U[c]	18.3 (11.1)	14.2 (7.7)	13.6 (6.9)	13.4 (4.2)
Composite Pain Score[d]	4.99 (2.08)	4.08 (1.75)	3.27 (1.84)	3.65 (1.56)

[a] Scores could range from 0 – 100.
[b] Scores could range from 0 – 59.5.
[c] Scores could range from 0 – 44.8.
[d] Scores could range from 0.29 – 10.00.

of the scree plot confirmed the suitability of the single-factor solution), accounting for 74.5% of the variance in pain rating scores. The principal component weights for the VAS, DDS-I and DDS-U were 0.871, 0.891 and 0.826 respectively. To facilitate interpretation and dissemination, the resulting standardized composite pain score was rescaled (using a linear transformation) to approximate a 0 – 10 scale, with higher values indicating higher pain ratings. The composite pain variable ranged from 0.29 to 10.00.

The means (and standard deviations) of the composite pain scores for the groups are presented in Table 13. To determine if there were age related differences in composite pain ratings, a one-way ANOVA was conducted, with Tukey post hoc tests where appropriate. The groups significantly differed on the composite pain score, $\underline{F}(3, 156) = 6.64$, $\underline{p} < 0.05$, with the 2-month-old infants having higher composite pain rating scores than the 6-month ($\underline{p} < 0.05$) and 12-month ($\underline{p} < 0.05$) old infants. No other significant group differences in composite pain scores were observed.

Age Related Differences in the Importance of Pain Cues

Table 14 summarizes the means (and standard deviations) of the perceived importance of various cues used by parents in making their pain judgments. To determine if parents rated certain cues as differing in importance depending on the infant's age, a MANOVA was conducted with the importance of each cue as dependent variables. The omnibus F was not significant ($\underline{F}(36, 441) = 1.05$, $\underline{p} > 0.05$) indicating no group differences in the importance of the cues in making pain judgments.

Since no group differences were found, the groups were collapsed to allow for an analysis of which cues were most important in making parental judgments of pain. The collapsed means (and standard deviations) are reported in Table 15. A one-way ANOVA

Table 14

Means (and Standard Deviations) of the Reported Importance of Cues in Parental Judgments of Pain for Each Group

Cue	2-months	4-months	6-months	12-months
Infant's age	5.81 (3.27)	5.60 (2.68)	5.50 (3.00)	5.00 (3.27)
Infant's sounds	8.25 (2.23)	8.31 (1.73)	7.90 (2.45)	8.77 (1.67)
Infant's capacity to understand pain	6.51 (3.24)	6.60 (2.75)	6.75 (2.82)	6.29 (2.99)
Infant's capacity to remember pain	3.62 (3.18)	5.07 (2.58)	4.63 (3.01)	4.40 (3.09)
Infant's size	4.79 (3.19)	5.07 (2.58)	3.88 (3.04)	3.41 (3.09)
Infant was in a medical setting	1.88 (2.79)	2.95 (3.01)	3.70 (3.52)	3.00 (2.65)
Infant's facial expressions	8.05 (2.37)	8.35 (1.70)	7.60 (2.34)	7.95 (2.41)
Infant was receiving a needle	6.26 (3.33)	6.90 (2.63)	6.83 (2.93)	6.69 (2.91)
Infant's mood	5.29 (3.51)	6.18 (2.68)	5.90 (2.93)	5.49 (2.87)
Infant's body movements	6.67 (2.65)	6.85 (2.49)	6.98 (2.40)	7.10 (2.58)
Infant was healthy	5.52 (3.73)	6.03 (3.01)	6.25 (3.06)	4.92 (3.83)
Infant's capacity to focus on his/her surroundings	4.16 (3.04)	5.43 (2.85)	6.18 (3.05)	4.95 (3.36)

Note: Scores could range from 0 – 10.

Table 15

Means (and Standard Deviations) of the Importance of Cues in Parental Judgments of Pain Collapsed Across all Age Groups Ordered from Greatest to Least Importance

Infant's sounds	8.31 [a] (2.05)
Infant's facial expressions	7.99 [a] (2.22)
Infant's body movements	6.90 [b] (2.51)
Infant was receiving a needle	6.67 [b,c] (2.94)
Infant's capacity to understand pain	6.54 [b,c] (2.93)
Infant's mood	5.71 [c,d] (3.01)
Infant was healthy	5.68 [c,d] (3.44)
Infant's age	5.48 [d,e] (3.05)
Infant's capacity to focus on his/her surroundings	5.18 [d,e] (3.14)
Infant's capacity to remember pain	4.43 [e,f] (2.99)
Infant's size	4.11 [f] (3.09)
Infant was in a medical setting	2.88 [g] (3.06)

Note: Means with different superscripts differ at $p < 0.01$ or better.

found that the various cues differed in importance ($F(11, 1908) = 47.44$, $p < 0.05$). Post hoc Tukey analyses are summarized in Table 15. The three behavioural cues ranked as the most important cues; "infant's sounds" and "infant's facial expressions" were the highest rated cues, followed by "infant's body movements". Parents did not seem to consider "infant's age" as valuable in making pain judgments, rating it significantly less important than the three behavioural cues.

Predicting Parental Ratings of Pain from the Behavioral Responses of Infants

Regression analyses were used to examine how facial activity, body movement, crying and age of the infants predicted parental pain ratings. The predictor variables were the "needle" phase NFCS and IBCS scores, whether the infant cried or not and the age of the infant (in days). The criterion variable was the composite pain rating score. Initially, four separate regression analyses were conducted to determine if each predictor variable significantly predicted the criterion composite pain rating score, independent of other information. As can be seen in Table 16, facial activity, crying and infant age were all found to be significantly related to composite pain rating scores, while body movement was not. The order of importance of the variables in predicting composite pain ratings were crying, infant age and facial activity. Infants who were younger, cried and displayed greater facial activity were judged as experiencing the most pain.

A final regression analysis was conducted to examine each predictor's ability to account for unique variance in composite pain scores, above and beyond the other predictors. Together, facial activity, body movement, cry and infant age accounted for 14% of variance in the composite pain score, $F(4, 155) = 6.20$, $p < 0.05$. The analysis then took the approach of examining each predictor's ability to account for unique variance after all other predictors had been entered into the equation. As can be seen in Table 17, infant age accounted for the most unique variance (6.2%) in composite pain ratings followed by whether the infant cried (2.3%). Facial activity (1.4%) and body movement (0.1%) accounted for minimal amounts of unique variance in the composite pain scores.

Table 16

Facial Activity, Body Movement, Crying and Infant Age as Predictors of Composite Pain Ratings

	Beta	$F(1, 158)$	p-value	R^2
Facial Activity	0.23	9.07	$p < 0.05$	0.054
Body Movement	0.03	0.00	$p > 0.05$	0.000
Presence of Cry	0.25	10.50	$p < 0.05$	0.062
Age of the Infant	-0.24	9.34	$p < 0.05$	0.056

Table 17

Regression Analyses Examining Unique Variance Accounted for by Facial Activity, Body Movement, Crying and Infant Age as Predictors of Composite Pain Ratings

	Beta	$F(1, 155)$ Change	p-value	R^2 Change
Presence of Cry	0.18	4.13	$p < 0.05$	0.023
Age of the Infant	-0.25	11.09	$p < 0.05$	0.062
Facial Activity	0.14	2.52	$p > 0.05$	0.014
Body Movement	0.03	0.21	$p > 0.05$	0.001

Discussion

Infants in the first year of life are highly dependant on caregivers for all of their survival needs. In order to have these survival needs met, information concerning their nature must be available to caregivers if they are to determine the source of infant need. This can be a challenging task, as they must extract information specific to pain from generalized distress reactions, substantial variability in response and similarities in response to noxious and non-noxious aversive events. Additionally, infants undergo major developmental changes in sensory, motor, cognitive and emotional systems throughout the first year of life, which potentially influence their ability to, and the manner in which they express pain (further complicating the assessment process). However, little empirical research has explored how infant pain expression and parental assessments of pain change throughout the first year of life.

The present study provided a systematic and detailed examination of infant facial activity, body movement and cry in response to immunization injections in a cross-sectional sample of 160 infants 2-, 4-, 6- and 12-months-old. In addition, parental assessments of infant pain and the importance of cues used in making pain judgments were compared for the different ages of infants. Finally, the ability of various behavioural and contextual factors to predict parental ratings of pain was examined and served as a comparison to subjective parental ratings of the importance of the cues. The major findings to be discussed below were the following. Contrary to hypotheses, infants demonstrated relatively minor age related differences in behavioural pain expression. However, parents tended to attribute greater pain to younger infants while reporting similar importance of various cues used in making their judgements. In addition, the parental ratings of subjective importance of cues were discordant with objectively coded cues (age, cry, facial activity) that most strongly predicted ratings of infant pain.

Age Related Consistency of Pain Related Facial Activity

As expected, infants in the present study displayed increased overall facial activity in response to the immunization injection, relative to facial activity during the apparently innocuous events preceding the injection. The increase in overall facial activity was associated with an increase in a number of discrete facial actions including: furrowed eyebrows, eyes squeezed shut, deepened nasolabial furrow, open mouth with associated vertical and horizontal mouth stretch and a tense, cupped tongue. This profile of facial actions is consistent with the literature on pain in infants (Craig & Grunau, 1993; Craig et al., 2000; Grunau & Craig, 1987; Grunau et al., 1990; Izard et al., 1983; Johnston et al., 1993; Lilley et al., 1997). However, contrary to hypotheses, there was no evidence of developmental changes in either overall facial activity or the profile of discreet facial action units.

It was predicted that there would be age related differences in facial activity with older infants demonstrating reduced increases in facial activity in response to the immunization injection. This hypothesis was based primarily on the assumption that as infants develop within the first year of life, their capacity to modulate and cope with pain would be expected to increase (Craig & Grunau, 1993), resulting in the infant experiencing and expressing less pain. However, including the present study, there has been little empirical evidence to support the notion of age related differences in the facial pain response of full-term infants in the first year of life. Izard et al. (1983) found that the facial response to immunizations in infants became less prominent with age, but they relied on global facial pain responses and the only significant differences reported were between infants under 8-months-old and 19-month-old infants. The present study used a more fine-grained analysis for measuring infant facial pain.

Other studies using similar, fine-grained analysis (Craig et al., 1993; Johnston et al., 1993) found some age related differences in facial activity, but only between premature and full-term infants. When examining the facial pain response of 2- and 4-month-old infants, Johnston et al. (1993) found no significant differences. The study with the most similar methodology to the present study was Lilley et al. (1997), who reported that 4-month-old infants had lower overall facial action scores in response to an immunization than 2- and 6-month-old infants. However, this was only observed during the "recovery" phase, which was twenty seconds after the final immunization injection. When considering the coded segments (referred to as "baseline" and "injection") that most closely match the segments examined in the present study, Lilley et al. found no differences in overall facial activity in infants 2- to 12-months-old.

The explanation for a lack of age related differences in acute facial reactivity and Lilley et al.'s finding of age differences only during the "recovery" stage may be found in considering the timeframe of the immunization procedure. As hypothesized in the present study and speculated in Lilley et al., age related differences in facial pain response would likely result from an increasing ability (with age of the infant) to self-soothe, modulate and cope with pain. This may explain why infants in the Lilley et al. study demonstrated age related differences in facial activity during the "recovery" stage, which occurred 20 seconds after the final immunization injection. By that time in the procedure, older infants may be able to use developmentally acquired skills to self-soothe and cope with pain. However, the present study examined acute facial pain responses in the 10 seconds immediately after the first immunization (a recovery interval was not coded in this study because infants in different age groups received different numbers of shots: three shots for the 2-, 4-, & 6-month-olds and two shots for the 12-month-olds). The pain responses were likely associated with greater pain intensity and surprise (on the part of the infant) compared to what infants would have been experiencing 20 seconds after a second or third injection; any abilities of older infants to modulate pain may not be activated during that acute period, 10 seconds after the injection. This could explain why no differences facial pain responses were found among the four age groups.

Age Related Differences in Pain Related Body Movement

As with facial activity, all four infant age groups demonstrated an increase in overall body movement in response to the immunization injection. This was a predictable finding as overall increases in infant body movement in response to a painful stimulus have been previously reported (Craig et al., 1993; Craig et al., 2000; Franck & Miaskowski, 1997). It was hypothesized that as infants become older, their global reactions would become more sophisticated, demonstrating less overall body movement and more anticipatory responses and goal-directed movements. However, contrary to hypotheses, there was no evidence of developmental changes in overall body movement in response to the immunization.

To further examine potential age related changes, the individual body movements were examined to discover if there were changes in the profile of body movement, as opposed to a summative index of overall body movement. When the body movements were considered individually, there was evidence of developmental differences.

Specifically, 12-month-old infants displayed less movement in their hands and feet and legs in response to the immunization, compared to the younger age groups. At the same time, there was a trend towards 12-month-old infants displaying more head and torso movements than the other groups, although this finding did not reach statistical significance. These findings provide an explanation as to why no developmental differences were found in overall body movement; while the 12-month-old infants have less movement in their hands and feet and legs, they tended to have greater movement in their heads and torsos, thus cancelling out overall differences.

When considered from this perspective, the body movement findings are in line with previous findings. Many authors have referred to diffuse, undifferentiated body movements in younger infants responding to pain (McGrath & Craig, 1989; McGraw, 1945; Owens, 1984), contrasting that to more sophisticated, goal directed movements of older infants (Craig et al., 1984). However, none of the prior research has examined individual body movements using the same fine-grained analysis as the current study. The diffuse body movement reported in previous literature focussed on large movements of the extremities of the infant. In comparison, movements of the head and torso can be more subtle. Therefore, while at first glance, younger infants may appear to have more body movement in response to a painful stimulus, the present study suggests they do not. The developmental differences appear to be in the profile of movements; younger infants have greater movement in their extremities, while older infants have greater head and torso movements.

These results can also be reconciled with the idea of more goal-directed movements in older infants. The movement of the torso could represent the older infant's increased capacity for articulated movement, attempting to twist away and escape from a noxious stimulus. The movement of the head could be to protect it from potential damage by turning away from the source of the tissue damage. By contrast, the increased movement in the hands and feet and legs of the younger infants appears to have little goal directed-purpose other than reflexive withdrawal. Conceivably, it could also serve the purpose of shaking off a harmful insect or other predator, as well as attract parental attention. The average age that infants begin to crawl is around 7 months (Berk, 2002), thus making it unlikely that infants 6 months and younger move their legs in an attempt to escape a noxious stimulus. However, this is all speculative, as IBCS only codes for the presence or absence of movement; it does not describe what the movements are, leaving much unknown about the potential purposes of the movements.

Age Related Consistency in Pain Related Cry

As with body movement, the cries of the infants in response to the immunization injection demonstrated small age related changes. The vast majority of the infants (91%) responded to the immunization with a cry vocalization and there was no evidence that different aged infants cried more frequently than others. There were large individual differences and variability and no significant developmental differences observed in cry latency, duration or tenseness. The cry features that appeared to differ developmentally were maximum fundamental frequency and dysphonation percentage, with a trend towards older infants having higher maximum fundamental frequencies and greater dysphonation than younger infants. These trends were opposite to hypotheses; younger infants were expected to have cries characterized by higher maximum fundamental frequencies and greater dysphonation due to a lesser capacity to modulate and cope with pain compared to older infants.

The fundamental frequency and dysphonation of cry are indexes of the amount of stress the infant is experiencing; the greater the dysphonation and fundamental frequency, the greater the overload on the larynx and the more stressed the infant (Lester, 1984; McGrath, 1996). One possible explanation would be that fundamental frequency and dysphonation are indexes of stress not specific to pain. Therefore, it is possible that the 12-month-old infants were experiencing greater stress during the immunization than the 2-month-old infants. The question then becomes, why were the older infants experiencing greater stress? One explanation would be that 12-month-old infants have greater cognitive processing capacities, allowing for anticipation of future painful situations (McGrath & McAlpine, 1993). Therefore, they may have been anticipating subsequent injections, immediately after the first one and this could have led to anticipatory anxiety and distress. On the other hand, the 2-month-old infants would have had no prior experience to go by and therefore could not anticipate further injections. Therefore, one explanation could be that the 12-month-old infants had higher pitched cries with greater dysphonation because they were experiencing greater distress due to anticipation of further injections.

When considering all of the cry variables together, there appears to be little significant developmental differences in the infant cries. While age related differences were anticipated, the lack of such findings may be representative of the dearth of empirical examination of developmental changes in infant cry (Green et al., 1995, 2000). The only other study involving similar methodology was Johnston et al. (1993) who examined the pain cries of premature, full-term newborns, 2- and 4-month-old infants.

The only developmental difference in cry was for premature and full-term newborns compared to 2- and 4-month-old infants; the premature infant cries had the highest fundamental frequency followed by the full-term newborns. Johnston et al. (1993) reported no differences between the acoustic features of the cries of 2- and 4-month-old infants. There was little empirical basis on which to make hypotheses and therefore they were based on an assumption of greater self-soothing in older infants and an associated reduction in pain and distress. The cry data (as well as facial activity and body movement) from the present study clearly raises questions about this assumption, at least in terms of acute pain response.

Age Related Differences in Parent Ratings of Pain

In contrast to the behavioural data, there was evidence of significant age related differences in parental assessment of infant pain. Using a pain measure composed of both intensity and affective ratings of pain, parents attributed greater pain to 2-month-old infants than to 6- or 12-month-old infants. Again, this finding was contrary to expectations. It was hypothesized that as parents observed greater behavioural reactivity in their infants responding to the immunization, they would attribute greater pain to their infants. However, as previously discussed, only modest behavioural differences in body movement profile, fundamental frequency and dysphonation percentage were observed among the four age groups. Notably, the differences in fundamental frequency and dysphonation suggested that older infants were expressing greater pain than younger infants, which ran contrary to the parental judgements. It is important to emphasize that there was a dramatic difference in the behavioural responses of the infants after the immunization compared to before the immunization. Parents of infants of different ages likely used infant behavioural responses to identify the presence of pain, but utilized the behavioural information differently (in a manner not well understood) when making their assessments of pain severity. Therefore, encoded behavioural cues of the infant likely play an important role in the decoding process of the parents, but other factors are clearly involved.

Pillai Riddell (2003) used a similar methodology in a study examining parents judging pain in videotapes of infants (who were not their own) aged 2- to 18 months receiving immunization injections. Behavioural responses of the infants in the videos were controlled such that all infants demonstrated a vigorous pain response, but without differences in facial activity, cry or body movement across the age levels studied. Pillai Riddell found differences in the amount of pain attributed to different ages of infants. However, unlike the current study, older infants were attributed more pain than younger infants. The results are explained as judges attributing more pain to older infants because they are viewed as having greater abilities to cognitively process the pain experience (Pillai Riddell, 2003).

The differences in Pillai Riddell's findings and the present study can be accounted for by differences in the relationship between the infants and the parents in the two studies. Pillai Riddell had parents watch videotapes of immunizations of infants with whom they had no connection and were unrelated. In contrast, the present study examined parental assessments of pain when the infants subjected to an immunization procedure (during which they were present) were *their own* infants. Parents in the present study did not watch videotapes, but actively participated in the immunization, holding their infants during the procedure. As opposed to judging pain in infants to whom they had no connection, parents in this study were required to judge pain in their own children, with whom they presumably have a strong emotional bond. This is consistent with the prediction in the sociocommunications model that the relationship between who is making the judgement and the person in pain will affect the outcome of the judgement.

For the parents of the 2-month-old infants, the immunization procedure may have represented one of the first times they were present when a painful event was intentionally inflicted on their infants since birth. No research has documented the incidence of painful medical procedures in healthy infants during the first 2 months. However, it is likely that during the first 2 months of life, healthy infants experience relatively few painful procedures and are protected from potential sources of injury (they are relatively non-mobile and spend considerable amount of time sleeping). Therefore, the immunization may have been a considerably anxiety provoking experience for parents who may have had relatively little prior experience observing their infants in acute pain. This is a common response as parents often display heightened stress responses and anxiety during infant immunizations (Felt, Mollen, Diaz et al., 2000) and parents of younger infants tend to be more anxious during medical procedures than parents of older children (Choy, Collier, & Watson, 1999). Anecdotally, many of the parents of the 2-month-old infants expressed distress during and after the immunization. The resulting attribution of pain may have been influenced by a number of factors including parental anxiety and distress about inflicting pain on the infant and limited experience observing the infant in acute pain. Heightened levels of parental anxiety during pediatric medical procedures have been associated with higher attributions of pain to infants and children (Cassidy, Reid, McGrath et al., 2001; Choy et al., 1999). The parental assessment of pain may have included part of their distress during the procedure. The limited experience observing the infant in acute pain may have limited the frame of reference (the acute response to the immunization may have been greater than any previous pain response the parent had observed in the infant) they could use to judge pain in the infant. Both of these factors could contribute to higher attributions of pain in the 2-month-old infants.

In contrast, the parents of the 6- and 12-month-old infants would have had more experience with their infants and in particular, their infants in acute pain. The older the infant, the greater likelihood the parent has experience with the infant's response to painful events. For example, as the infants become more mobile, they are at greater risk for pain from falling and bumping into things. Mobile and active young children experience numerous painful incidents every day, on average, once every three or four hours (Fearon, McGrath, & Achat, 1996; Gilbert-MacLeod, Craig, Rocha et al., 2000). This gives the parent a much broader spectrum of acute painful events, of which he or she can use to gauge the infant's response to the immunization. In addition, by the time infants are receiving their 6- and 12-month vaccinations, the parents have had multiple prior experiences of their infants receiving an immunization injection. Having observed prior immunizations, the parent may become less distressed with each subsequent immunization procedure. These factors may explain why parents of older infants attribute less pain compared to the attributions of parents of younger infants.

Age Related Consistency in the Importance of Pain Cues

There was no evidence of developmental differences in the ratings of importance given to pain cues by the parents. Parents subjectively rated infant sounds, facial activity and body movement as the most important cues used in making their judgements of pain. Infant sounds and facial activity were rated as the most important cues followed by body movement. By comparison, contextual cues and factors related to the developmental status of the infant were considered significantly less important. The pattern of results is consistent with a number of previous studies. Behavioral cues such as facial activity, vocalizations and body movement have consistently been identified as some of the most important cues used by caregivers to assess pain in infants (Fuller & Conner, 1996; Fuller et al., 1996; Pigeon et al., 1989; Pillai Riddell, 2003; Shapiro, 1993; Smith et al., 2002).

It was hypothesized that the pain responses of younger infants would have been more disorganized and non-specific, resulting in parents placing greater importance on contextual versus behavioural cues. However, with no evidence of major developmental differences in the pain response of the infants, the lack of between-group differences in cue importance makes sense. Since the infants in different age groups appear to respond to pain with similar behavioural responses, it would seem reasonable for parents of different aged infants to attribute similar importance to cues. These findings suggest that infants throughout the first year of life use similar ways to communicate pain and distress to caregivers, who then use relatively consistent cues in making their judgements.

However, it must be emphasized that parents were self-reporting what they believed to be the importance of various cues. The previously discussed results (parents of younger infants attributed greater pain compared to parents of older infants) suggest that contextual factors (infant age, occurrence of a presumably painful event) are also very important in judgements, despite what parents self-reported. It is possible that parents downplayed the importance of contextual cues because, on the surface, behavioural cues should be the ones used in making judgements. The main assumption is that parents were able to identify and self-report the key determinants of their judgements, but it is unclear if this assumption is valid. Overvaluing and undervaluing particular information and unreliable information acquisition is pervasive in clinical judgements (Stewart & Luck, 1994) and it is unclear if parents in the current study could accurately report how important various cues were in making their pain judgements.

Objective Predictors of Parental Ratings of Infant Pain

To further explore the factors that influenced parental judgments of infant pain, the predictive strength of behavioural cues and infant age on parental judgements was examined. Modest amounts of variance in parental assessments of infant pain were accounted for by the pain behaviours of the infant. Of the behavioural cues, only the presence of crying and facial activity of the infant predicted parental ratings of infant pain; body movement did not. Infant age (a cue parents rated as significantly less important than the behavioural cues) also predicted parental ratings of infant pain. When considered together, cry, facial activity and infant age predicted a small proportion of the variance in parent ratings of pain. When considering the unique variance accounted for by the cues, infant age accounted for the most unique variance followed by cry. Facial activity and body movement accounted for essentially no unique variance in pain ratings, although the vigorous behavioural activity likely contributed to the judgements that pain was present.

The results are in stark contrast to parents' subjective reports of the importance of various cues and a number of previous studies. Prior studies have reported that facial activity accounts for the majority of unique variance in caregiver ratings of infant pain, followed by cry characteristics, body movement and gestational age, which contribute very little unique information above and beyond facial activity (Craig et al., 1988; Hadjistavropoulos et al., 1994, 1997). Again, the discordant findings may lie in methodological differences between the studies. The Craig et al. and Hadjistavropoulos et al. studies had observers view and rate videotaped reactions of infants experiencing painful medical procedures. The videotapes may have focussed the observer attention on the primary cues observable from the videos, which were facial activity, body movement and cry. Therefore, it is not surprising that judges in the studies would use those cues, since they were the primary sources of information provided to the judges. There are certainly differences between watching a videotape of an infant in pain versus being present and holding an infant during a painful procedure. Parents in the current study had other cues available to them (i.e. the reactions of the nurse or physician, the feeling of holding the infant during the procedure), which could have contributed to their ratings of pain. In addition, as has been previously discussed, the emotional bond between parents and their infants would likely have an influence on pain ratings, which would not be observed in unrelated judges assessing pain in unfamiliar children.

Additionally, the infant's age in this study was not just an index of the developmental status of the infant. The infant's age also represented the duration of the relationship and the amount of prior history between a parent and an infant. For example, informing an unrelated observer that an infant is 4-months-old (as has been done in prior studies, e.g. Pillai Riddell, 2003) gives that observer information only about the developmental status of the infant. However, for a parent of a 4-month-old, the age of the infant represents not only developmental status, but also the amount of time that the parent has spent with the infant. Essentially, the age of the infant represents the amount of experience the parent has had with the infant. When considered in this context, it is understandable that infant age would be one of the better predictors of parental ratings of pain because parents with greater experience with the infants have a greater set of past infant reactions, to which they can compare the infant response to the immunization. In addition, as previously discussed, the pain judgements for the 2-month-old infants may have been inflated, in part due to parental distress and fears for the infant during the immunization procedure. These factors can explain why infant age is negatively associated with parental attributions of pain.

It must be noted that the vast majority of variance in parental assessments of pain was unaccounted for. Over 85% of the variance in pain ratings was unexplained by the age of the infant and objectively coded behavioural cues. Clearly, there are significant, unaccounted sources of information that parents are using in making their judgements. As empirical findings are lacking in this area, one can only speculate at the factors that are influencing parental ratings of pain. Some factors have already been identified (emotional state of the parent during the procedure, past episodes of acute pain in the infant observed by the parent).

Lens Model

The preceding discussion highlights the complexity of the judgement task faced by parents and the many factors that contribute to the judgement process. Stewart and Lusk (1994) describe an expanded lens model for evaluating the numerous interrelated factors involved in judgements and forecasting that can be useful in understanding the parental judgement process in this study. According to the expanded lens model, the judgement of an observed event depends on the objective cues used, the subjective interpretation of the cues and the relationship between the subjective interpretation and the judgement. Therefore, variability can be introduced in a number of different ways: error in acquiring cue information; error in the subjective interpretation of cues; and error in information processing.

In terms of acquiring cue information, parents in the present study may have been heavily focussed on the immunization procedure and would not have paid as much attention to their infants' facial displays, cry or body movements. In addition, since the infants typically sat on the parents' laps during the immunization, parents may have had difficulty seeing their facial expressions, which could have influenced their ability to use information from facial activity in their judgements. Error in the subjective interpretation of cues was observed in that parents attributed high importance to behavioural cues of the infants, even though these behavioural cues accounted for only small amounts in the variance of actual pain judgements. This may be related to the ambiguous nature of some of the behavioural cues, particularly cry, which has not demonstrated specificity to pain, but is more of a general distress call (Barr, 1998). Finally, it is not known how parents process multiple sources of information in order to make attributions of pain to their infants. Multiple sources of information increase the complexity of the judgment task and impose a cognitive burden that may exceed human information-processing capacity (Stewart & Lusk, 1994). As reported earlier, according to parents, age of the infant was not deemed as important as behavioural factors, but there were substantial differences in the attributions of pain across age groups. Judgemental heuristics used by parents for making attributions of infant pain have not been well studied, although it is likely that cognitive biases, relationship to and experience with the infant, knowledge and sensitivity influence information processing (Craig et al., 1996).

Further research is necessary to elucidate the possible contribution of all of these factors in parental assessment of infant pain. Possible approaches to study and improve the reliability of information processing, include combining several independent judgements (having both parents provide judgements), requiring justification for judgements and decomposing the judgement task (Dawson, 1996; Stewart & Lusk, 1994).

Implications for Theory

The first year of life is characterized by massive changes in physical, behavioural, cognitive, emotional and social development. Between the ages of 2 and 12 months, infants display significant changes in all of these domains (Berk, 2002; Schickedanz et al, 2001; Seifert & Hoffnung, 2000). The underlying assumption of the current study was that in the context of these considerable developmental changes in physical, cognitive and emotional function, there could be associated differences in pain experience and expression in infants throughout the first year of life. This assumption appears to be incorrect. The results of the present study suggest an astonishing consistency in the pain expression of infants throughout the first year of life, even though they experience major developmental changes in all other aspects of life. When compared to these massive developmental changes, the findings of minor differences in the profile of body movement and trend toward changes in cry seem relatively modest.

The sociocommunications model of pain (Figure 1) can provide a framework for understanding the lack of major developmental differences in infant pain expression. In order for the infants to get help or relief from pain they are experiencing, they must express their pain in a way that is recognized by caregivers (Craig & Badali, 2002). After the caregivers have determined the infants are in pain, they can then take steps to alleviate the pain. In evolutionary terms, it is of adaptive benefit for the pain behaviours of the infant to be specific and interpretable by adult caregivers who can help (Williams, 2002). The primordial importance of communicating pain demands that pain expression be so solidly inbuilt, that even early signs of cognitive capability do not have an impact. This may explain why the same expression of pain is evident in healthy people throughout life, as well as populations with profound cognitive limitations (Hadjistavropoulos et al., 1998, 2000; LaChapelle et al., 1999; Nader et al., 2004).

In order to be specific and interpretable, pain expression should remain relatively consistent and constant throughout infancy. This would help the caregiver more readily identify and discriminate pain in the infant from other emotional, motivational, and cognitive states. If pain expression developed and changed throughout infancy, that would significantly complicate the decoding process for the caregiver; essentially the caregiver would be aiming at a "moving target" of infant pain expression. Therefore, from an evolutionary point of view, it would be beneficial for pain expression in infants to remain consistent throughout the first year of life, at least.

However, this pattern of consistent and relatively unchanging pain expression would only be advantageous if infants were able to effectively communicate their pain experience from very early on in development (i.e. at or prior to birth). The current study supports the position that there is a recognizable pattern of behaviour, as parents of infants of all ages rated the same behavioural cues (facial expression, cry, body movement) as being the most important cues in decoding their infants' pain expressions. The fact that the behavioural cues were not weighted more or less heavily by parents of younger or older infants suggests that the pain expression behaviours influence the decoding process in a stable, unchanging manner. What might this imply about the importance and functioning of the pain expression system in infants? Compared to the relatively underdeveloped physical, cognitive, emotional and perceptual systems of early infancy, pain experience and resulting expression appears to be highly developed very early in life. This is in stark contrast to the previously discussed myths regarding pain insensitivity in infants (Anand & Carr, 1989; Craig et al., 1984). It appears that young infants have a highly developed capacity to experience and express pain, equivalent to much older infants.

The findings of the current study limit speculation as to when pain expression may transform in infancy. The relatively reflexive or automatic features of non-verbal expression do not appear to be particularly transformed by maturation and experience on the part of the infant. However, there was some indication of differences in verbal and non-verbal expressions that are more subject to voluntary control (limb movement, cry features). These differences could represent the beginnings of transformation of infant pain expression, however it is unlikely that there are *major* age related differences in pain expression until the development of verbal language. As discussed above, it is adaptive for infants to have a consistent manner of pain expression until they develop a more specific way in which to communicate pain. Verbal language may be that more specific way of communicating pain to caregivers. A recent study found that pain language begins to develop at approximately 17 or 18 months with the use of words like "hurt", “ouch” and “ow”. Not until infants are much older, do they begin using words like “ache” (36 months), “sore” (45 months) and “pain” (72 months) (Stanford, Chambers, & Craig, 2005). Until infants have developed pain language, they must rely on non-verbal channels to communicate pain to caregivers.

The lack of a strong relationship between parental ratings of infant pain and behavioural displays of the infants is puzzling, but explanatory hypotheses can be generated using the sociocommunications model. While parents are able to subjectively report what cues are important in their judgements of infant pain, these apparently are not the only factors involved in their decision making process. The sociocommunications model and lens model contend that caregivers assessing pain will decode the encoded behaviours of the infant, but a number of factors influence this decoding process. Some of these influencing factors could be the caregiver-infant relationship (Craig et al., 1988), caregiver beliefs about (and past experience with) pain and caregiver sensitivity (Grunau, Whitfield & Petrie, 1994). It is clear that much is left unexplored regarding factors influencing parental assessment of infant pain. The process of attributing pain to infants by caregivers is an area requiring greater understanding and study.

Clinical Implications

The findings of this study have implications for caregiver assessment of acute pain in infants. The results lend support to the utility of behaviourally based multidimensional infant pain scales (in addition to unidimensional scales such as NFCS) like the NIPS (Lawrence et al., 1993), CRIES (Kretchel & Bildner, 1995), PIPP (Stevens et al., 1996) and FLACC (Merkel et al., 1997). Given that there appears to be little developmental change in behavioural pain expression through infancy, to the extent that the items assessed are sensitive and specific to pain, the behavioural indices identified by the scales are likely useful indicators of pain in infants of varying ages. In addition, the scales require caregivers to attend to the behavioural cues of the infant in making their assessments of pain.

An increased focus of caregiver attention to observable behavioural cues could result in more reliable and valid assessment of infant pain than is available through global pain judgments made by caregivers, although this requires further empirical study. Considerations irrelevant to the condition of the child, for example, the biases identified earlier, are less likely to intrude upon the judgement. In the current study, global judgements of infant pain were only marginally related to the behavioural responses of the infant. Rather, it appears that parental beliefs, attitudes and relationship to the infant have a stronger influence on pain assessment than the actual behavioural response of the infant. Therefore, global judgements of pain made by caregivers may inform more about the emotional status, attitudes or past experiences of caregivers than they do about the pain experienced by infants. While global judgements of pain are easily obtained, they may not be the most useful or valid measures of pain in infants. It is possible that training caregivers to focus greater attention to behavioural indices like facial activity, cry and body movement, or increasing use of behaviourally based multidimensional infant pain scales could result in more accurate and useful judgements of pain.

Limitations of the Study

The findings of this study should be tempered with careful consideration of some important limitations. First, while conducting the study in clinical settings enhanced its ecological validity, it led to an inability to control all potential determinants of the infant reactions. While all of the infants were receiving immunization injections, the injected vaccines differed; the 12-month-old infants received different vaccinations (MMR and meningococcal conjugate) than the other age groups (DTaP, IPV and Hib). In addition, a few of the older infants received the immunization injection in the upper arm as opposed to the thigh, as was the case for the other infants. Therefore, the pain stimuli may not have been identical across the groups. However, we have been unable to find any empirical studies demonstrating a differential pain response in infants receiving injections in the arm versus the leg, nor with different vaccines. In terms of immediate, acute response, the primary pain stimulus appears to be the penetration of the needle instead of the injection of vaccine. The differences in the pain stimuli should be noted however. Another potential source of variance in the immunization procedure was that a number of different physicians and nurses administered the injections. It is possible that individual nurses and physicians have different techniques for giving the injection and this could lead to greater or lesser pain experienced by the infant. However, given that the research was conducted in active and busy clinical settings, there was no way to control who was giving the immunizations. Given this range of potential variation in the infants behaviour, the consistency across age groups is all the more notable. Factors related to the specifics of the physical insult and the social context in which this took place appeared to be relatively unimportant.

Another limitation of the study involves factors that may have influenced the parental ratings of pain after the immunization procedure. Most of the infants received more than one immunization injection (although only the first was analyzed in this study). When the parents were asked to make their judgements of pain, they were asked to consider only the first immunization injection; however, it is possible that the reactions of the infants to subsequent injections also influenced parental judgments of pain. There was no way of avoiding this confound, as the subsequent injections occurred within a short time after the first immunization, leaving no time for the parent to give ratings after the first injection. Therefore, the parental ratings of infant pain may have been influenced by infant behavioural responses that were not coded.

Finally, it is important to emphasize that the current study only considered the immediate, acute pain reactions to the immunization procedure. Therefore, while there appear to be relatively small age differences in the immediate, acute pain reactions of the infants, this may not necessarily generalize to longer term (for example, 2 to 3 minutes after immunization) responses of the infants. It is entirely possible that infants show larger age related differences in terms of how quickly they recover from painful events; this could not be examined in the present study because of the differing number of injections experienced by the different age groups of infants.

Suggestions for Future Research

The results of this study contribute significantly to the understanding of the development of infant pain responses throughout the first year of life. Clearly, there appear to be few age related differences in infant pain expression throughout the first year. An interesting area of future research would be to explore when significant developmental differences in pain expression begin to occur. Earlier in the discussion, it was hypothesized that changes in pain expression may take place with the development of verbal language. While there has been some recent research on the development of pain language, further research in this area could clarify the role of pain language in developmental changes in pain expression.

Another area for future research could be to examine the generalizability of video judgement studies to real-world pain judgements. This study found that there were striking differences between parents rating pain in their own children and previous studies involving judges rating pain in videotapes of infants. It is not clear what could be the source of these discrepant findings. One possibility is that the differences are due to relational differences between the judge and the infant in pain (parent judging pain in own infant versus stranger judging pain in unrelated infant). Another possible explanation for the discrepancy between studies could be the medium with which the infant is presented to the judge (real life observation versus watching a video). The discrepancies between findings of different studies could be a result of one or both of these factors. Further research is required to examine the generalizability of video judgement studies to real world situations.

A critical area for further research is the factors that influence parental judgements of infant pain. The findings of the current study suggest discordance between the self-reported importance of cues by parents and objectively coded behavioural responses of the infants; parents reported that behavioural cues were the most important in making their judgements, but their judgements were only minimally related to behavioural responses of the infants. Further research is necessary to examine the decision-making processes parents engage in when presented with their infants' responses to painful events. Related to this, research is required to examine what role parental anxiety and distress (during the immunization procedure) may play in influencing pain judgments and how this may change with subsequent immunizations.

Conclusions

Infants undergo major physical, behavioural, sensory, emotional and social changes throughout their first year of life. In the context of these major developmental changes, it has been hypothesized that infant pain expression also undergoes significant changes. However, empirical knowledge in this area has been lacking and the association between infant behavioural expression and parental judgments of pain has been relatively unexplored. The current study used the framework of the sociocommunications model of pain to examine how infant pain expression and parental judgments of pain differ throughout the first year. The results of this research suggest that there are few differences in infant facial display, body movement and cry in response to pain between 2 and 12 months. In addition, parents self-report relying on similar cues when making pain judgments in infants throughout the first year of life. However, parental judgments of pain did demonstrate developmental differences and they appeared to be more influenced by other factors, unrelated to the behavioural display of the infants. These findings suggest that caregiver attributions of pain in infants may have less to do with the objective behavioural responses of the infants and more to do with caregiver factors, including cognitive biases, sensitivity, knowledge and emotional availability to the infant.

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Parental Consent: I understand that my decision to allow my baby to participate in this study is entirely voluntary and that I may refuse to participate or I may withdraw my baby from the study at any time without any consequences to my baby's medical care. I also understand that my signature on the consent form does not waive any of my legal rights.

I have received a copy of this consent form for my own records.

I consent to my baby participating in this study.

Parent Signature Date

Parent Name (Please Print)

Witness Date

APPENDIX B: Demographics and health status of the infant.

INFANT QUESTIONNAIRE

Subject Number: ________ **Today's Date:__________**

Have you participated in this study before? O Yes O No (check one)

What is your baby's first name? ______________________

What is your baby's birthdate? (Year/Month/Day) ______________

Is your baby male or female? O Male O Female (check one)

Was your baby premature? O Yes O No (check one)

If "Yes", how many weeks before your due date was he/she born? ___

What was your baby's weight at birth (lbs)? ________________

Is this baby your first-born child? O Yes O No (check one)

If "No", how many older children do you have? ____________

Is your baby generally healthy? O Yes O No (check one)

If "No", what illness or condition does he/she have? __________

____

What is *your* age? ______________________________

What is your relation to your baby? O Mother O Father Other______

How many hours has it been since your baby was fed? ____________

How many hours has it been since your baby woke up? ____________

Did you give your baby Tylenol or another medication before the shot? ____

If "Yes", what? O Tylenol O Other ____________

APPENDIX C: Pain rating form.

Participant # ____________

1. **Place a mark on the line to show how much pain you estimate your infant experienced during the immunization. There are no right or wrong answers.**

No Pain ———————————————————————— **Worst Pain Possible**

2. **Please circle the highest level of pain Intensity *and* the highest level of pain unpleasantness that you estimate your infant experienced during the immunization. There are no right or wrong answers.**

Intensity	**Unpleasantness**
A. Extremely intense	**A. Very intolerable**
B. Very intense	**B. Intolerable**
C. Intense	**C. Very distressing**
D. Strong	**D. Slightly intolerable**
E. Slightly intense	**E. Very annoying**
F. Barely strong	**F. Distressing**
G. Moderate	**G. Very unpleasant**
H. Mild	**H. Slightly distressing**
I. Very Mild	**I. Annoying**
J. Weak	**J. Unpleasant**
K. Very Weak	**K. Slightly annoying**
L. Faint	**L. Slightly unpleasant**
M. No sensation of pain	**M. No discomfort**

APPENDIX D: Importance of cues questionnaire.

Participant # ____________

Now that you have given your estimates of pain in your infant, we are interested in your reasons for giving the pain estimates you did. Please rate the level of importance to your judgments each of the following reasons had. If there were other reasons you used to make your judgments, please list them below. The scale ranges from 0 (not important) to 10 (extremely important).

0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Not Important					Moderately Important					Extremely Important

<u>List of Reasons</u> **<u>Rating of Importance (0-10)</u>**

1. **Your infant's age** __________
2. **Your infant's sounds** __________
3. **Your infant's capacity to understand pain** __________
4. **Your infant's capacity to remember pain** __________
5. **Your infant's size** __________
6. **Your infant was in a medical setting** __________
7. **Your infant's facial expressions** __________
8. **Your infant was receiving a needle** __________
9. **Your infant's mood** __________
10. **Your infant's body movements** __________
11. **Your infant was healthy** __________
12. **Your infant's capacity to focus on his/her surroundings** __________
13. **Other:** ______________________________ __________
14. **Other:** ______________________________ __________

APPENDIX E: Frequency of observed facial actions.

Action Unit	Percent of Segments in Which Action was Observed
Open lips	85
Nasolabial Furrow	62
Brow Bulge	56
Horizontal Mouth Stretch	55
Eye Squeeze	49
Taut Tongue	35
Vertical Mouth Stretch	33
Tongue Protrusion	4
Lip Purse	3
Chin Quiver	0