THE FACIAL EXPRESSION OF PAIN IN INFANTS: DEVELOPMENTAL CHANGES AND INDIVIDUAL DIFFERENCES

by

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ABSTRACT

The purpose of the study was to examine the role of the negative emotionality dimension of temperament as a factor underlying individual differences in the facial expression of pain in infants. It was also of interest to identify developmental changes in the facial expression of pain during the first two years of life, both in the overall degree of pain expressed and in individual facial actions.

Subjects were infants undergoing routine immunization injections, which are administered at 2, 4, 6, 12, and 18 months of age. Consequently, the five age groups were compared. Temperament was assessed via a parent report questionnaire.

A hand-held video camera was used to record the reactions of infants undergoing inoculation. The infants' facial reactions, as captured on videotape, were scored by trained coders using two systems: (1) the Neonatal Facial Coding System (NFCS), a brief measure limited to actions related to pain, and (2) Baby FACS, a comprehensive system with categories for all possible facial actions. The coders scored three 10-second segments for each infant in order to capture a baseline, the infant's immediate reaction, and a recovery period.

The results of the study did not confirm a relationship between temperament and a pain summary score derived by principal components analysis. This finding was unexpected. The need for further investigation of the stability of individual differences in the pain response and the impact of situational factors was discussed.

The investigation of developmental changes revealed some differences in the degree of pain expressed by infants in different age groups. During the baseline and immediate reaction to injection, 2-month old infants displayed more distress than 4-month old infants and 6-month old infants, but not more than 12- or 18-month old infants. During the recovery period, 6-month old infants and 18-month old infants displayed more distress than 4-month old infants. No other differences were significant. While these results require replication, they are suggestive of a drop in the degree of pain expressed around the age of 4 months. Possible reasons for such a pattern were discussed, with attention paid to the development of inhibitory mechanisms and the impact of other negative emotions such as anger and anxiety. Age-related changes in the occurrence of individual actions were also identified. The results of the present study suggest that clinicians assessing pain in infants be aware of developmental changes such that they compare their charges to infants of the same age.

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INTRODUCTION

The last decade has seen substantial changes in the concepts of pain in infancy. Once considered nonexistent or negligible (e.g., Sroufe, 1979), pain in the neonate is gradually becoming recognized as a widespread phenomenon and a potentially dangerous stressor (McLaughlin, Hull, Edwards, Cramer & Dewey, 1993). These alterations in attitude reflect a growing body of research concerned with the measurement and alleviation of pain in the young child. This research has demonstrated that infants respond to invasive stimuli with physiological, behavioural, and metabolic reactions paralleling those of adults experiencing acute pain (e.g., Anand & McGrath, 1993). Furthermore, the use of better anesthetics during surgery has been shown to have a dramatic effect on morbidity and mortality, especially in the preterm, whose metabolic resources are limited (Anand & Hickey, 1992). However, a great deal remains to be understood.

There is a pressing need for more research to contribute to both basic and applied science. In clinical settings, new methods of controlling pain in infants are in great demand. However, effective pain prevention and pain control will require the development of efficient, accurate measures of pain. Both assessment and treatment will benefit from more basic knowledge about factors underlying the experience and expression of pain.

A number of physiological and behavioural indices are available for the assessment of infant pain (Craig & Grunau, 1993; Franck, 1986; Johnston & O'Shaughnessy, 1988; McGrath, 1990; Porter, Porges & Marshall, 1988). For example, researchers have monitored heart rate, respiration rate, and oxygen saturation (Stevens & Johnston, 1991) and examined temporal and spectrographic characteristics of cry (Johnston & O'Shaughnessy, 1988). However, concerns about the specificity of physiological measures (McGrath, 1990) and ambiguous results in the cry literature (e.g., Grunau, Johnston & Craig, 1990; Johnston & O'Shaughnessy, 1988) have led to the assertion that the evidence derived from facial expression is ''most convincing to date'' (McIntosh, Van Veen & Brameyer, 1993).

Infants' facial expressions convey considerable information, and a number of coding systems have been developed. Objective, anatomically-based scales, such as Baby FACS (Oster & Rosenstein, 1993) and the Neonatal Facial Coding System (NFCS; Grunau & Craig, 1987) seem especially useful. Baby FACS is a comprehensive measure, with little published material on its use in pain assessment per se. NFCS was developed with pain assessment in mind. However, with the exception of one investigation (Johnston, Stevens, Craig & Grunau, 1993), which examined the reactions of neonates and 2- and 4-month old infants, all studies using NFCS to examine pain have looked at neonatal pain. Descriptions of the facial display in older infants, as measured by an objective instrument, are not available.

The existing studies suggest that there are substantial individual differences in infants' behavioural responses to painful stimuli (e.g., Grunau et al., 1990). Relatively little is known about the stability of such differences, or their correlates. One construct hypothesized to be important (e.g., Hamilton & Zeltzer, 1994) is temperament. Temperament refers to relatively consistent traits that appear early in life and modulate expressions of activity, reactivity, emotionality and sociability (Goldsmith et al., 1987). The dimensions comprising temperament and the measures used to assess these dimensions are the subject of energetic debate among various theorists. Several researchers have suggested that temperament is related to individual differences in psychobiological responses to stress (Boyce, Barr & Zeltzer, 1992). It is therefore plausible that the expression of pain would be related to temperament, particularly that aspect of temperament modulating the frequency and intensity of negative emotionality. This relationship may shed light on the etiology of individual differences in pain perception.

Age, as an index of biological maturation, is likely to be associated with the expression of pain and the experience of pain. The first 2 years of life witness dramatic changes in almost all areas of functioning. Pain expression is likely to change due to maturation, the development of different communication skills, and the greater ability to remember painful experiences. Studying the developmental course of pain expression may help to understand the pain experience as individuals get older. In addition, accounting for developmental level is one of the primary concerns of any kind of assessment carried out with infants and children. The study of developmental changes in the expression of pain provides information relevant to accurate assessment. Surprisingly, there have been relatively few studies of developmental changes in pain expression during infancy (e.g., Craig, McMahon, Morison, &

Zaskow, 1984; Izard, Hembree, & Huebner, 1987), and none used objective coding systems for capturing changes in facial activity, despite the importance of the face for communicating infant distress.

The present study investigated developmental changes in the facial expression of pain following routine immunization at ages 2, 4, 6, 12, and 18 months, using a cross-sectional design. In addition, the study examined the relationship between facial activity in response to the injection, and temperament as measured by a parent report questionnaire.

LITERATURE REVIEW

The Capacity of the Infant to Experience Pain

Early researchers concluded that newborn infants did not feel pain because their nervous system was not sufficiently developed to transmit this type of information (e.g., McGraw, 1943). As well, it was reasoned that a relative inability to perceive pain would be adaptive during the birth process (Bondy, 1980). Such notions probably persisted because of the methodological difficulties inherent in studying a subjective experience in subjects incapable of verbal communication. Also, doctors feared that the use of analgesics might be damaging to the neonate's delicate physiological systems and cause complications (Bauchner, May & Coates, 1992; Rogers, 1992). Since they were reluctant to give drugs, it was more acceptable to believe that newborns could not feel pain.

These beliefs have resulted in the use of little or no analgesics during pediatric procedures. Studies have shown a reluctance to use analgesic agents for both major and minor surgery among paediatric anesthetists (Purcell-Jones, Dormon, & Sumner, 1988) and directors of neonatal intensive care units (NICUs) in the United States and Canada (Bauchner et al., 1992). However, attitudes may be changing. McLaughlin et al. (1993) surveyed doctors who were board certified in neonatal-perinatal medicine. Almost all of the physicians affirmed the neonate's ability to perceive pain, and more than 75% reported that in their practice, anesthesia was always used intraoperatively for major and minor surgical procedures, regardless of the patient's age. Post-operative analgesia was somewhat less common

(McLaughlin et al., 1993). The majority of physicians (87%) reported that attitudes about pain and pain management in newborns have changed recently (McLaughlin et al., 1993). This shift reflects evidence that newborn infants do feel pain and that anesthetic techniques can be used safely. Improvements in the assessment of pain will facilitate the adoption of these techniques and improve their efficacy.

The changing attitudes among physicians reflect several developments in research. Anand and Hickey (1987) carefully reviewed the evidence and concluded that the nervous system of the neonate is sufficiently developed to permit the perception and localization of pain. Anatomical and functional requirements such as nociceptive nerve endings, the laminar arrangement of the dorsal horn, synaptic interconnections, specific neurotransmitter vesicles, the tachykinin system and the endogenous opiate system are all present. Although myelination may not be complete in nociceptive nerve tracts, this will slow down transmission, not prevent it. The decrement in speed is offset by the fact that impulses travel shorter distances in the infant.

While it is possible to argue that some premature infants may not have reached a sufficient level of development to experience pain, most research conducted with preterm subjects is consistent with the notion that pain is part of their experience. For example, another research team has used the cutaneous flexor reflex, in which a limb is withdrawn from a tactile stimulus, as a measure of pain perception in preterm infants (Fitzgerald, Millard & McIntosh, 1989; Fitzgerald, Shaw & MacIntosh, 1988). It was found that the threshold of this reflex in preterm neonates is very low and gradually increases with post-conceptional age, suggesting that preterms are actually hypersensitive to pain, relative to fullterm infants and adults (Fitzgerald et al., 1988). As well, it was found that repeated stimulation produced sensitization rather than the habituation seen in adults. Further studies (Fitzgerald et al., 1989) demonstrated that the preterm infant's flexion reflex was exaggerated following tissue damage from heel stick, paralleling the tenderness following injury experienced by adults.

Painful stimuli have long-term effects. Anand and Hickey (1987) reviewed the metabolic stress response in infants undergoing surgery. Over 24 hours, it was possible to observe increases in various stress hormones and a decrease in insulin. As a result, fat and carbohydrate stores were broken down, resulting in hyperglycemia, the breakdown of proteins, and other metabolic changes.

In the case of infants who are ill or premature, the metabolic balance is already precarious. Consequently, the stress response described above can be dangerous. Pain demands too many resources; the stress of pain depletes body stores, which is detrimental to recovery and growth. Anand, Sippell and Aynsley-Green (1987) studied the addition of fentanyl, an opioid, to the minimal anesthesia routinely administered to infants undergoing a surgical procedure to close a heart valve. Fentanyl was found to reduce the major hormonal responses to surgery. Anand and Hickey (1992) compared deep anesthesia with sufentanil to light anesthesia with halothane and morphine in infants subjected to surgery. It was found that deep anesthesia reduced the stress response, and also had a substantial impact on morbidity and mortality. Infants given sufentanil had a significantly lower incidence of infection and other complications. There were no post-operative deaths among the 30 neonates given sufentanil, while 4 of the 15 infants given halothane plus morphine died. The use of a drug with a stronger anesthetic effect produced a marked improvement in the outcome of surgery.

These data make a powerful case for the use of deep anesthesia in neonates during major surgery to alleviate the damaging effects of pain. Doctors have been urged to "extend to neonates the principle that complete intraoperative anesthesia improves the outcome of surgery, a concept that is widely accepted in the care of adult patients" (Rogers, 1992, p. 56).

Infants in the NICU are repeatedly subjected to procedures that are less invasive than major surgery, but still painful. Indices of pain observed during such procedures as heel stick for blood sampling purposes or injection of vitamins or vaccines raise the possibility that even these stressors may be detrimental.

Growth is particularly important in premature infants. Infants who are otherwise stable are often kept in the NICU until they gain weight. Interventions which increase the amount of energy available may facilitate growth (Deiriggi, 1990). Since pain uses up metabolic resources, the reduction of even mild pain may reduce energy expenditure and increase growth.

In addition to the detrimental physical sequelae of pain, recent research suggests that long-term effects on behaviour may also exist. Taddio, Goldbach, Ipp, Stevens, and Koren (1995) compared male infants who had and had not undergone circumcision, and found that circumcised males reacted to DPT injections with greater vigour. Similarly, Grunau and her colleagues (Grunau, Whitfield & Petrie, 1994; Grunau, Whitfield, Petrie & Fryer, 1994) studied toddlers who had been extremely low birthweight (ELBW) infants, and thus typically exposed to a number of painful medical procedures. The results suggest that the ELBW group differed from normal children on measures of pain sensitivity and somatization. However, the direction and time course of this difference are not clear, and the question requires further study.

Alleviation of the intense pain of major and minor surgery, and the repeated pain of procedures such as heel lance is becoming a priority in neonatal wards. However, efforts at pain reduction will not be successful without an accurate means of measuring the pain experienced by newborns and older infants.

Assessment is difficult, given that we are forced to infer a subjective state through nonverbal responses. However, infants display a number of quantifiable changes following painful stimulation.

Physiological and Behavioural Measures of Infant Pain

Craig, Lilley, and Gilbert (1995) have presented a model of children's pain behaviour which emphasizes its function as communication, alerting caregivers to an infant's distress. Figure 1 presents the model, which delineates the role of the child (experiencing and expressing pain) and the role of the adult (interpreting behaviour and responding appropriately). The model is presented here in order to draw attention to the fact that the experience of pain and its expression are distinct, though related, phenomena. However, the researcher or caregiver has direct access to expression only. It is difficult, if not impossible, to know how an infant experiences the world. It is important to remain aware that any extrapolation from an infant's expression to his or her experience is an inference.

It may be argued that the anatomical substrates and metabolic responses described above indicate nociceptive activity, that is, activity in body systems sensitive to invasive events, rather than subjective distress. However, infants do respond to invasive stimuli with the physiological and behavioural responses that accompany subjective pain in adults.

Johnston and Strada (1986) described the neonate's immediate responses to vaccination. The initial response consisted of a drop in heart rate, followed by a long, high-pitched cry, then by a period of apnea, rigidity of the torso and limbs, and a facial expression of pain. This was followed by a sharp increase in heart rate, lower-pitched but dysphonated cries (in which more effort was exerted and the harmonies of the cry pattern were

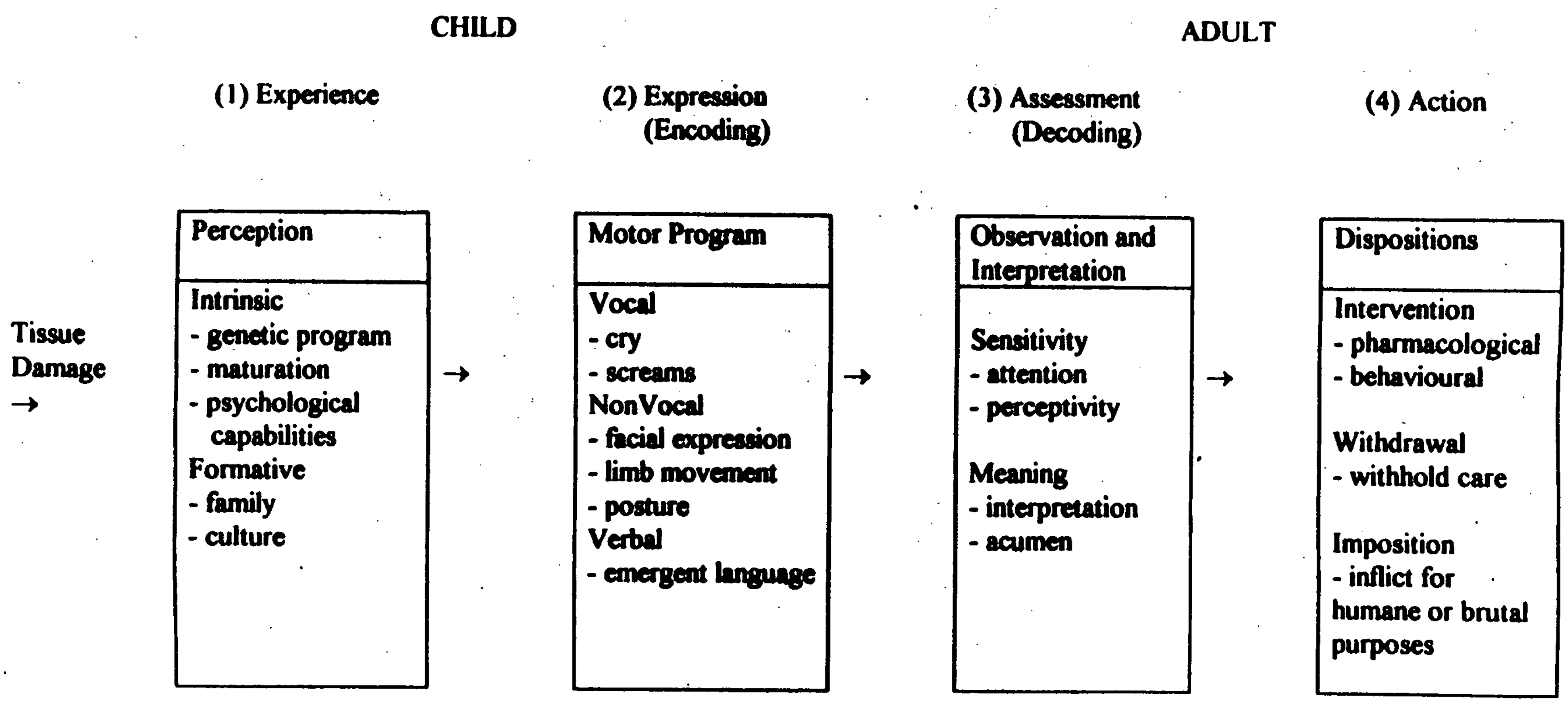


Figure 1. A Communication Model for Understanding Children's Pain
From "Social Barriers to Optimal Pain Management in Infants and Children" by K.D. Craig, C.M. Lilley, and C.A. Gilbert, 1995. Manuscript submitted for publication.

obscured by overloading at the larynx), and less body rigidity. The facial expression of pain persisted. After 30 seconds, heart rate remained elevated, cries were lower in pitch, mostly phonated, and more rhythmic with a rising and falling pattern of intonation. Body posture returned to normal and facial expression returned to the at rest configuration.

A number of physiological indices have been used to assess pain. Heart rate is a common measure, since it increases due to activation of the sympathetic nervous system (Craig & Grunau, 1993). Respiration rate and transcutaneous oxygen levels decrease (Craig, Whitfield, Grunau, Linton & Hadjistavropoulos, 1993). Oxygen saturation typically decreases in response to painful events and intracranial pressure shows substantial fluctuation (Johnston & Stevens, 1991; Stevens & Johnston, 1991). Cardiac vagal tone, an indication of parasympathetic action, decreases as the body devotes more resources to the stress response (Porter et al., 1988). Variability in physiological indices may carry as much information as changes in the mean value (McIntosh et al., 1993). The use of physiologic measures is somewhat problematic as such responses are likely to reflect stress in a general sense rather than pain (McGrath, 1990). Accordingly, physiological measures are most useful when combined with behavioural signs of distress.

The dramatic results of preventing pain with analgesics suggest that newborns suffer from a limited ability to communicate their pain to caregivers rather than a limited ability to perceive pain (Craig & Grunau, 1993). However, infants do have several means of communicating their experience.

One of the most salient to caregivers is cry, which has obvious adaptive value in summoning aid for the child. For this reason, cry has been referred to as a "biological siren" (Zeskind & Marshall, 1988). Cry contributed to adult judgments of sensory intensity and affective discomfort in neonates undergoing heel lance (Craig, Grunau & Aquan-Assee, 1988). Various parameters of crying change in response to pain. When the painful stimulus of injection was contrasted with non-painful stimuli, in this case head restraint and exposure to a jack-in-the-box, spectral analysis showed that pain cries were more irregular, higher pitched, and contained more energy in the higher spectra (Johnston & O'Shaughnessy, 1988). However, these results were not replicated in a study that used different stimuli as the non-invasive controls: Grunau et al. (1990) compared intramuscular injection with two tactile stimuli, the application of dye to the umbilicus and the application of an alcohol swab to the thigh, and found that the pain cry differed only in having shorter latency and longer duration of the first cry cycle. Recently, a single parameter, the H-value, has been proposed as an indicator of overall level of distress (Xie, Ward, & Laszlo, 1990). This index is derived from the "cry phonemes" of trailing, double harmonic break, dysphonation, hyperphonation, and inhalation, as well as the total duration of cry. However, the H-value was developed to reflect parents' subjective ratings of distress and may not be specific to pain.

Body movements also provide information. The Infant Body Coding System (IBCS; Craig et al., 1993) provided a framework for scoring motor activity relevant to pain. Movement was scored as present or active for the hands, feet, arms, legs, head, and torso of 56 preterm and full-term newborns undergoing heel lancing. Activity increased during a preparatory swab procedure, suggesting that the body movements studied do not discriminate pain, although they became still more vigourous during the lance.

Increasingly, researchers are using scales based on facial expression to assess pain. This modality has considerable importance as a behavioural measure, because research has consistently identified a number of facial actions associated with physical distress, while there have been contradictory findings in regards to the features of cry. Several systems allow the quantification of infants' facial activity during painful stimulation. Izard, Hembree, Dougherty & Spizziri (1983) observed 36 infants between the ages of 2 and 19 months during an immunization procedure. Video records were used to score facial expression using the Maximally Discriminative Facial Movement Coding System (MAX; Izard, 1979). MAX is based upon judgments that infant facial expressions conform to prejudged templates of specific emotions and physical distress, with the brow, eye, and mouth regions of the face examined separately. The MAX coded expressions were later examined using a system called Affex, in which templates are applied to the entire face. The experimenters identified a reliable 'physical distress' expression in response to the injection.

Other systems available for coding the facial expression of pain were derived from the Facial Action Coding System (FACS) developed by Ekman and Friesen for use with adults (1978). FACS may be used to score either still photos or videotapes using stop action and slow motion viewing. The system is anatomically based and comprehensive, and involves scoring the presence or absence of individual action units rather than global expressions.

Baby FACS (Oster & Rosenstein, 1993) was developed directly from FACS. Like FACS, it is an exhaustive set of anatomically based action units which are coded without reference to configurations thought to specify certain emotions. Because Baby FACS is comprehensive and capable of making very subtle distinctions, it is extremely useful as a research tool. However, these virtues make it unwieldy and inappropriate for clinical applications. Baby FACS was used to examine the pain responses of 56 premature and fullterm infants undergoing heel lance for blood sampling purposes (Craig, Hadjistavropoulos, Grunau & Whitfield, 1994). The following actions were significantly more common during heel lance than during a preliminary swabbing: AU4-Brow Lower, AU6-Cheek Raise, AU12-Lip Corner Pull, and AU26-Jaw Drop.

The Neonatal Facial Coding System (NFCS; Grunau & Craig, 1987) was adapted from applications of FACS to the study of pain in adults, in order to index pain in infants. NFCS is not anatomically comprehensive, but is limited to facial actions relevant to the expression of pain. Ten actions are scored: brow bulge, eye squeeze, deepened naso-labial furrow, open lips, vertical stretch mouth, horizontal stretch mouth, lip purse, taut tongue, chin quiver, and tongue protrusion. Grunau et al. (1990) videotaped neonates while an intramuscular injection was administered in the thigh, alcohol was rubbed on the opposite thigh, and dye was applied to the umbilical stub. Trained coders blind to the type of stimulus used NFCS to score the tape. It was found that NFCS allowed discrimination of the injection from the other two non-invasive tactile events. The painful stimulus provoked significantly greater total facial activity and a shorter latency to facial movement. The facial actions most consistently associated with pain were brow bulge, eye squeeze, deepened nasolabial furrow, and open mouth. NFCS has also been used successfully with premature infants. Facial activity was found to be significantly greater during heel lance than during baseline, swab, or recovery intervals (Craig et al., 1993). However, the premature infants in this study displayed less facial activity in comparison with fullterm infants. Facial activity was found to be more specific to the heel lance than were measures of bodily activity (the IBCS) and physiological responses.

In an earlier study (Grunau & Craig, 1987), infants undergoing heel lancing for blood sampling purposes were observed in order to determine the effect of sleep/wake states and sex. Awake/alert infants were found to display more facial activity in response to the lance than infants in quiet sleep. Male infants were faster to respond than female infants.

Nurses have reported that they incorporate information about facial activity into judgments of infant pain (Pigeon, McGrath, Lawrence & MacMurray, 1989). When adults were asked to view videotapes of newborns undergoing heel lance and judge the intensity of their pain experience, the judges' decisions were influenced by facial expression (Craig et al., 1988; Hadjistavropoulos, Craig, Grunau & Johnston, 1994). Both cry and facial activity determined the ratings they made, but scores derived from NFCS were more influential than indices of cry.

The present study used facial expression as an index of pain, since a behavioural measure with a record of consistent findings was desired. Two coding systems were used: the Neonatal Facial Coding System (NFCS; Grunau & Craig, 1990) and Baby FACS (Oster & Rosenstein, 1982, 1993). Both systems were included because each has different strengths. NFCS is simpler and more appropriate for clinical use but Baby FACS is more detailed and better able to capture subtle distinctions.

The Construct of Temperament

Babies vary widely in behavioural characteristics, and these qualities are likely to reflect and influence an infant's subjective experience and have an impact on the environment, especially the social environment. For example, Korner (1971) noted that differences in crying, soothability and self-comforting are likely to affect the infant's experience of pleasure and pain and the memory traces these may leave. They are also likely to affect caregivers' responses to the child.

Different authors offer competing definitions of temperament. McCall (in Goldsmith et al., 1987) attempted to integrate varying views by defining temperament as relatively consistent, basic dispositions inherent in the person that underlie and modulate the expression of activity, reactivity, emotionality and sociability. Most researchers feel that elements of temperament are present in infancy, and those elements are likely to be strongly influenced by biological factors. As children mature, the expression of temperament is increasingly dependent on experience and context (Goldsmith et al., 1987).

The theoretical emphasis on biology is supported by a growing body of research on individual differences in psychobiological responses to stress. It is hoped that the temperament construct will elucidate the relationship between stable individual differences at the level of the central nervous system and stable individual differences at the level of behaviour. This is particularly true of a component of temperament given various names in different formulations but centering around the experience and expression of negative emotions.

Interest in infant temperament originated with the New York Longitudinal Study (NYLS), carried out by Thomas, Chess, Birch, Hertzig and Korn in 1963. These researchers conceived of temperament as behavioural style, that is, the how of behaviour instead of the why or the what (Goldsmith et al., 1987). The NYLS consisted of parent interviews which were then subjected to an "inductive content analysis" in order to derive nine categories of temperament: Activity Level, Approach/Withdrawal, Regularity, Adaptability, Threshold, Intensity, Mood, Distractability, and Attention Span/Persistence (Thomas & Chess, 1977). The research interview was later simplified to produce the Infant Temperament Questionnaire (ITQ; Carey, 1970) and the Revised Infant Temperament Questionnaire (RITQ; Carey & McDevitt, 1978), using the same categories. These categories were also combined to characterize three types of infant: easy, difficult, and slow-to-warm-up. A difficult child, for example, was irregular in biological functions, slow to adapt, intense in mood, showed relatively frequent negative mood, and tended to withdraw from novel stimuli (Thomas et al., 1963). The authors endorsed an interactive viewpoint in that they emphasize the "goodness-of-fit" between temperament and environment (Thomas & Chess, 1977). That is, whether a given child is "difficult" depends not only on characteristics of the child, but on the match between qualities in the child and qualities in the parent. The NYLS has been criticized because it offered no guidelines for independent replication of the derivation of the nine categories and because there were problems of overlap among the categories (Goldsmith & Campos, 1982).

A different approach came from Buss and Plomin (1984), who were dissatisfied with the broad definition of temperament used by Thomas and Chess and disappointed by the psychometric problems of the NYLS and the RITQ. Buss and Plomin defined temperament as a set of inherited personality traits that appear early in life (Goldsmith et al., 1987), placing a considerable emphasis on biology and genetics. They described three elements of temperament. The first was labelled Emotionality, although it is actually specific to negative emotions of fear, anger, and distress. Emotionality is the tendency to become upset easily and intensely. It is believed to stem from an inherited sympathetic reactivity. Buss and Plomin (1984) believe that emotionality is largely responsible for the easy/difficult dimension. The other elements in their theory of temperament are Activity, which refers to the tempo and vigour of behaviour, and Sociability, a tendency to respond warmly to human contact.

These dimensions were measured with age-appropriate versions of the EAS Temperament Survey for Children (Buss & Plomin, 1984).

Bates (1980) utilized a definition of temperament very similar to Buss and Plomin, but picked up on the dimension of infant difficultness that originated with the NYLS. Hypothesizing that infant difficultness would be important for individual differences in personality development, children's effect on adult socialization agents, and the early origins of childhood behaviour problems, Bates drew questions from various sources, administered them to the parents of 322 infants and factor-analyzed the results to produce the Infant Characteristics Questionnaire (ICQ; Bates, Freeland, & Lounsbury, 1979). The first factor of the ICQ, labelled Fussy-Difficult, concerned the frequency and intensity of negative affect expressions. It therefore corresponded to the Mood and Intensity categories of the NYLS and RITQ, and the Emotionality dimension of the EASI (Bates, 1980). The Fussy-Difficult factor accounted for 59.8% of the variance on the ICQ, and showed good reliability and validity (Bates et al., 1979). The other factors were Unadaptable, Dull, and Unpredictable, but these dimensions were somewhat unsatisfactory in terms of reliability and validity. Bates (1980) emphasized the fact that difficult temperament, as measured by parent report questionnaires, is a social perception having both objective and subjective components, but noted that even the subjective aspects of parent perception may have developmental importance.

Rothbart conceived of temperament as individual differences in the reactivity and self-regulation of behavioural, endocrine, autonomic, and central nervous system responses (Goldsmith et al., 1987). These characteristics were believed to show up as differences in threshold, latency, intensity, rise time, and recovery time for the elements of negative reactivity, positive reactivity, behavioural inhibition to novel or intense stimuli, and capacity through effort to focus and shift attention. Goldsmith's formulation also emphasized variables such as latency and duration but predicted the independence of these parameters for each of the primary emotions (Goldsmith et al., 1987).

Kagan (1992) studied infants' behavioural responses to unfamiliar stimuli and identified subgroups at the extremes of the population distribution. The 'inhibited' group showed a pattern of minimal motor activity and little crying; the 'uninhibited' group showed consistently high motor activity and vigourous crying. These profiles were preserved from age 2 to age 8 and were associated with peripheral physiological characteristics implying stable variations in the threshold of the limbic system in response to novel and challenging events (Kagan & Snidman, 1991).

Similarly, Michael Lewis has identified stable individual differences in infants' reactivity to stressful stimuli (1992). He found that the intensity of an infant's initial vocal and facial response to heelstick as a newborn predicted the same infant's facial and vocal reaction to immunization at 2 months of age. An infant's latency to quiet following each procedure was also stable across time. Lewis interpreted the stability of individual differences in behavioural response as reflections of individual differences in threshold and dampening at the level of the nervous system. He also suggested that such parameters underlie the construct of temperament (Lewis, 1992).

It should be noted that negative emotionality and the expression of distress is central in all of the above conceptions. In Chess and Thomas' framework, approach, adaptability, mood, and intensity all tapped into negative emotionality (1977). Buss and Plomin's Emotionality factor (1984), Bates' Fussy/Difficult factor (1979), and Rothbart's Negative Reactivity (Goldsmith et al., 1987) seem to be measuring the same construct. The studies by Kagan (1992) and Lewis (1992) likening temperament to psychobiological responses have focused on behavioural expressions of distress such as cry, facial expression, and motor activity.

Negative emotionality is also of concern in clinical and theoretical research on adult populations. Larsen and Diener (1987) reviewed the literature and concluded that adult temperament has four major dimensions: emotionality, activity level, sociability/extraversion, and sensory arousability. Clinically, emotional stability has been found to predict psychological distress and psychological well-being in adult subjects (Windle, 1989). The Normative Aging Study of Boston veterans demonstrated that emotionality accounted for approximately 23% of the variance in mental health status 10 years later (Levenson, Aldwin, Bosse & Spiro, 1988). Levenson and his colleagues used this finding to argue for a general construct of negative affectivity that is relatively stable over time.

The structure of theories of child and adult temperament, and studies of individual differences in physiological reactivity converge on the following hypothesis: individual differences in behavioural responses to stress are an integral part of the construct of temperament, and these differences are behavioural manifestations of individual differences in psychobiological responses to stress. These relationships have been most studied for the temperamental dimension of emotionality. Assuming that pain is an example of negative emotionality, it was hypothesized that individual differences in an infant's response to painful stimuli would be related to the child's temperamental profile. Specifically, infants high on negative emotionality were predicted to show the most intense pain response.

In the present study, temperament is seen as a set of individual difference factors which appear early in life and are relatively stable. These factors result in characteristic styles of expression relating to activity, reactivity, emotionality, and sociability. These styles of expression may reflect individual differences in psychobiological reactions to stimuli, especially in regards to stimuli provoking negative emotionality. The finding that behavioural expressions of pain are positively related to scores on a measure of negative emotionality would suggest that individual differences in the pain response are related to a stable trait apparent across diverse situations.

Temperament was measured using the Infant Characteristics Questionnaire (ICQ; Bates et al., 1979). The ICQ is one of the five most popular questionnaire series used to measure temperament in the United States (Goldsmith & Rieser-Danner, 1990). It has separate forms for infants aged about 6, 13, and 24 months, and data suggests that the different versions are comparable (Bates, 1992). The ICQ was chosen because it has good psychometric properties on the negative emotionality (Fussy/Difficult) factor, compared to other temperament questionnaires (Hubert, Wachs, Peters-Martin & Gandour, 1982). Reviewers have recommended using the ICQ in studies where the major goal is correlates of difficult temperament (Hubert et al., 1982). In addition, it is brief and relatively age-appropriate.

The 6 month form is recommended for use with infants aged aged 4-7 months. The decision to use it with 2 month old infants in the present study was justified based on examination of the items. The only item that may be inappropriate for very young infants concerns their reaction to solid food, and this item does not contribute to the Fussy/Difficult factor. The ICQ has been used previously with infants in this age range (e.g., Anderson & Coll, 1989; Lester & Boukydis, 1992). The decision to use the 13 month form for infants aged 12 2 18 months was also based on examination of the items.

Several investigators have examined the link between temperament and pain in older children. Davison, Faull and Nicol (1986) found that in a sample of 6 year old children, boys who suffered from recurrent abdominal pain scored higher on a measure of temperamental difficulty than boys who did not report recurrent pain. The relationship was not significant among girls. Young and Fu (1988) studied children aged 4 to 7 undergoing fingerstick or venipuncture. Scores on the Rhythmicity and Approach dimensions of a questionnaire developed by Thomas and Chess (1977) were related to some facets of subjective and behavioural response to the medical procedures. However, the relationships, while significant, were extremely small. Wallace (1989) looked at children between the ages of 3 and 7 undergoing elective surgery involving the urinary system. Children rated as high on an emotional intensity factor received a significantly greater number of postoperative analgesic medications than children rated as low intensity. Schechter, Bernstein, Beck, Hart and Scherzer (1991) found that in a sample of 5 year olds receiving immunizations, children rated as temperamentally difficult had higher scores on observer ratings of pain. The individual temperamental dimension of adaptability was also predictive of behavioural distress. In summary, studies with older children were consistent with the notion that high scores on temperament scales measuring negative emotionality predict greater behavioural responses to pain. It should be noted that temperament is considered to be more predictive of behaviour in infancy, because the effects of socialization are fewer. Consequently, the relationship between temperament and pain response in infancy was hypothesized to be stronger than that seen in older children.

Developmental Changes in the Expression of Pain

Much of the literature on infant pain concerns neonates, and there is a need to extend the knowledge base to older infants. If there are developmental changes in the expression of pain, the incorporation of age into normative data for measures could result in increased accuracy. Some age-related changes in pain response have been identified. Using a composite measure of facial expression and cry, Lewis and Thomas (1990) found that 6-month old infants quieted faster than 2- or 4-month olds following DPT immunization. Similarly, Maikler (1991) found that, following inoculation, the duration of pain expression (as measured by the MAX facial expression of physical distress, cry, and body movement) was longer in infants under 4 months than in infants over 4 months. Craig et al. (1984) noted developmental changes in behaviour following an immunization injection. Infants under 12 months of age showed a diffuse response while infants aged 12 to 24 months demonstrated more goal-directed behaviour. However, in the above studies, facial expressions were not studied in detail.

Izard et al. (1983) used Affex to code the facial response to immunization in infants aged 2 to 19 months. It was found that older infants displayed the 'physical distress' expression for a smaller proportion of time, and displayed anger and blended expressions for longer proportions. This finding was later replicated with a longitudinal sample (Izard et al., 1987). However, in the Affex system, coders compare observed appearance changes to formulas or templates representing specific emotions. Affex is not sensitive to changes in the individual actions making up a given expression, and a more molecular coding system, such as NFCS or Baby FACS, is needed to provide a detailed description of developmental changes.

Oster, Hegley and Nagel (1992) pointed out that in the Affex system, the distress-pain and anger expressions are very similar. In fact, the only difference between the two is that the eyes are closed for distress-pain and open for anger. Consequently, the results of Izard et al.'s (1987) study indicated that older infants open their eyes immediately after the shot, while younger infants keep them closed. Craig and Grunau (1993) noted that the only major difference between the expression of pain in newborns and in adults is that newborns characteristically squeeze their eyes shut. Craig went on to argue that this may be an adaptive difference, reflecting the fact that adults can use visual information to protect themselves from the source of pain, while infants have no such recourse. Thus, the changes in the affective response identified by Izard et al. (1983) may also be reasonably interpreted as reflecting variation in the expression of pain. Others have suggested that these changes reflect different intensities of distress rather than distinct emotions (Camras, Sullivan, & Michel, 1993). Such debate is not surprising, given that opinions differ on whether infants experience distinct negative emotions or undifferentiated distress (Camras et al., 1993).

Grunau and Craig's coding system has uncovered some response differences related to age. Premature infants undergoing heel lance displayed less total facial activity than fullterm infants exposed to the same stimulus (Craig et al., 1993). Johnston et al., (1993) compared (1) premature infants of 32 to 34 weeks gestational age undergoing heel lance, (2) fullterm neonates undergoing intramuscular vitamin K injection, (3) 2- and 4-month-old infants undergoing subcutaneous injection of the diphtheria-pertussis-tetanus vaccine. Preterm infants were found to display more horizontal mouth stretch than 2- and 4-month old infants, but less taut tongue than newborns. Fullterm newborns showed more horizontal mouth stretch than older infants, and more taut tongue than any of the other groups. The 2- and 4- month old infants showed similar responses, and there were no other facial differences among groups. Developmental changes deserve more attention.

Summary and Hypotheses

The present study examined the bases of individual differences in infants' response to pain. Cross-sectional samples of infants were observed undergoing immunizations at 2, 4, 6, 12, and 18 months of age. Ratings of pain based on facial expression were related to age and parent report of temperament. For the most part, the analysis of developmental changes was descriptive, since the developmental course of the facial expression of pain has generally not been studied with detailed coding systems. However, it was predicted that at older ages, infants would keep their eyes open following the injection. It was also hypothesized that composite pain ratings would be positively related to scores on a measure of the negative emotionality dimension of temperament as reported by parents.

METHOD

Setting

The study was conducted at child health clinics run by the West-Main and South Units of the Vancouver Health Department. The clinics function as drop-in centres for parents and young children, where the children can be weighed and measured, and parents have an opportunity to speak to community health nurses about any concerns they may have. Parents also made appointments for immunizations on certain days. There were four clinics in all, serving areas of varied ethnic composition and socioeconomic status. Two or three nurses staffed each clinic, with a total of 11 different nurses who administered immunizations.

Sample

According to the guidelines of the Canadian Medical Association (Canadian Immunization Guide, 1989), infants should receive subcutaneous injections for immunization against diphtheria, pertussis and tetanus (DPT), as well as Haemophilus influenzae type b (Hib) at 2, 4, 6, and 18 months of age. Prior to July 1994, these vaccines were given as two separate injections, each 0.5 cc in volume; one shot was administered in each thigh. After July 1994, these vaccines were combined into a single shot, 0.5 cc. in volume, administered in the thigh. At 12 months of age, the guidelines recommend that infants receive an intramuscular injection, 0.5 cc. in volume, administered in the upper arm, as protection against measles, mumps and rubella (MMR). In the present study we examined infants in each of the age groups subjected to these procedures.

A convenience method of sampling was used. Between January 1994 and April 1995, infants who met the inclusion criteria participated in the study. Sampling continued until data from 15 infants had been collected for each age group. The inclusion criteria were as follows:

1. Infants received injections within 31 days of the median age for a given shot;

2. A parent who spoke and read English accompanied the infant.

3. The parent accompanying the infant agreed to have the child participate in the study.

Refusers and infants excluded from the study

Of the 102 parents approached by a clinic nurse to participate in the study, 79 (77%) agreed to take part. Although the reasons for declining were not formally assessed, several parents stated that they themselves were afraid of needles or found the immunization stressful, and consequently they ''just wanted to get it over with.'' Others expressed concern that questionnaire completion would take too long. Two infants were excluded because they were given the wrong questionnaire package (i.e. 18-month-old infants were given the ''6 month'' version of the questionnaire), two infants were excluded because very little of their facial expression was visible on the videotape. It is not possible to rule out the hypothesis that parents who knew that their infants reacted particularly violently to injections declined to participate in the study or delayed in bringing the children to be immunized such that they did not meet age criteria.

Apparatus

A hand-held colour video camera was used to record the infants' facial behaviour. Two cameras were used in the course of the study, the first a Sony CCD-TR81 HandyCam, the second a Minolta Master Series V18R. A Panasonic WJ-810 time-date generator was used to superimpose a digital time display on the video so that specific time segments could be selected and coded. A JVC 20'' colour monitor (AV-20CM4) and a Panasonic video cassette recorder (AG-1970P) with remote control, stop action and slow motion feedback were used during video coding.

Procedure

Once informed consent was obtained, the immunization process began. In each clinic, it was carried out in a small room adjacent to the waiting room. Infants were seated on their parent's lap while the nurse swabbed the skin with alcohol to cleanse it, and administered the injection. Infants in the 2, 4, 6, and 18 month age groups received the shots in the thigh. Infants in the 12 month age group received the shot in the arm. If the infant was receiving two injections (i.e. the standard protocol for DPT and Hib injections prior to July, 1994), the nurse quickly turned the infant after the first injection and administered the second shot in the contralateral thigh.

Throughout the entire procedure, video recording was carried out by a technician, who focussed the camera on the infant's face. The nurse indicated the moment when the needle penetrated the skin by saying "Now."

Following the immunization, parents were required to remain in the waiting room for 15 minutes to ensure their child did not experience an adverse reaction to the vaccine. During this period, they were given a package containing (1) questions about basic demographic information and other factors that may have influenced the infant's response, such as time since waking and time since last feeding, and (2) the Infant Characteristics Questionnaire (ICQ; Bates, 1992). The parents of infants aged 2-6 months were given the "6 month" form; the parents of infants aged 12-18 months were given the "13 month" form. The package typically took less than 15 minutes to complete. See Appendices A and B for copies of the background characteristics questionnaire and sample items from the ICQ.

It would have been preferable to have parents complete the temperament questionnaire before the immunization procedure, in order to avoid the possibility that their responses were biased by their observations of the child during the injection. However, the clinic staff found that this interfered with the nurses' duties, and asked that the questionnaire be completed during the 15 minute waiting period. The instructions on the questionnaire stated "Please base your answers on how your baby usually reacts, not on how your baby reacted to today's shot." Means on the temperament scale were compared to available norms in order to determine whether witnessing the injection altered mothers' perceptions of temperament.

Coding of Infants' Facial Actions

Two systems were used to provide detailed descriptions of facial activity: the Neonatal Facial Coding System (NFCS; Grunau & Craig, 1990) and an adaptation of the Facial Action Coding System (FACS; Ekman & Friesen, 1978) intended for use with infants (Baby FACS; Oster & Rosenstein, 1982, 1993). See Appendices C 2 D for detailed descriptions of the coding systems. Each facial action described for NFCS or Baby FACS was scored as present or absent during five successive 2-second segments coded for each of three events (''baseline,'' ''injection,'' and ''recovery''). Baby FACS coding also assigns an intensity score (1-5) to each of the actions present. In addition to the facial action units, the Baby FACS system includes the option of coding head and eye position. This was not done in the present study as there is no empirical or intuitive reason this would be related to pain, and as it greatly increases the time required to code an event.

Coders were able to use slow motion and stop frame feedback. The segments on each tape were coded in random order. The coders were blind to the temperament scores and exact age of the infants. NFCS coding was carried out by two trained coders who had demonstrated high levels of inter-rater reliability. Baby FACS coding was carried out by a single trained coder certified according to the FACS proficiency test (Ekman & Friesen, 1978).

Scores for each action unit were summed over five 2-second segments for each event. Only those action units observed in more than 10% of 2-second segments were analyzed. By current conventions (Ekman & Friesen, 1992), both Adult FACS and Baby FACS are coded on an intensity dimension, a scale which ranges from 0-5. These scores were then summed over the 5-second segments of each event in order to derive a single value for each action. Total scores could range from 0 (no action) to 25 (action occurs at the highest level of intensity in every segment). As a result, the Baby FACS scores in the current analysis are influenced by the intensity of actions as well as their frequency. This will serve to lessen the comparability of NFCS and Baby FACS; however, both systems were included in the present study with the intent to obtain different types of information, rather than to compare the two directly.

For each of NFCS and FACS, a secondary coder scored 25% of the segments in order to determine interrater reliability. Reliability was calculated according to the formula given 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. The resulting figures were 0.89 for NFCS and 0.80 for Baby FACS. Since, as expected, only a small proportion of Baby FACS actions met the criteria for inclusion in the final analysis, reliability was also calculated on these actions alone. According to this procedure, reliability reached 0.88. Intensity scoring for each of the agreed upon Baby FACS AUs was correlated, yielding a Pearson product-moment coefficient of 0.88.

The following 10 second segments were coded whenever possible: (1) a baseline period beginning 30 seconds prior to the first injection, (2) reaction to the first injection, and (3) a recovery period beginning 20 seconds after the last injection. However, the following exceptions arose:

<u>Selection of the ''baseline'' event</u>

The ''baseline'' event was included in the analysis as a control, showing the infants' facial actions during a period when no invasive events are taking place. It should be noted that infants will be subjected to some non-invasive tactile stimulation during this period as they are typically being undressed and positioned for the injection at this time. A "true" baseline period was found to slow down the nurses considerably and interfere with the primary functions of the clinic.

Whenever possible, a section of videotape from 30-20 seconds before the first injection was selected as a ''baseline'' event. This was possible for 51 (68%) infants. However, for 24 (32%) infants, there was less than 30 seconds of videotape prior to the injection. Consequently, for 8 (10.7%) infants the ''baseline'' event occurred from 20-10 seconds before the first injection. For another 11 (14.7%) infants the ''baseline'' event occurred from 10 seconds before the first injection up to the injection. The ''no baseline'' segment was missing completely for 5 (6.7%) infants (see ''Missing Data'' below). There is no theoretical reason that these events should differ in the facial actions reflective of pain, as nothing painful is happening to the infants in any case. This assumption was tested by conducting a one-way MANOVA for each of the coding systems, with the relevant facial variables as dependent measures and the temporal location of the ''baseline'' event as the independent variable. Neither MANOVA was significant ($p>.2$), and consequently the events were treated as equivalent.

<u>Selection of the ''recovery'' event.</u>

The recovery event was included in order to provide some indication of the infant's reaction over time. Originally, it was planned that this event would take place from 20-30 seconds after the second injection, in the case of infants receiving the DPT and Hib vaccines, and 20-30 seconds after the first and only injection in the case of 12 month-old infants receiving the MMR vaccine. However, in July of 1994, the Canadian immunization guidelines were changed such that the DPT and Hib vaccines were given in the same syringe, and all infants received a single injection. For these infants, as in the 12-month group, the ''recovery'' segment was taken from 20-30 seconds after the first and only injection. However, this meant that, within the same cell, infants differed in the number of injections they had received. Of the total sample, 49 infants (65.3%) had received one injection, and 19 (25.3%) had received two injections. The infant's face was not visible during the ''recovery'' event for 7 infants (9.3%; see ''Missing Data'' below). As before, the assumption that the two events (recovery after one shot versus recovery after two shots) were equivalent was tested by conducting a one-way MANOVA for each of the coding systems, with facial variables as dependent measures and the number of shots as the independent variable. In this case, the MANOVA produced significant results in the case of the NFCS variables (Pillais $F(5,62)=5.55618$, $p<.001$) and nearly significant results in the case of the Baby FACS variables (Pillais $F(10,43)=1.82697$, $p<.10$). Consequently the two types of segments were not treated as equal in further analyses.

Although inconvenient at present, the finding of differences due to the number of painful stimuli is an interesting one. The time course of the pain reaction has not been studied in great detail and the interaction between time and repeated painful stimuli is unknown. Follow-up analyses were conducted on the NFCS data, in the form of univariate ANOVAs for each of the facial actions. These analyses revealed that the difference lay in three actions: brow bulge ($F(1,66)=10.8891$; $p<.001$), deepened nasolabial furrow ($F(1,66)=5.5825$; $p<.05$), and taut tongue ($F(1,66)=6.4274$; $p<.05$): infants who had undergone a single shot scored higher on brow bulge and deepened nasolabial furrow than did infants who had undergone two injections. In contrast, infants who had undergone two shots displayed more taut tongue than those who had undergone a single shot.

Coding of Parents' Soothing Interventions

In addition to the coding of facial actions, some means of describing parents' efforts to soothe the child were desired. The following 10 categories of soothing interventions were derived from a reading of the literature (Bell & Ainsworth, 1972; Gustafson & Harris, 1990; Papousek & Papousek, 1990) and an examination of pilot data.

1) Holding Laterally: Baby is cradled or held face up in caregiver's arms or hands.

2) Holding Ventrally: Baby is held against caregiver's shoulder, in an upright position, with chest toward caregiver.

3) Arm Restraint: Baby is held so that neither arm is free to move, due to the position of the caregiver's hands, arms, or torso.

4) Vestibular Stimulation: Caregiver moves baby in a rhythmic manner (including bouncing, swaying, rocking, or jiggling).

5) Tactile Stimulation: Caregiver pats, rubs, tickles, or kisses baby, or strokes baby's face, head, hands, etc.

6) Breast Feeding: Caregiver puts nipple in baby's mouth.

7) Bottle Feeding: Caregiver puts nipple in baby's mouth.

8) Giving Pacifier: Caregiver puts pacifier in baby's mouth.

9) Distraction: Caregiver attempts to divert baby's attention verbally (e.g., ''Look at that'' or ''What's she doing?''), or by presenting a toy.

10) Soothing Vocalization: Caregiver speaks to the baby with a soothing tone 2 message (e.g., ''That's OK'' or ''All finished now''), or makes soothing sounds (e.g., ''Shhhhhh'').

The above actions were coded as present or absent over an interval stretching from the initial injection to 30 seconds following the last injection given. Thus, the duration of this interval varied from infant to infant. The primary coder was an undergraduate research assistant. Twenty-five percent of the tapes were coded by a secondary coder in order to determine reliability, which was 0.83 according to Ekman and Friesen's formula (1978).

<u>Analyses</u>

<u>Preliminary analyses</u>.

Descriptive statistics were compiled on background characteristics of the sample, and the relationships among background characteristics and the independent variables were examined using chi-square tests, ANOVAs, and correlation coefficients, depending on the nature of the variables. Similarly, the frequency of the various soothing interventions exhibited by parents were tabulated, and chi-square tests and ANOVA were used to determine whether parents altered their behaviour according to a child's age and temperament. Next, descriptive statistics were calculated for the independent variables. The relationship among the independent variables was assessed using a oneway ANOVA.

<u>The research questions</u>.

The data were analyzed using SPSS/PC to answer the research questions, with some additional hand calculations. All analyses were conducted separately for NFCS and Baby FACS. In order to derive a ''pain summary score'' for each coding system, variables occurring in more than 10% of segments were entered into a principal components analysis. Factor loadings from this analysis were then used as weights in a linear combination of facial variables. This procedure is consistent with previous studies using NFCS and Baby FACS (e.g., Craig et al., 1994). In order to address the relationship between infant temperament and reaction to the injection, correlation coefficients between the pain summary scores and scores on the fussy-difficult dimension were examined.

As described above, results of preliminary analyses indicated that, for the recovery event, it was not appropriate to treat infants receiving two injections as equivalent to those receiving a single injection. Consequently, the analysis was handled differently than originally planned. Where infants received two injections, the interval between the injections was variable. In six cases this interval was longer than 30 seconds, and it was possible to recode a ''recovery'' event 20-30 seconds after the first injection. However, in 13 subjects the interval was less than 30 seconds and recoding was not possible. As a result, the correlation coefficients calculated between temperament scores and the facial action summary scores for the ''recovery'' event were computed using only 55 infants. Since no significant relationships between temperament and pain scores were discovered, temperament was not included as a factor in further analyses.

In order to examine developmental changes in the degree of pain expressed in response to the shot, pain summary scores were entered into an ANOVA. According to original plans, data was to be entered into a 5x3 between-within ANOVA, with age as a between-subjects factor having five levels (2, 4, 6, 12, and 18 months of age), and event as a within-subjects factor having three levels (''no pain,'' ''injection,'' and ''recovery''). In order to examine developmental changes in the individual facial actions comprising the pain expression, the basic design was then to be repeated using a MANOVA format, with the individual facial actions entered as dependent variables, rather than a single summary score.

However, as mentioned previously, 13 infants had received two injections before the ''recovery'' event and it was necessary to exclude these subjects from the analysis. As a result, two MANOVAs were conducted for each coding system, rather than the one originally planned. The ''baseline'' and ''injection'' events were analyzed in a 5x2 between-within MANOVA with age as the between-subject factor and event as the within-subject factor. The full set of 75 subjects was included in this analysis. The ''recovery'' event was analyzed in a separate oneway MANOVA with age as a between-subject factor. Infants for whom it was not possible to code a ''recovery'' period after a single shot were deleted. In addition, five other infants were randomly deleted such that cell sizes remained equal. This was necessary in order that the results be robust to violations of the assumption of homogeneity of variance-covariance matrices. In considering the significance of correlations and of main effects derived from ANOVAs and MANOVAs, an α level of .05 was used. In follow-up analyses, the value of α was lowered according to the number of groups or variables involved.

It should be noted that, in the 12 month group, age is confounded with stimulus properties as these infants were immunized with a different vaccine at a different site on the body. This confound is unavoidable and was considered when the results were interpreted.

RESULTS

Descriptive characteristics of the sample

Of the 75 infants included in the final analysis, 36 (48%) were male and 39 (52%) were female. Male infants made up 8 (53%) of the 2-month group, 6 (40%) of the 4-month group, 6 (40%) of the 6-month group, 10 (67%) of the 12-month group, and 6 (40%) of the 18-month group. Twenty-eight (37.3%) of the infants were first born, 32 (42.7%) were second born, 10 (13.3%) third born, 3 (4.0%) fourth born, and 1 (1.3%) sixth born. One parent did not answer the question. Eight infants had been premature (10.7%). All of the infants' parents answered yes to the question ''Is your baby generally healthy?'' but one infant suffered from Turner's Syndrome, a chromosomal abnormality usually associated with intelligence in the low normal range. As all scores on temperament, facial variables, and pain summary scores were within two standard deviations of the mean, the infant was retained for the analysis. Analyses run without this subject indicated that results were not different from those when the infant was retained.

Sixty-three infants (84%) were held by their mothers, and twelve (16%) by their fathers. Forty-five (56%) of parents had given their child acetominophen before the shot. This was recommended by the clinic nurses as prevention for the fever that can result from immunization. It is not expected to have any effect on the pain of a needle stick. The time since feeding ranged from half an hour to 7 hours, with a mean of 2.03 hours. The time since waking ranged from 0 to 8 hours, with a mean of 2.58 hours.

Relationships between these characteristics and the independent variables of age and temperament were examined. Where background characteristics were categorical (clinic, nurse, gender, birth order, prematurity, parent, and use of medication), chi-square tests were used to examine the relationship with age and ANOVAs were used to examine the relationship with temperament. Where background variables were continuous (time since feeding and time since waking), ANOVAs were used to examine the relationship with age and correlation coefficients were used to examine the relationship with temperament. These analyses are summarized in Appendix E. None of the analyses were significant ($p > .05$).

Soothing Interventions

The percent occurrence of various interventions are given in Table 1.

Table 1

Percent of Parents Using Each Soothing Intervention

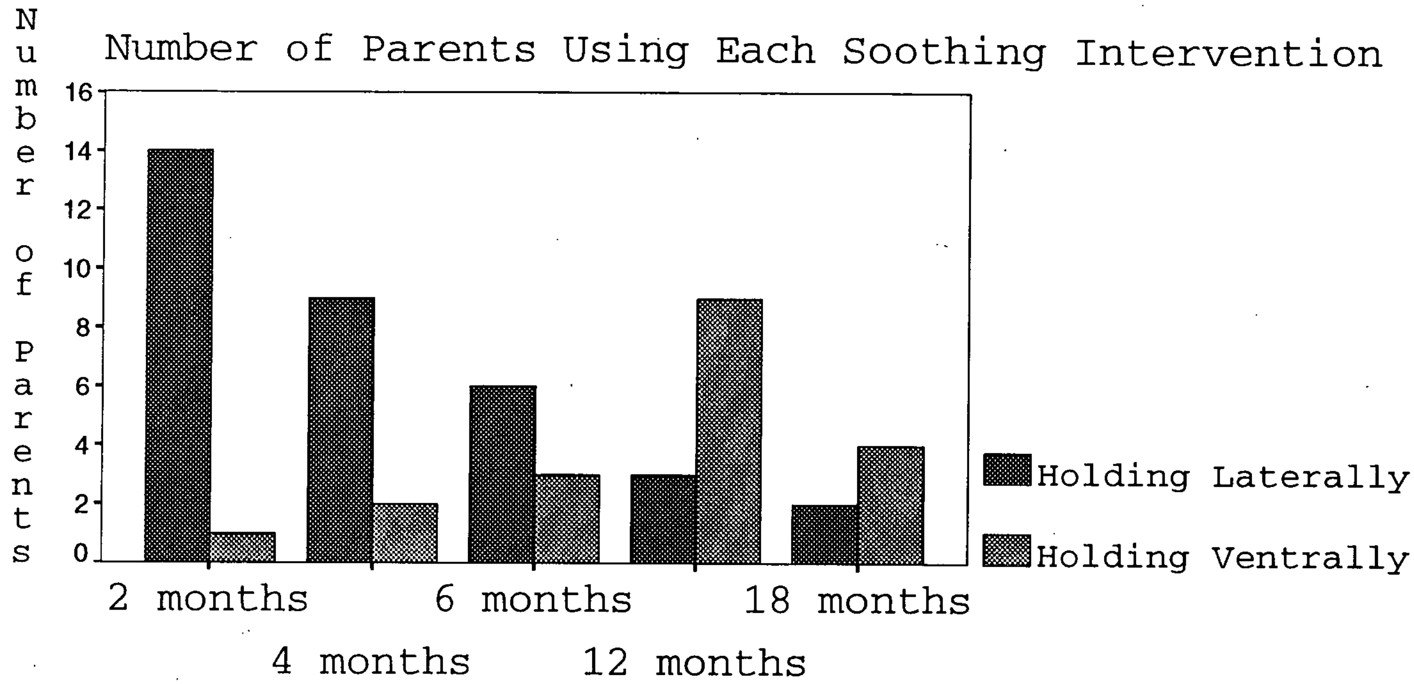
Intervention	% of Parents Using the Intervention
Soothing Vocalization	93
Arm Restraint	67
Tactile Stimulation	64
Holding Laterally	45
Holding Ventrally	25
Vestibular Stimulation	24
Distraction	19
Giving Pacifier	9
Breast Feeding	4
Bottle Feeding	0

n=75

Chi-square tests were used to examine whether the frequency of each intervention varied with age. Significant results were obtained for Holding Laterally (χ^2_4=25.50, p<.0001), and Holding Ventrally (χ^2_4=13.67, p<.01). The frequencies of these actions are shown graphically in Figure 2. Examination of the graphs suggests that parents are more likely to comfort young infants by holding them laterally (i.e. cradling them in their arms). Holding ventrally shows a slight decline interrupted by a sharp increase in frequency at the age of 12 months. This may be due to the fact that in this age group, the locus of injection was the upper arm rather than the thigh. Holding ventrally may allow

Figure 2

Number of Parents Using Each Soothing Intervention



Age Group

the nurse access to the arm while maintaining close contact between parent and child.

The relationship between child temperament and soothing interventions was assessed through a series of t-tests, with the presence or absence of each soothing intervention as the grouping variable. None of the soothing variables reached significance at the .05 level.

The Independent Variables

Age.

Since infants received immunizations at five different ages, age was treated as a categorical variable, with 15 subjects per group. The resulting groups are summarized in Table 2.

Table 2

Description of Age Groups.

Age Group	Mean Age in Days	Standard Deviation	Minimum Age in Days	Maximum Age in Days
2 months	68	7.38	59	84
4 months	132	13.60	104	154
6 months	201	16.38	176	228
12 months	380	12.41	362	407
18 months	563	17.86	536	594

n=15

Temperament.

Scores on the fussy/difficult factor were calculated for each version of the questionnaire. The means and standard deviations are given in Table 3, along with the means and standard deviations from Bates' (1992) standardization sample.

Table 3

Distribution of Temperament Scores

Current Sample:

Questionnaire Form	Mean	Standard deviation
``6 months''	17.29	4.54
``12 months''	29.12	5.71

Standardization Sample:

Questionnaire Form	Mean	Standard deviation
``6 months''	17.77	5.88
``12 months''	28.64	7.43

Parents failed to answer a question contributing to temperament score in two instances, which represents 0.37% of the questionnaire data. The scores were replaced with mean values for the item according to Bates' (1992) standardization data.

In order to have the scores from the two forms comparable, the observed scores were standardized using the means and standard deviations from Bates' sample. The standardized scores were used in subsequent analyses.

The relationship between age and temperament.

The relationship between age and temperament was examined with a oneway ANOVA. There was no significant relationship between the two ($F(4,70)=0.37$, $p>.5$).

The Dependent Variables

Collapsing of Baby FACS actions.

Previous studies using FACS to investigate the facial expression of pain in adult subjects have noted the difficulty in distinguishing between certain action units. For example, Ekman, Friesen and Simons (1985) disregarded the ''finer distinction'' between AU6 (cheek raise) and AU7 (lids tight) in their analysis of the startle response. Others have found it difficult to distinguish between AU9 (nose wrinkle) and AU10 (upper lip raise) and suggested that these actions are part of the same basic process (Prkachin & Mercer, 1989). Consequently, Prkachin (1992) has recommended that analyses be conducted on the composite variables of "orbit tightening" (AU6/AU7) and "levator contraction" (AU9/AU10). Oster and Rosenstein (1993) note that "the distinction between AUs 6 and 7 is one of the most difficult to make in infants....in many cases both are probably acting" (pp. 18-19). Similarly they note that "confusion between AU 9 and AU 10 is even more frequent in infants than in adults....In many cases, it is likely that both are acting....if it is not clear which are acting, it may be best to acknowledge the ambiguity by coding "AU 9 and/or 10" (p. 27). In light of these comments, Prkachin's recommendations seem suitable for infants as well as adults, and the variables were collapsed according to his instructions.

Frequency of occurrence of facial variables.

Frequency and percent occurrence were calculated for the 10 NFCS action units and the 45 Baby FACS action units examined in this study. Percent occurrences are given in Appendix F.

The following five NFCS action units were observed to occur in more than 10% of coded segments: Brow bulge, Eye squeeze, Deepened nasolabial furrow, Open lips, and Taut tongue. These actions were retained for further analyses. The other five actions (Vertical mouth stretch, Horizontal mouth stretch, Lip purse, Chin quiver, and Tongue protrusion) were observed to occur in less than 10% of coded 2-second segments, and thus were discarded from further analyses. The following 10 Baby FACS action units were recorded in more than 10% of coded segments: AU 1-Inner Brow Raise, AU 3-Brow Knit, AU 4-Brow Lower, AU6/AU7-Orbit Tightening, AU9/AU10-Levator Contraction, AU17-Chin Raise, AU26-Jaw Drop, AU43-Eyes Closed, AU44-Squint, and AU75d-Tense, Concave Tongue. These actions were retained for further analyses, while the other Baby FACS actions were discarded.

Missing data.

Because parents and nurses were told to ''proceed as usual,'' there were inevitably segments in which the infant's face was obscured. According to NFCS coders, the entire face was not visible in 7.29% of segments. In addition, individual actions were not visible in the following percentage of segments: brow bulge, 1.07%; eye squeeze, 0.44%; nasolabial furrow, 1.42%, and open lips, 1.69%. According to the primary FACS coder, the entire face was obscured in 7.29% of segments; the upper face was not visible in 0.98% of segments and the lower face was not visible in 2.13% of segments.

If only one or two of the five segments from an "event" were missing, they were replaced with the mean score taken from the visible segments for that infant. If more than two of the segments were missing, that event was omitted from correlational analyses conducted to examine the role of temperament. However, in order to retain equal cell sizes in the MANOVA conducted to examine the role of age, the infant's scores for the entire event were replaced with the mean values for that cell, i.e. the mean values observed in infants in the same age group during the same event. This was necessary for nine events (4% of the total). There is precedence for such an approach in previous studies (e.g., Craig et al., 1993).

<u>Construction of the Pain Summary Scores</u>.

In order to answer the research questions, a single index of the amount of pain expressed by the infant was desired. With this in mind, the facial actions observed within each coding system during the "injection" event were subjected to a principal components analysis.

The results of the principal components analysis conducted on the NFCS variables will be discussed first. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy was .71, above the .6 required to conduct the analysis (Tabachnick & Fidell, 1989). The Bartlett Test of Sphericity was significant, indicating that there were sufficient correlations among the variables to warrant factor analysis. A single factor with an eigenvalue of 2.88 was identified, and inspection of the scree plot confirmed the suitability of the single-factor solution (Cattell, 1966). As well, this factor structure is comparable to that found in previous research (Craig et al., 1994). This factor accounted for 57.7% of the variance in NFCS actions, a figure somewhat lower than has been found in previous research (Craig et al., 1994). All five of the NFCS actions loaded positively on the factor, which makes conceptual sense. Factor loadings are presented in Table 4.

Table 4

Factor Loadings for the NFCS Facial Actions

Facial Action	Factor Loading
Brow bulge	.82
Eye squeeze	.80
Deepened nasolabial furrow	.91
Open lips	.61
Taut tongue	.62

The principal components analysis conducted on the Baby FACS action units produced similar results. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy was .70 and the Bartlett Test of Sphericity was significant. The analysis identified three factors with eigenvalues greater than one. However, inspection of the scree plot (Cattell, 1966) suggested that the single factor solution was more appropriate. Furthermore, the second and and third factors were not easily interpretable and somewhat unstable as they were based on only one or two action units. As a result, the solution was restricted to one factor. This factor had an eigenvalue of 4.29 and accounted for 42.9% of the variance in Baby FACS actions. All of the Baby FACS actions loaded positively on the factor, with the exception of AU1, inner brow raise. Factor loadings are presented in Table 5.

Table 5

Factor Loadings for the Baby FACS Actions

Facial Action	Factor Loading
AU1-Inner brow raise	-.32
AU3-Brow knit	.74
AU4-Brow lower	.76
AU6/7-Orbit tightening	.89
AU9/10-Levator contraction	.86
AU17-Chin raise	.27
AU26-Jaw drop	.75
AU43-Eyes closed	.70
AU44-Squint	.13
AU75d-Tense, concave tongue	.62

These factor loadings were highly consistent with expectations. Within each coding system, the individual action units previously observed to be associated with painful stimuli loaded onto the factor. The factor loadings are seen as representing the contributions of individual actions to the global pain expression. By examining the actions that load heavily on each factor, it is possible to derive a qualitative description of the "pain face" according to each coding system. According to NFCS, the facial expression of pain in infants is created by lowering the eyebrows and drawing them together, squeezing the eyelids together, deepening the nasolabial furrow and pulling it upwards, opening the lips, and displaying a raised tongue with sharp, tensed edges. According to Baby FACS, the facial expression of pain is created by knitting and lowering the brows, tightening the muscles surrounding the eye, closing the eyes, wrinkling the nose and raising the upper lip, dropping the jaw, and displaying a tense, concave tongue. Although there are some differences, these results are generally consistent with the results of previous studies (Craig et al., 1993; Craig et al., 1994; Grunau et al., 1990).

The factor loadings were used to derive pain summary scores: for each coding system, the factor loadings were used as weights in a linear combination of facial actions. The same weights were used to calculate pain summary scores for each infant for each event. These pain summary scores were then used as dependent measures in further analyses.

<u>Two measures of pain</u>.

If the summary scores derived from the two coding systems were each measuring pain, significant correlations between the two measures would be expected. Pearson product-moment correlation coefficients were calculated between the NFCS pain summary and the Baby FACS pain summary for each of the events expected to be painful i.e. ''injection'' and ''recovery.'' The results are given in Table 6.

Table 6

<u>Correlations between NFCS and Baby FACS pain summary scores</u>

Event	n	r	p
''injection''	75	.79	<.001
''recovery''	55	.79	<.001

Both of the above correlations were significant at the .001 level, consistent with the proposition that both summary scores are measures of pain.

In order to further examine concordance between the two measures, the correlations between individual action units were also computed. Two correlation matrices were constructed, one for actions of the upper face (Table 7), and one for actions of the lower face (Table 8).

Table 7

Correlations between NFCS Actions and Baby FACS Actions: The Upper Face

	NFCS Actions		
Baby FACS Actions	Brow Bulge	Eye Squeeze	Deepened Nasolabial Furrow
AU1-Inner Brow Raise	r=-.16 p<.10	r=-.30 p<.001	r=-.13 p<.015
AU3-Brow Knit	r=.49 p<.001	r=.52 p<.001	r=.45 p<.001
AU4-Brow Lower	r=.50 p<.001	r=.63 p<.001	r=.43 p<.001
AU6/AU7-Orbit Tightening	r=.55 p<.001	r=.76 p<.001	r=.63 p<.001
AU9/AU10-Levator Contraction	r=.58 p<.001	r=.68 p<.001	r=.65 p<.001
AU43-Eyes Closed	r=.39 p<.001	r=.66 p<.001	r=40 p<.001
AU44-Squint	r=.22 p<.015	r=.25 p<.005	r=.23 p<.01

Table 8

Correlations between NFCS Actions and Baby FACS Actions: The Lower Face

	NFCS Actions	
Baby FACS Actions	Open Lips	Taut Tongue
AU17-Chin Raise	r=.10 p<.25	r=.13 p<.15
AU26-Jaw Drop	r=.49 p<.001	r=.47 p<.001
AU75d-Tense, Concave Tongue	r=.22 p<.05	r=.68 p<.001

On the basis of content, the strongest correlations would be predicted between a) NFCS Brow Bulge and Baby FACS AUs 3-Brow Knit and 4-Brow Lower, b) NFCS Eye Squeeze and Baby FACS AU6/AU7-Orbit Tightening, c) NFCS Deepened Nasolabial Furrow and Baby FACS AU9/AU10-Levator Contraction, d) NFCS Open Lips and Baby FACS AU26-Jaw Drop, and e) NFCS Taut Tongue and Baby FACS AU75d-Tense, Concave Tongue. All of these correlations were found to be significant. However, interpretation of the matrix is complex. This issue will be examined further in the Discussion section.

The Relationship between Pain and Temperament

The first research question to be addressed focussed on the relationship between facial expression in response to a painful stimulus and the negative emotionality dimension of temperament. It was hypothesized that infants who were rated by their parents as more fussy or difficult would show the greatest facial response to the injection.

Pearson product-moment correlation coefficients were calculated to assess the relationship between pain summary scores and scores on the fussy-difficult factor for each event. The results are summarized in Table 9.

Table 9

Correlations between Pain Summary Scores and Temperament Scores

Analyses based on NFCS actions:

Event	n	r	*p*
``baseline''	70	-.04	>.75
``injection''	75	-.14	>.20
``recovery''	55	.00	>.90

Analyses based on Baby FACS actions:

Event	n	r	*p*
``baseline''	70	-.01	>.90
``injection''	75	-.09	>.40
``recovery''	55	-.13	>.30

Statistical significance was not observed in any of the relationships reported. Infants perceived by their parents as fussier and more difficult did not react to the injection with greater intensity. Since no relationship was observed between temperament and pain scores, and preliminary analyses had not shown a relationship between temperament and age group, temperament was not included as a factor in the MANOVAs conducted to examine age differences in the pain response.

Developmental Changes in the Facial Expression of Pain

The second research question to be addressed involved the identification of developmental change in the facial expression of pain, both in the overall degree of pain expressed and the individual facial variables.

Developmental Changes in the Intensity of the Pain Reaction

To address this question, a series of ANOVAs were conducted using pain summary scores as the outcome measure.

Analyses conducted on the ''baseline'' and ''injection'' events.

For each coding system, a 5x2 between-within ANOVA was conducted, with age as the between-subjects factor and event as the within-subjects factor. Cell means and standard deviations from the NFCS data are presented in Table 10.

Table 10

Cell Means and Standard Deviations:

NFCS Pain Summary Scores by Age by Event

		Age Group:				
Event		2 Months	4 Months	6 Months	12 Months	18 Months
''baseline''	M	8.74	3.39	4.01	3.35	5.69
	SD	6.91	2.20	2.75	4.07	5.36
''injection''	M	14.74	12.06	14.58	14.37	13.43
	SD	4.45	5.17	5.16	3.68	4.86

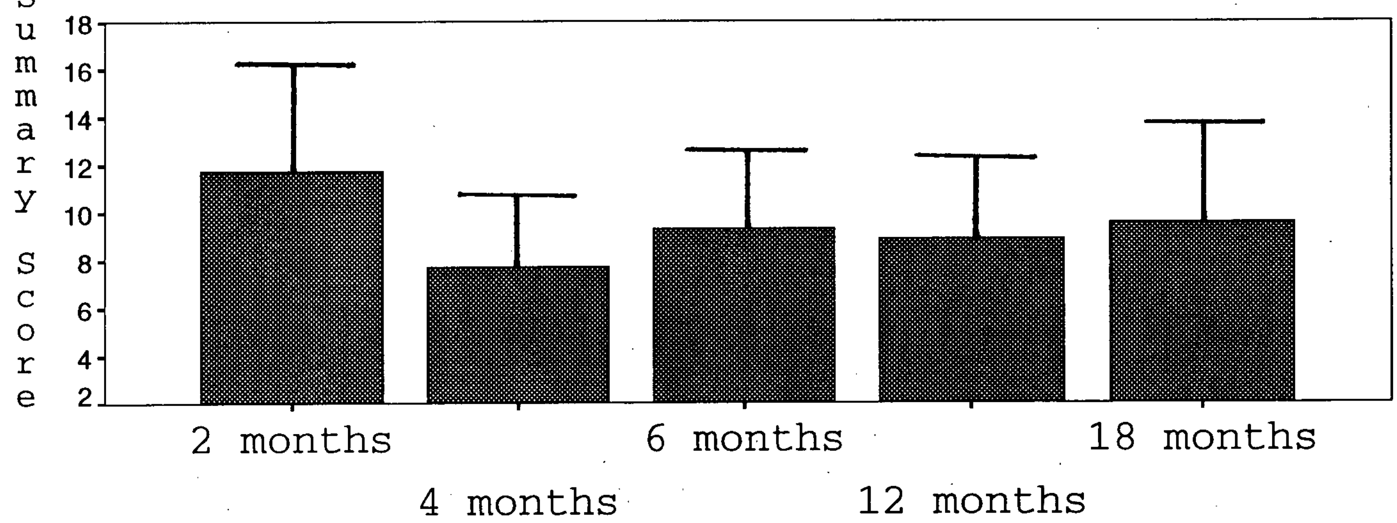
n=15

The interaction between age group and event was non-significant (p>.10). Both the main effect of age group (F(4,70)=2.61, p<.05) and the main effect of event (F(1,70)=157.15, p<.001) were significant. With regards to the main effect of event, examination of marginal means revealed that the pain summary scores were, as expected, significantly higher during the ''injection'' event than during the ''baseline'' event. The overall pain summary score for the ''baseline'' event was 5.04; for the ''injection'' event, it was 13.84. Follow-up analyses (Tukey) of the age effect, with α dropped to the 0.01 level, revealed that 2 month old infants had pain summary scores significantly higher than those of 4 month old infants. No other differences were significant. These results are depicted graphically in Figure 3.

Figure 3

NFCS Pain Summary Scores by Age

Mean scores across "baseline" and "injection" events



Age Group

Cell means and standard deviations obtained from the baby FACS data are presented in Table 11.

Table 11

Cell Means and Standard Deviations:

Baby FACS Pain Summary Scores by Age by Event

Age Group:

Event		2 Months	4 Months	6 Months	12 Months	18 Months
''baseline''	M	30.94	8.00	6.67	5.73	17.67
	SD	30.27	6.92	6.71	8.92	23.10
''injection''	M	74.28	54.64	53.89	64.71	54.53
	SD	21.61	27.54	29.25	25.96	25.46

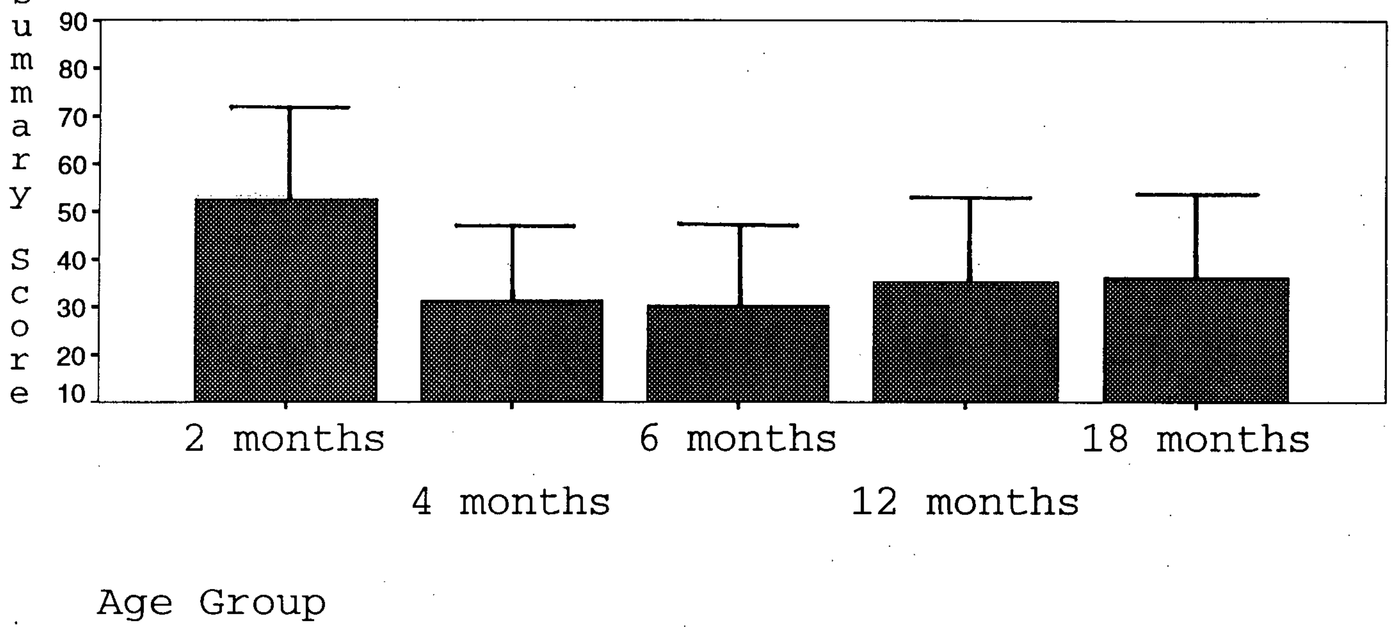
n=15

Again, both the main effect of age group ($F(4,70)=4.37$, $p<.005$) and the main effect of event ($F(1,70)=182.08$, $p<.001$) were significant. Examination of the marginal means revealed that pain summary scores were significantly higher during the ''injection'' event than during the ''baseline'' event. Tukey tests performed as follow-up analyses of the main effect of age with α dropped to the 0.01 level, revealed that 2-month old infants had significantly higher pain summary scores than 4-month old infants or 6-month old infants. No other differences were significant. Figure 4 is a graph of these results.

Figure 4

Baby FACS Pain Summary Scores by Age

Mean scores across "baseline" and "injection" events



Analyses conducted on the ''recovery'' event.

For each coding system, a oneway ANOVA was conducted , with age group as a between-subjects factor. Cell means and standard deviations are presented in Table 12.

Table 12

Cell Means and Standard Deviations

NFCS Actions: NFCS Pain Summary Scores by Age

Age Group:

	2 Months	4 Months	6 Months	12 Months	18 Months
M	11.16	6.00	11.91	10.74	12.63
SD	6.14	4.70	4.03	3.15	2.06

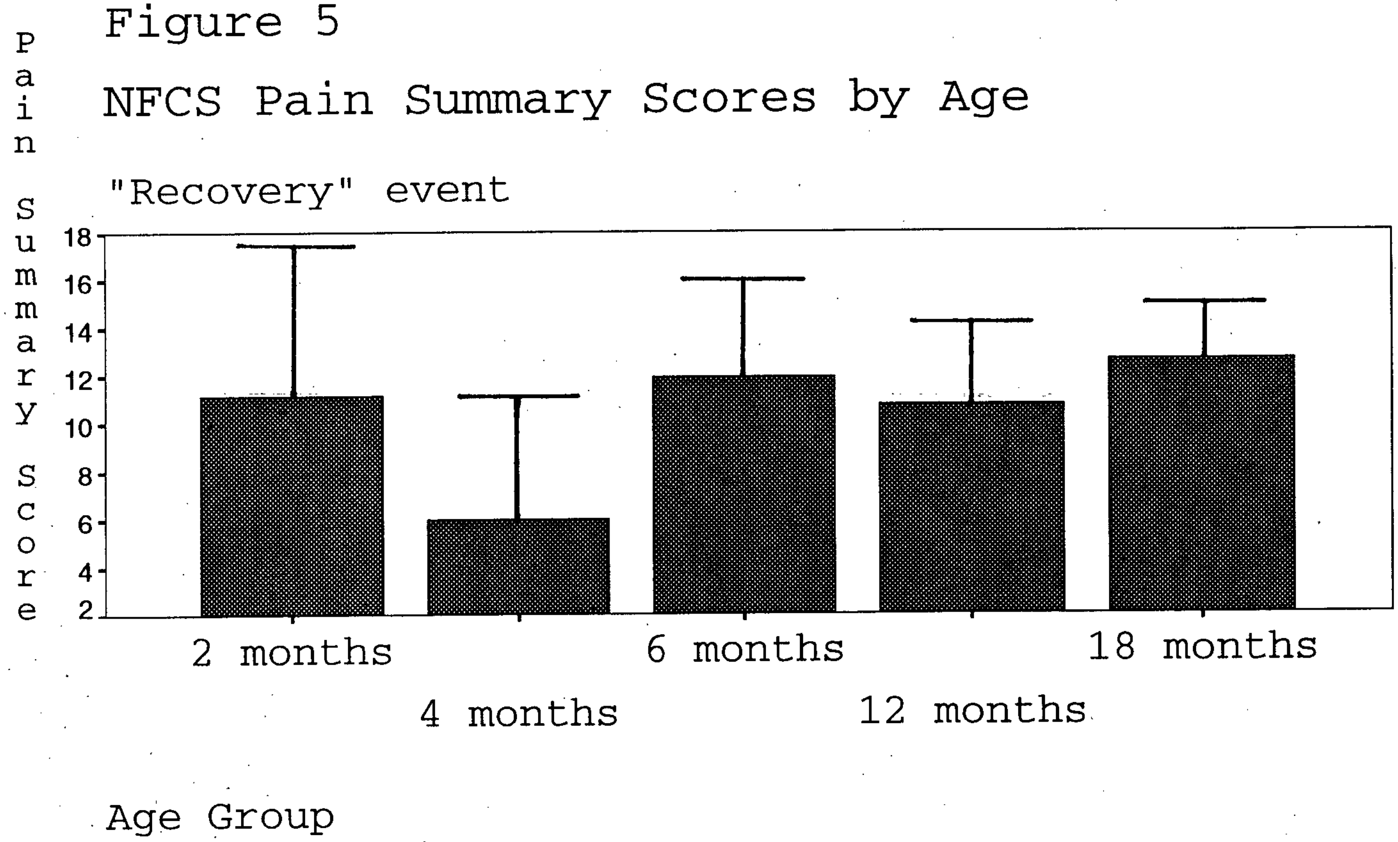
n=10

The main effect of age group ($F(4, 50)=3.27$, $p<.05$) was significant. Follow-up analyses took the form of Tukey tests. When α was dropped to 0.01, none of the differences reached significance. However, at the 0.05 level, it was apparent that 4-month old infants had pain summary scores that were lower than either 18-month old infants or 6-month old infants. No other pair of means differed significantly. The differences, shown graphically in Figure 5, should properly be regarded as trends.

Figure 5

NFCS Pain Summary Scores by Age

"Recovery" event



Cell means and standard deviations from the Baby FACS data are presented in Table 13.

Table 13

Cell Means and Standard Deviations:

Baby FACS Pain Summary Scores by Age

	2 Months	4 Months	6 Months	12 Months	18 Months
M	45.44	20.95	33.37	39.13	47.82
SD	28.67	18.26	21.12	16.22	24.30

n=10

The main effect of age group on Baby FACS pain summary score during the ''recovery'' event did not reach significance ($p>.05$). The data are shown graphically in Figure 6. Examination of the figure indicates considerable variability among the groups.

Developmental Changes in the Nature of the Pain Expression

To address this question, a series of MANOVAs were performed, with the individual facial variables as dependent measures. Only those variables occurring in more than 10% of segments were included in the analysis.

Analyses conducted on the ''baseline'' and ''injection'' events.

The relationship between age and the facial expression of pain during the ''baseline'' and ''injection'' events was examined through a 5x2 between-within MANOVA with age as the between subjects factor and event as the within-subjects factor. Cell means and standard deviations obtained from this analysis for the NFCS data are given in Table 14.

Figure 6

Baby FACS Pain Summary Scores by Age

"Recovery" event

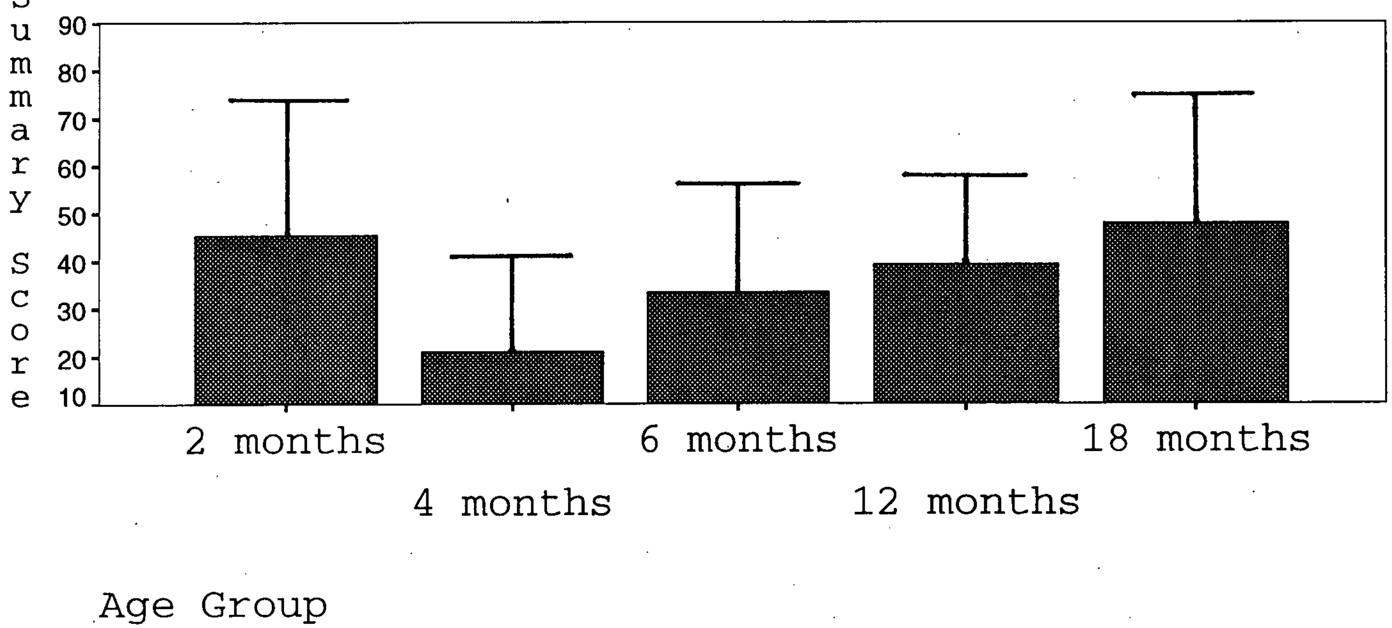


Table 14

Cell Means and Standard Deviations:

NFCS Actions by Age

''Baseline'' event: Age group:

Action Unit		2 Months	4 Months	6 Months	12 Months	18 Months
Brow bulge	M	2.80	0.81	1.13	1.27	1.86
	SD	2.15	1.13	1.64	1.68	2.20
Eye squeeze	M	1.67	0.00	0.00	0.29	0.29
	SD	2.23	0.00	0.00	1.03	1.03
Deepened naso-labial furrow	M	2.00	0.56	0.87	0.68	1.50
	SD	2.33	1.17	1.36	1.30	2.13
Open lips	M	4.20	3.65	3.63	2.41	3.32
	SD	1.74	1.97	2.11	2.43	2.20
Taut tongue	M	1.20	0.00	0.13	0.00	0.91
	SD	2.08	0.00	0.52	0.00	1.76

n=15

''Injection'' event: Age group:

Action Unit		2 Months	4 Months	6 Months	12 Months	18 Months
Brow bulge	M	4.43	3.77	4.40	4.47	4.21
	SD	1.40	1.49	1.40	0.99	1.74
Eye squeeze	M	3.93	2.93	3.72	3.47	2.93
	SD	1.83	1.67	2.02	1.73	2.19
Deepened naso-labial furrow	M	4.20	3.39	4.20	4.42	4.33
	SD	1.74	1.61	1.61	0.91	1.76
Open lips	M	4.67	4.00	4.73	4.63	4.93
	SD	1.29	1.77	0.70	0.81	0.26
Taut tongue	M	2.13	1.82	2.13	1.80	1.13
	SD	2.36	2.06	2.23	2.04	2.07

n=15

Neither the interaction between age and event nor the main effect of age was significant ($p > .50$ and $p > .10$ respectively).

However, as expected, the main effect of event was significant ($F(5,66)=105.44$, $p<.001$). Follow-up analyses in the form of 5 paired t-tests indicated that means for all of the NFCS actions were greater during the ''injection'' event than during the ''baseline'' event.

Cell means and standard deviations obtained for the Baby FACS actions are given in Table 15.

Table 15

Cell Means and Standard Deviations:

Baby FACS Actions by Age by Event

''baseline'' event: Age group:

Action Unit		2 Months	4 Months	6 Months	12 Months	18 Months
1 Inner Brow Raise	M	1.00	0.33	1.53	1.07	1.48
	SD	1.89	0.69	3.38	2.63	3.00
3 Brow Knit	M	5.60	0.17	0.82	0.70	3.20
	SD	7.22	0.51	1.98	1.68	5.63
4 Brow Lower	M	5.13	0.17	0.07	0.63	1.14
	SD	6.74	0.51	0.26	1.69	4.12
6/7 Orbit Tightening	M	6.73	1.94	0.50	0.52	3.68
	SD	8.03	4.76	1.94	1.55	6.45
9/10 Levator Contraction	M	5.60	0.10	0.80	0.59	4.57
	SD	7.41	7.41	2.08	1.81	6.44
17 Chin Raise	M	2.73	0.00	0.13	0.26	2.21
	SD	5.18	0.00	0.52	0.86	5.68
26 Jaw Drop	M	11.78	7.69	6.93	5.06	8.09
	SD	6.21	4.69	4.46	5.46	6.62
43 Eyes Closed	M	2.60	0.31	0.08	0.36	1.21
	SD	4.60	0.69	0.32	1.29	4.38
44 Squint	M	3.93	0.42	0.00	0.00	1.50
	SD	7.11	1.28	0.00	0.00	5.41
75d Tense, Concave Tongue	M	0.80	0.00	0.13	0.00	0.00
	SD	1.52	0.00	0.52	0.00	0.00

_n_=15

''Injection'' event:

Age group:

Action Unit		2 Months	4 Months	6 Months	12 Months	18 Months
1 Inner Brow Raise	M	0.33	1.60	1.13	0.53	0.67
	SD	1.05	3.60	2.70	0.99	1.29
3 Brow Knit	M	14.32	12.35	6.89	12.60	9.93
	SD	6.88	6.31	5.43	7.77	7.60
4 Brow Lower	M	12.67	9.78	7.69	12.33	7.53
	SD	8.03	5.54	6.59	6.60	7.32
6/7 Orbit Tighten-ing	M	15.78	11.85	12.20	13.60	12.13
	SD	5.22	7.38	7.32	6.02	7.31
9/10 Levator Contract-ion	M	17.30	12.38	12.20	15.56	13.78
	SD	5.50	5.01	8.38	6.61	7.32
17 Chin Raise	M	4.57	2.67	2.33	3.33	1.78
	SD	5.38	5.64	6.14	5.04	4.30
26 Jaw Drop	M	17.79	11.98	16.47	16.05	15.77
	SD	4.92	6.34	4.93	4.72	5.45
43 Eyes Closed	M	12.52	9.12	11.05	8.93	8.33
	SD	6.70	7.90	7.88	7.19	7.24
44 Squint	M	3.73	2.67	1.93	4.20	2.20
	SD	8.77	4.19	6.24	5.16	6.47
75d Tense, Concave Tongue	M	2.26	1.52	1.60	1.53	0.93
	SD	2.09	1.82	2.10	1.96	1.34

_n_=15

In this analysis, both the main effect of age ($F(40, 233)=1.80$, $p<.005$) and the main effect of event (F(10, 61)=38.13, $p<.001$) reached significance. The interaction between age group and event was not significant ($p>.10$). Follow-up analyses on the main effect of age were conducted in the form of individual oneway ANOVAs for each of the 10 facial variables, with α dropped to the 0.005 level. The results are presented in Table 16.

Table 16

Univariate Results: Baby FACS Actions by Age

Action Unit	F(4,70)	p
AU1-Inner Brow Raise	0.07	>.05
AU3-Brow Knit	2.17	>.05
AU4-Brow Lower	3.11	<.025
AU6/AU7-Orbit Tightening	2.46	>.05
AU9/AU10-Levator Contraction	6.86	<.001
AU17-Chin Raise	0.55	>.05
AU26-Jaw Drop	0.74	>.05
AU43-Eyes Closed	0.54	>.05
AU44-Squint	0.29	>.05
AU75d-Tense, Concave Tongue	0.09	>.05

The analyses indicated a significant effect of age for AU9-Levator Contraction. AU4-Brow Lower, approached significance. The other 8 ANOVAs were non-significant. Follow-ups were performed on the mean scores for AU9, using the Tukey method, with α again set at 0.005. These analyses indicated that 2 month old infants displayed more levator contraction than 4, 6 and 12 month-old infants. The mean scores on Levator Contraction and Brow Lower for all 5 age groups are displayed in Figure 7.

Follow-up analyses on the main effect of event were conducted in the form of paired t-tests for each of the facial variables, with α dropped to 0.005. The results are provided in Table 17.

Figure 7

Individual Baby FACS Actions by Age

Mean scores across "baseline" and "injection" events

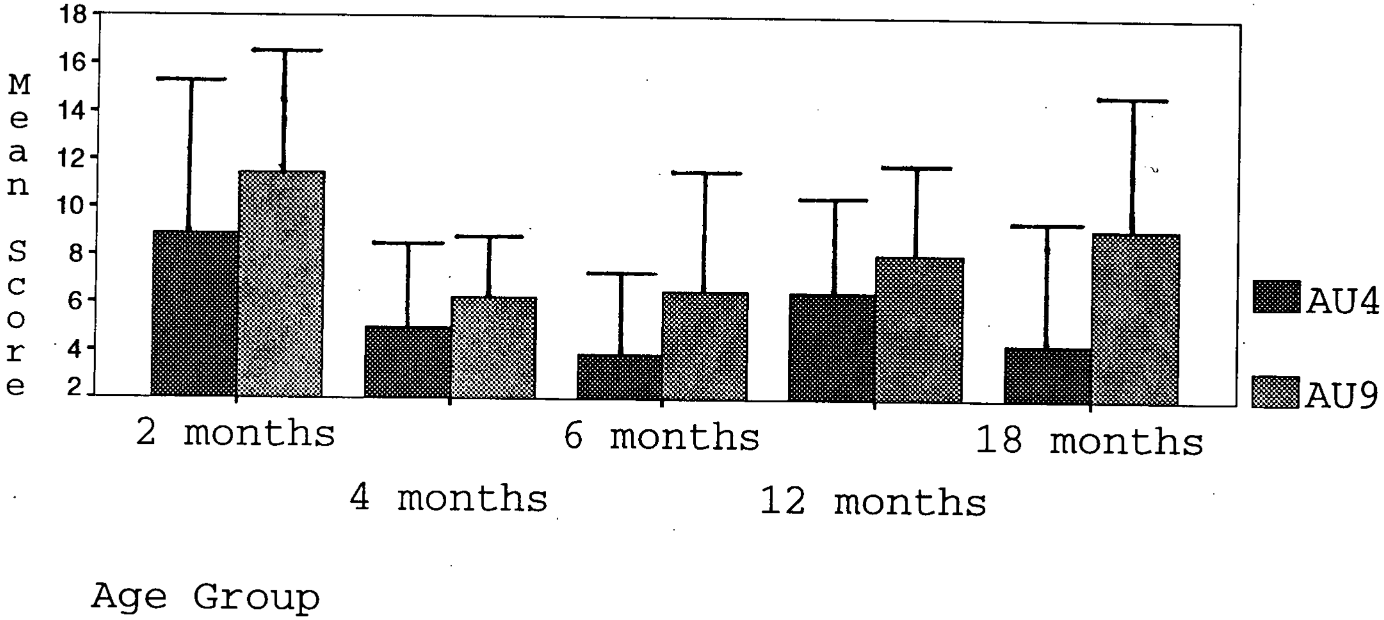


Table 17

Results: Baby FACS Actions by Event

Action Unit	t	*p*
AU1-Inner Brow Raise	0.75	>.40
AU3-Brow Knit	10.32	<.001
AU4-Brow Lower	10.92	<.001
AU6/AU7-Orbit Tightening	11.27	<.001
AU9/AU10-Levator Contraction	13.57	<.001
AU17-Chin Raise	2.48	<.02
AU26-Jaw Drop	9.68	<.001
AU43-Eyes Closed	10.19	<.001
AU44-Squint	3.03	<.005
AU75d-Tense, Concave Tongue	6.96	<.001

The analyses revealed that the following variables occurred more frequently during the ``injection'' event than the ``baseline'' event: AU3-Brow Knit, AU4-Brow Lower, AU6/7-Orbit Tightening, AU9/10-Levator Contraction, AU26-Jaw Drop, AU43-Eyes Closed, AU44-Squint, and AU75d-Tense, Concave Tongue. AU 17-Chin Raise was also more frequent during the ``injection'' event but this finding did not reach significance. AU1-Inner Brow Raise did not discriminate between the two events.

Analyses conducted on the ''recovery'' event.

The relationship between age and qualitative changes in the facial expression of pain during the ''recovery'' event was examined by conducting a oneway MANOVA with the five levels of age as the independent variable and the various facial actions as dependent variables. Once again, this was conducted separately for each of the coding systems. Cell means and standard deviations obtained from this analysis for the NFCS data are given in Table 18.

Table 18

Cell Means and Standard Deviations:

NFCS Actions by Age

		Age group:				
Action Unit		2 Months	4 Months	6 Months	12 Months	18 Months
Brow Bulge	M	4.10	2.03	4.20	3.43	4.35
	SD	1.52	1.57	1.14	1.71	0.87
Eye Squeeze	M	3.00	0.58	2.10	1.58	1.50
	SD	1.89	1.58	2.08	1.83	1.72
Deepened Naso-labial Furrow	M	3.60	1.83	4.00	3.38	4.38
	SD	1.96	1.76	1.49	1.10	0.84
Open Lips	M	4.23	3.70	4.60	4.35	4.55
	SD	1.60	2.06	0.97	1.42	0.67
Taut Tongue	M	1.70	0.22	0.60	0.95	0.00
	SD	2.06	0.46	1.08	1.17	0.00

$n=10$

The main effect of age group ($F(20, 137)=1.86$, $p<.05$) was significant. Follow-up analyses were conducted in the form of 5 oneway ANOVAs on the individual facial action variables, with α at the 0.005 level. The results are given in Table 19.

Table 19

Univariate Results: NFCS Actions by Age

Action Unit	F	p
Brow Bulge	4.72	<.005
Eye Squeeze	2.37	<.10
Deepened Nasolabial Furrow	4.30	<.005
Open Lips	0.64	>.50
Taut Tongue	3.23	<.05

n=10

According to the α=0.005 criterion, significant results were obtained for Brow Bulge and Deepened Nasolabial Furrow. Trends were present for Taut Tongue and Eye Squeeze. Follow-up analyses (Tukey, α=0.005) on Brow Bulge and Nasolabial Furrow revealed that 18 month old infants displayed more brow bulge and deepened nasolabial furrow than 4-month old infants, and that 6-month old infants displayed more deepened nasolabial furrow than 4 month old infants. Figure 8 depicts the means for each age group. Inspection of the means for Eye Squeeze and Taut Tongue suggested that 2-month old infants displayed more eye squeeze than 4-month old infants, and that 2-month old infants displayed more taut tongue than 18-month old infants.

Cell means and standard deviations obtained from the Baby FACS coding are given in Table 20.

Figure 8

Individual NFCS Actions by Age

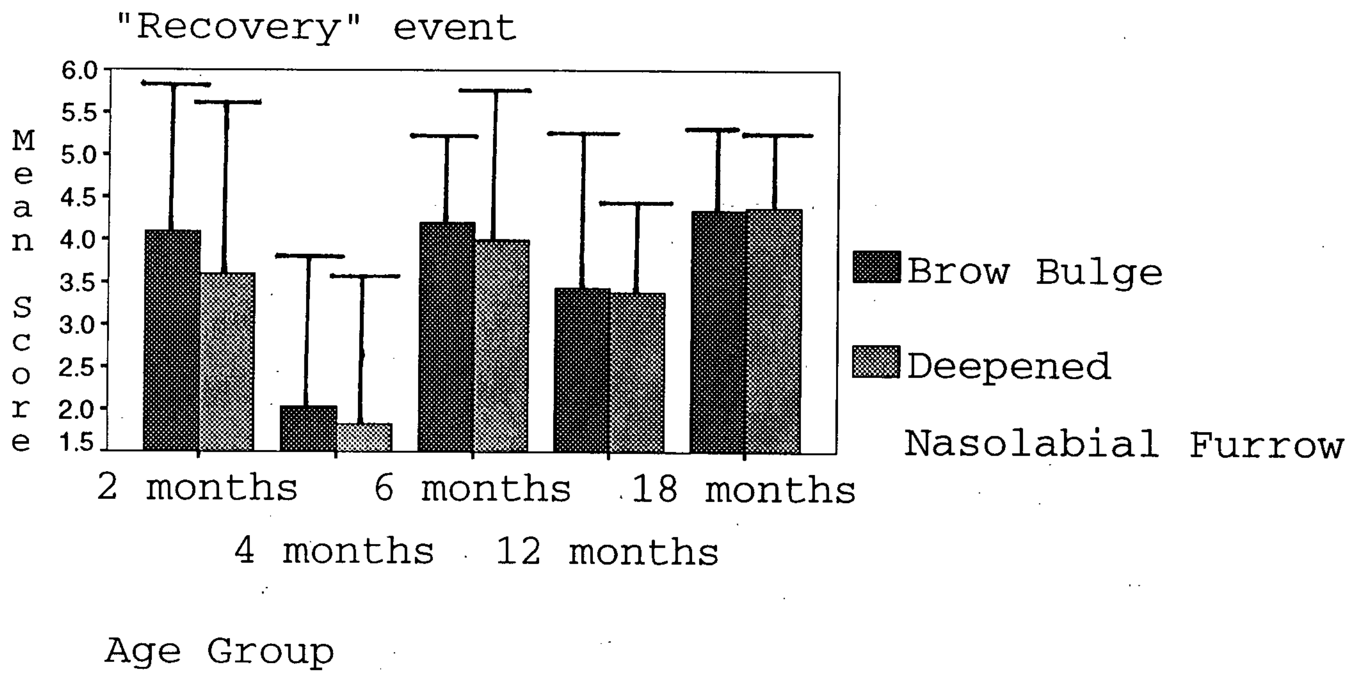


Table 20

Cell Means and Standard Deviations: Baby FACS Actions by Age

Action Unit		Age group: 2 Months	4 Months	6 Months	12 Months	18 Months
1 Inner Brow Raise	M	0.10	0.48	1.73	0.60	0.48
	SD	0.32	0.84	2.69	1.35	0.50
3 Brow Knit	M	9.03	2.48	6.26	7.98	8.59
	SD	7.12	2.31	4.71	5.25	5.48
4 Brow Lower	M	8.80	3.03	5.06	4.02	8.48
	SD	7.45	4.73	4.84	4.07	4.80
6/7 Orbit Tighten-ing	M	10.90	3.17	7.85	8.22	8.65
	SD	6.03	3.75	6.00	5.73	7.00
9/10 Levator Contract-ion	M	10.50	4.23	7.85	10.67	10.90
	SD	6.45	6.62	6.42	5.37	5.15
17 Chin Raise	M	3.20	1.22	2.30	3.35	3.00
	SD	6.25	3.46	3.83	5.21	5.49
26 Jaw Drop	M	15.90	12.25	13.70	12.27	14.45
	SD	7.28	3.97	3.36	4.68	3.81
43 Eyes Closed	M	6.10	1.79	5.48	3.43	4.08
	SD	7.39	3.17	5.29	6.27	5.86
44 Squint	M	3.20	0.68	2.70	1.67	2.28
	SD	6.48	1.62	5.46	3.33	4.03
75d Tense, Concave Tongue	M	1.20	0.03	0.73	1.27	0.55
	SD	2.098	0.08	1.35	1.64	0.93

n=10

The main effect of age group was not significant for the Baby FACS actions during the "recovery" event ($F(40,138)=1.23$, $p<.20$).

DISCUSSION

Facial Actions Expressing Pain in Infants

The present study is consistent with the literature on pain in neonates (e.g., Craig & Grunau, 1993; Johnston et al., 1993) in identifying a constellation of facial actions that occur in response to a painful event. Higher scores were obtained immediately following the injection than during the baseline period for these actions: NFCS Brow Bulge, NFCS Eye Squeeze, NFCS Deepened Nasolabial Furrow, NFCS Open Lips, NFCS Taut Tongue, Baby FACS AU3-Brow Knit, Baby FACS AU4-Brow Lower, Baby FACS AU6/AU7-Orbit Tightening, Baby FACS AU9/AU10-Levator Contraction, Baby FACS AU26-Jaw Drop, Baby FACS AU43-Eyes Closed, and Baby FACS AU75d-Tense, Concave Tongue. Thus the infants responded by lowering and drawing together their brows, tightening the muscles around their eyes, closing their eyes, deepening their nasolabial furrows, opening their mouths and displaying a tense, cupped tongue.

Principal components analyses determined that a single factor solution was most appropriate for each coding system, which is consistent with the view that the different actions reflect a single underlying construct, that of pain.

These findings are largely consistent with other descriptions of the infant pain expression. For example, the infant pain expression, as defined in Izard's MAX system (1979) consists of sharply lowered and drawn together brows with bulges between them, vertical furrows on the forehead, a broadened bulging nasal root, tightly closed eyes with a horizontal furrow of the upper lid, raised cheeks with an increase in tissue mass, a deepening of the nasolabial fold, and an open, squarish, angular mouth.

Using NFCS, Grunau et al., (1990) identified the cluster of lowered brow, deepened naso-labial furrow, eyes squeezed shut, open lips, and a taut, cupped tongue, which is perfectly consistent with the present study. Similar results were obtained by Grunau and Craig (1987) and Johnston et al. (1993). While the use of Baby FACS in the study of neonatal pain has been infrequent, Craig et al. (1994) used an earlier version of Baby FACS (Oster & Rosenstein, 1982) in coding the facial expressions of preterm and fullterm infants undergoing heel lance. They found that the following actions were common immediately following a painful stimulus: AU4-Brow Lower, AU6-Cheek Raise, AU12-Lip Corner Pull, AU25-Lips Part, AU26-Jaw Drop, and AU43-Eyes Closed. All but AUs 25 and 43 were significantly more frequent following heel lance than during a preliminary swabbing.

In the present study, seven facial actions occurred with sufficient frequency to be included in the analysis, and showed a significant difference between the "baseline" and "injection" events. Three of these, AUs 4, 6, and 26, were among those identified by Craig et al (1994).

However, in contrast to the previous findings (Craig et al., 1994), AUs 3, 9/10, 43, and 75d, did differ significantly between "baseline" and "injection" segments in the present study. This finding may be due to the addition of intensity coding, which was not done in the earlier study. As well, most of the infants studied by Craig et al. were premature. Consequently, age differences may be responsible for discrepant findings. AU9/10-Levator Contraction and AU43-Eyes Closed have been observed in studies of adult facial expressions of pain using the FACS system (e.g., Hadjistavropoulos & Craig, 1994). AUs 3-Brow Knit and 75d-Tense, Concave Tongue are not scored in adults, as they are modifications added to FACS to make it more suitable for use with infants (Oster & Rosenstein, 1982).

Temperament and the Facial Expression of Pain

Infants show considerable variability in their response to painful stimuli (Grunau et al., 1990). Consequently, researchers have speculated that individual difference factors such as temperament may play a role (e.g., Grunau & Craig, 1987; Grunau et al, 1990; Hamilton & Zeltzer, 1994). In the current study, it was hypothesized that scores on a questionnaire measure of the negative emotionality dimension of temperament would predict the degree of response to a painful stimulus. This prediction was not borne out by the results of the study. When correlations between pain summary scores and temperament scores were examined, the absolute value of r was very small, ranging from .00 to 0.14, and none of the correlations reached statistical significance.

This finding was unexpected. An association between negative emotionality and pain expression would seem extremely logical. The negative emotionality dimension of temperament refers to individual differences in the frequency, intensity, and duration of expressions of negative affect. Since pain is a prime example of negative affect in the infant, it would seem likely that children whose parents rated them as higher on negative emotionality (i.e. "fussier" or "more difficult") would react to immunization with greater intensity (scoring higher on pain summary scores). Research with older children has identified temperament as a predictor of pain-related behaviours (Davison et al., 1986; Wallace, 1989; Schechter et al., 1991; Young & Fu, 1988). However, it is noteworthy that a recent study of immunization pain in infants (Taddio, Nulman, Goldbach, Ipp, & Koren, 1994) found no relationship between temperament and pain scores.

In light of the null findings, the power of the present study was examined. It was determined that the power to detect a correlation of medium magnitude (r=.30) during the "injection" event (n=75) was 0.75. At the "recovery" event, where the sample size dropped to 55, power was 0.62. It was concluded that the study had moderate power to detect a correlation in the population. However, the actual correlations obtained were very small (r=0.14), such that even if the study had sufficient power, and the results reached significance, temperament would predict 1.96% of the variance in pain response, a proportion of little practical significance. It is unlikely that the failure to find the predicted relationship was caused by low statistical power.

There is however, a second methodological concern in that the use of parent report questionnaires in the assessment of temperament has been heavily criticized. There is concern that the instruments are too subjective and reflect more about the parent than the child. Maternal characteristics, such as demographic and personality variables, have been found to predict questionnaire scores (Bates et al., 1979; Vaughn, Taraldson, Crichton & Egeland, 1981). However, while it is necessary to acknowledge the subjective component of parent report, there seems to be an objective component as well. For example, parent reports correlate with home observation measures (Bates et al., 1979), characteristics of crying including frequency, duration, and perceived aversiveness (Barr, Kramer, Pless, Boisjoly, & Leduc, 1989; Lounsbury & Bates, 1982), and the adrenocortical response to laboratory tests involving maternal separation (Gunnar, Mangelsdorf, Larson, & Hertsgaard, 1989). Consequently, Bates (1992) has argued that parent report measures deliver "the most meaning for the cost" and recommends their use as a first probe in unresearched areas.

In addition to concerns about validity, Hubert et al. (1982) reviewed the available instruments and concluded that "no single psychometrically adequate instrument is available" (p. 571). However, the "Fussy/Difficult" dimension of the Infant Characteristics Questionnaire used in the present study has shown high test-retest reliability and moderate to high stability, prompting Hubert et al. (1982) to recommend its use for the assessment of difficult temperament. While the assessment of temperament remains imperfect, its shortcomings probably do not account for the null findings discussed here.

A final methodological concern relates to the fact that the dependent measures used in the present study were summary scores. No attempt was made to tease apart the dimensions of frequency and intensity of the expression of pain. It is possible that temperament predicts one of these, and that such a relationship was obscured by the composite measure used in the present study.

The question that prompted the current study remains unanswered. Substantial individual differences in the response to painful stimuli were observed in the present study and in previous research (Grunau et al., 1990). Furthermore, there is evidence of moderate stability in the response to pain. For example, Worobey and Lewis (1989) found that reactivity to heel stick at 2 days of age correlated with reactivity to DPT injection at 2 months of age. Izard et al. (1987) found that the amount of time that an infant displayed the facial expression of "anger" rather than "pain" following immunization remained stable from 2 to 19 months. It should be noted that the long-term stability of the facial expression of pain as indexed in the present study (i.e. by NFCS or Baby FACS) has not been firmly established, although the Izard et al. (1987) finding is suggestive. If such stability in response to painful stimuli exists, it would suggest some dispositional factor or trait. However, the results of the present study suggest that such a trait is independent of the negative emotionality dimension of temperament.

What might account for individual differences in response to pain stimuli? One recent report suggests that previous pain experiences may play an important role. Taddio et al. (1995) found that male infants who had undergone circumcision received higher pain scores following immunization injections at 4 and 6 months of age, relative to uncircumcised infants. Circumcised infants cried longer following the injection and received higher scores on a composite pain measure derived from cry, facial expression, and body movements. It is possible that children who are subjected to more painful stimuli become sensitized and respond to pain with greater intensity. However, the analysis conducted by Taddio et al. (1995) was post-hoc in nature and needs to be replicated. It is consistent with evidence suggesting that toddlers who experienced prolonged hospitalization and multiple painful procedures as infants differ from normal controls on measures of pain sensitivity and somatization (Grunau, Whitfield & Petrie, 1994; Grunau, Whitfield, Petrie, & Fryer, 1994).

The present study fails to confirm expectations that temperament mediates the response to painful stimuli. In order to elucidate the factors behind individual differences in response to painful stimuli, it will be necessary to first establish whether the pain response remains stable across age. Longitudinal studies, though difficult to execute, are sorely needed. If stability of response is determined, researchers should further investigate the role of previous pain experience. Anatomical variations may also be of interest. During the present study, one of the nurses hypothesized that the musculature of the infant may mediate the pain response ("It's the skinny ones that scream").

If the pain response does not prove to be stable with age, attention should be focussed on variability relating to situational factors. Other factors such as the experience of the nurse, the anxiety level of the parent, or the physiological state of the infant prior to the injection may also play a role. It is likely that both dispositional and situational factors have an effect.

Developmental Changes in the Facial Expression of Pain in Infants

The present study also aimed to present a descriptive account of age-related changes in the facial response to a painful stimulus. Age-linked changes in the degree of pain expressed will be discussed first.

The analyses revealed that 2 month old infants scored higher than 4 month old infants on pain summary scores derived from the NFCS coding. Similarly, 2 month old infants scored higher than 4 and 6 month old infants on summary scores derived from the Baby FACS coding. In the "recovery" period, both 18-month old infants and 6-month old infants scored higher than 4-month old infants on the pain summary scores derived from NFCS coding. No other differences were significant. Of the five significant differences, four involved the 4-month age group, suggesting a dip in the intensity of pain expressed at that age. Such a decrease may reflect either a change in the intensity of the pain experienced, or a change in expression independent of what is felt.

It was surprising that, in the analyses conducted on the "baseline" and "injection" events, the interaction between age and event did not reach significance. This indicates that the 2-month old infants received higher pain scores than other groups during both events, i.e. even before the pain stimulus was introduced. It is thus possible that the youngest infants reacted to the relatively low level stimulation of the baseline period (such as being undressed and positioned for the injection) with distress, and continued to react to the injection with greater intensity. In fact, inspection of the means for each age group for each event (see Table 10 and 11) support this hypothesis, as the difference between the 2-month old infants and other groups is actually greatest during the ''baseline'' event. Possibly, an analysis of covariance would have been appropriate. Nevertheless, the developmental changes that were uncovered in this period are consistent with previous research, and it is believed that they represent consistent differences in the pain expression.

Previous research, while ranging widely in the indices of pain used, supports the notion of a decrease in the intensity of physiological and behavioural responses to pain around the age of 4 months. For example, Lewis and Thomas (1990) studied the rise in cortisol (a stress hormone) following DPT injection, and found that the increase was greater in 2-month old infants than in 4-month old infants. In behavioural analyses (the dependent variable combined facial expression and cry), the 2- and 4- month old groups did not differ, but 6-month infants quieted faster than either of the two younger groups. Ramsay and Lewis (1994) found that, for those infants showing a rise in cortisol, 2-month old infants showed a more intense pain reaction and a greater increase in cortisol than 6-month old infants. Maikler (1991), studying infants aged 2-6 months, split her sample into two groups, under 16 weeks and over 16 weeks (approximately 4 months). She found that the duration of the pain expression, as measured by facial expression, cry, and body movement, was longer for the younger group. She also noted that "exceptionally dramatic behavior [was] observed in the younger infants. Their behavior was generally characterized by the rigid extension of all extremities and intense crying" (p. 402). Taken as a whole, the available evidence suggests a drop in the degree of response to painful stimuli at approximately 4 months of age.

However, the present study found little evidence of a linear decrease in the pain response over the first 2 years of life. The data were at least suggestive of a later increase in the degree of pain response, in that 18-month old infants and 6-month old infants scored higher than the 4-month group on the NFCS pain summary score during the "recovery" event. Since these differences were not significant immediately after the injection, it seems likely that older infants do not initially respond with greater intensity than the 4-month olds. Instead, they take longer to quiet, such that 20 seconds after the injection, they are still achieving high scores on the pain summary measure.

Beyond the age of 6 months, there is a dearth of information on developmental changes in the pain response. Izard et al. (1983) found that the duration of the "physical distress" expression was shorter in 19 month old infants than in 2-month old infants or 6-month old infants. These results were replicated by Izard, Hembree, and Huebner in 1987. However, the duration of the "anger" expression was found to increase with age. The "physical distress" and "anger" expressions are actually extremely similar (Oster et al., 1992), yet they were treated as mutually exclusive in Izard's studies. Consequently, if Izard's data were coded with NFCS or Baby FACS a different conclusion may have been reached, and it is difficult to compare the results to the present study.

While properties of the stimulus were confounded with age (i.e. the 12-month old infants received a different injection, administered to the arm rather than the leg) it is unlikely that this affected the conclusions substantially. In fact, the infants in the 12-month group were not found to be significantly different from other age groups on any of the variables. However, it remains possible that differences that might otherwise have been identified were obscured by this confound.

Analyses of the relationship between age group and various background characteristics did not identify any factors confounded with the age distribution. However, it was noted that there were differences in the interventions parents chose to soothe infants of different ages. There was a general decrease with age in holding laterally (cradling the infant face up). As well, parents were more likely to hold their child ventrally (with the child's chest towards the caregiver's shoulder) during the 12-month MMR injection. These differences are likely mediated by practical concerns: it is considerably more difficult to cradle a toddler than an infant. Since the MMR immunization was the only shot administered in the arm, the ventral position probably allowed the nurse easier access to the child and protected the sore arm from inadvertant contact with the mother. It remains plausible that differences in parental soothing style contributed to differences in the pain response, but they do not seem to explain the results.

It is possible to speculate about the reasons for the observed developmental changes. A number of alternatives exist, including physical maturation, change in cognitive capacities, changes in affect, and the effects of socialization. In addition, these factors are likely to interact.

While the basic physiological mechanisms necessary for the perception of pain are in place at birth (Anand & Carr, 1989), the nervous system continues to develop as the child grows. This development may be manifested in age-related differences in the pain response. Using the cutaneous flexor reflex as an index of pain, Fitzgerald, Shaw, and McIntosh (1988) determined that preterm neonates were hypersensitive to nociceptive input (the application of graded von Frey hairs) in comparison with fullterm neonates. It was hypothesized that the age-related increase in pain thresholds reflected the maturation of inhibitory controls descending from the brain to the spinal cord. It was further noted that the threshold in fullterm infants (less than 2g) was still much lower than that found in adults, which is 30g or higher. Thus, the threshold must continue to increase during the postnatal period. While Fitzgerald and her colleagues studied the pain threshold rather than the intensity of response, a change in inhibitory mechanisms would likely affect both. Consequently, the observed decrease in pain response at approximately 4 months of age may reflect the same process of change that has been suggested to occur in younger infants: the maturation of mechanisms which inhibit the transmission of pain.

At this point, it is necessary to return to the model of pain behaviour and communication (Craig et al., in press), and recognize the distinction between expression and experience. In spite of evidence regarding the cutaneous flexor reflex (Fitzgerald et al., 1988) and the physiological and metabolic stress response mounted by the preterm infant (Anand & Hickey, 1987), which suggest hypersensitivity, studies of the premature infant's facial response to pain (e.g., Craig et al., 1993) have suggested that, relative to fullterm newborns, preterms show less activity in response to painful stimuli. It was concluded that premature infants are less capable of expressing their pain, but not less capable of experiencing it (Craig et al., 1993).

In comparison with premature infants, it is likely that the 4-month old does have a greater capacity to express the pain that she feels, since 4-month old infants display greater behavioural organization in a number of realms. However, the point that experience and expression are distinct, though difficult to differentiate experimentally, is well taken. The present study is not able to differentiate among the two, and it is possible that the differences observed in the 4 month age group were differences in the way in the degree to which pain and distress were expressed rather than the degree to which they were experienced by the infant. For example, these changes may reflect a greater degree of self-modulation or self-control, such that there is less need of adult intervention and less need to communicate one's pain.

Factors that may underlie the observed increase in pain response for the 6- and 18-month old infants during the "recovery" event also deserve attention. One possible explanation emphasizes the role of cognitive development. The older infant is more capable of attributing meaning to the situation. This may result in a more complex emotional reaction that takes longer to decay. At 6-8 months, pain begins to be confounded with anticipatory and concurrent anxiety (Craig & Grunau, 1991). As well, older infants may be more likely to express anger following immunization (Izard et al., 1983; Izard et al., 1987).

The literature on pain in adults emphasizes the inter-relations of pain and negative emotions such as anger, fear, and sadness (e.g., Melzack & Wall, 1988). In the infant literature, Izard et al. (1983) have suggested that negative emotions such as anger, fear, and sadness may "amplify and sustain the overall negative affective experience" (p. 419). Similarly, Peterson, Harbeck, Farmer and Zink (1991) have noted that it is difficult to separate anger and anxiety from a child's pain experience, and that these emotions can result in a ''spiraling increase in experienced pain'' (p. 44). There is empirical support for this proposition in that the time required for an infant to quiet after immunization is positively associated with the proportion of time that the facial expression of ''anger'' is expressed (Izard et al., 1983). Thus, older infants' ability to extract information from the situation (for example, to realize that someone they trusted held them so that another adult could stick something sharp into their skin) may have caused them to react with outrage and anxiety, which then prolonged or intensified their expressions of distress.

We must once again acknowledge that the observed age differences may exist in the perception of pain, the communication of what is felt, or both. Older infants may not experience more pain, but simply be more effective in expressing distress. They may also have acquired socialized display rules.

It is interesting to note that, in the second year of life, speech becomes a progressively more viable and useful tool for the child. This study did not examine differences in cry or language. Despite the increased availability and use of speech, the facial expression remained an important mode of expression for infants over a year of age.

Turning to individual action units, a number of age-related changes were identified. In the "baseline" and "injection" periods, a significant difference was identified in Baby FACS AU9/AU10-Levator Contraction. It was determined that 2-month old infants displayed more levator contraction than the 4-, 6-, or 12-month old groups. A trend on Baby FACS AU4-Brow Lower approached significance, suggesting that 2-month old infants achieved higher scores on brow lowering than did 6-month old infants. During the "recovery" period, differences were revealed in NFCS Brow Bulge and Deepened Nasolabial Furrow. Analyses determined that 4-month old infants scored lower than 18-month old infants on brow bulge, and lower than 6-month old infants on deepened nasolabial furrow.

These differences are roughly consistent with the results of the previous analyses in suggesting that 2-month old infants differed from other groups during the "baseline" and "injection" events, and 4-month old infants differed from other groups during the "recovery" period. Analyses on individual action units suggested that there are developmental changes in the facial actions which (1) lower the eyebrows and draw them together and (2) raise the upper lip and deepen the nasolabial furrow. The NFCS action of Brow Bulge and Baby FACS AU4-Brow Lower are roughly similar, as are NFCS Deepened Nasolabial Furrow and Baby FACS AU9/AU10-Levator Contraction. Despite this similarity, only actions from a single coding system achieved significance during a given event (NFCS during the ''baseline'' and ''injection'' events, Baby FACS during the ''recovery'' event), suggesting that the differences are fairly subtle. The task of interpreting the results of the two coding systems will be discussed in a later section.

The only previous investigation of age-related changes in individual action units was conducted by Johnston et al. (1993), who compared premature, full-term, 2- and 4-month old infants using NFCS coding. The pain stimulus was DPT injection in both the 2 and 4 month groups. The 2- and 4-month old infants were not found to differ on any of the NFCS actions. In light of these conflicting findings, and because of the difficulty of interpreting the pattern of findings in the present study, developmental changes in individual action units should be replicated before conclusions are drawn.

The final issue to be addressed in terms of developmental change is the issue of age-related changes in eye closure. Izard and his colleagues (Izard et al., 1983; Izard et al., 1987) have noted that with increasing age, the facial expression of anger becomes more prevalent. Because the facial expression of anger as defined by MAX is similar to the facial expression of pain in every detail but that the eyes are open instead of tightly closed, it was hypothesized that infants would show an age-related decrease in Baby FACS AU43-Eyes Closed. Although the means showed a slight decrease with age (see Tables 15 and 20), it did not reach significance. Further research will be needed to evaluate the conflicting findings.

There has been a call for age-appropriate instruments in the assessment of pain in young children (Peterson et al., 1991). From the current study, it would seem our measuring instruments adequately capture infant facial activity. The age variation appears primarily in the magnitude of response. However, because of these differences in the degree of response, clinicians assessing pain may benefit from the use of age-specific norms.

The Relationship between NFCS and Baby FACS Coding

While both of the systems of facial coding used in this study index certain actions reflective of pain, they are not equivalent instruments. Baby FACS is a comprehensive system, intended to record all of the facial actions instigated by an event. NFCS is limited to actions bearing on the facial expression of pain. While NFCS action units may be similar to Baby FACS AUs, the definitions are not identical. Familiarity with both systems of coding suggests that the following pairs of actions would be the most closely related: NFCS Brow Bulge and Baby FACS AU3-Brow Knit, NFCS Brow Bulge and Baby FACS AU4-Brow Lower, NFCS Eye Squeeze and Baby FACS AU6/AU7-Cheek Raise, NFCS Deepened Nasolabial Furrow and Baby FACS AU9/AU10-Levator Contraction, NFCS Open Lips and Baby FACS AU26-Jaw Drop, and NFCS Taut Tongue and Baby FACS AU75d-Tense, Concave Tongue. The examination of correlation coefficients (see Tables 7 and 8 in the Results section) revealed that the scores were significantly correlated for each pair. The values of r ranged from 0.49 (for Brow Bulge and AU3) to 0.76 (for Eye Squeeze and AU6/AU7). However, in evaluating the numbers, it is important to note that significant correlations would be expected among action units indicative of pain, even if the actions were anatomically dissimilar. For example, the correlation between NFCS Deepened Nasolabial Furrow and Baby FACS AU43-Eyes Closed was 0.40.

Not only are the definitions of individual action units slightly different in NFCS and Baby FACS, they are scored in a very different fashion. NFCS action are scored solely for presence or absence. Thus each 2-second segment receives either a 0 or a 1, and scores for the event range from 0 to 5. In contrast, Baby FACS coding assigns an intensity score to each action in each 2-second segment. This score may range from 0 to 5. Thus when Baby FACS scores are summed for the event, they may range from 0 to 25. Furthermore, if an infant were to display an action at a very low level throughout the entire event (for example, if the lips were just slightly parted), the child would receive a 5 out of 5 in NFCS, but only a 5 out of 25 in Baby FACS. Consequently, it makes sense that the correlation between between similar actions is less than perfect. This disparity between the two systems is likely responsible for analyses where only one type of coding showed a significant difference.

Given the differences between the two systems, it was gratifying that the pain summary scores constructed from each system correlated highly (r=.79). Such a finding suggests that the pain expression is robust enough to produce similar scores on instruments taking different approaches to measurement. While the present study was not explicitly designed to compare the two approaches, it does offer some information to investigators wishing to choose a single instrument. While the two systems produce different results, there is little evidence that one is better than the other for uncovering differences in the pain response. If a researcher must limit herself to a single instrument indexing the degree of pain expressed, we found little reason that investigators should invest the time necessary for more complicated Baby FACS coding. However, the fact that each coding system led to different patterns of findings does suggest that some additional information may be derived from the use of the Baby FACS system, or from the addition of an intensity dimension to NFCS.

The present study was the first to use NFCS with infants up to 18 months of age, while Baby FACS was designed for ''infants and young children.'' Consequently, we examined the results for any indication that NFCS is inappropriate for older infants. For example, findings of significant age differences in Baby FACS action units that have no counterpart in NFCS would have been cause for concern. The individual actions that showed age-related differences in the Baby FACS coding (AUs 4 and 9/10) are actions that have rough equivalents in NFCS coding. There is no evidence that NFCS is inappropriate for use with older infants and toddlers.

Differences in the Number of Pain Stimuli

Data collected for the present study provided the opportunity to look at differences in the pain expression resulting from the number of stimuli to which the infant was subjected. Due to a change in the immunization protocol, some infants received two injections, the DPT vaccine and the Hib vaccine. Others received both vaccines in a single injection. The two groups (one injection versus two injections) were compared on scores for individual action units in the period 20-30 seconds following the last invasive stimulus. It was found that infants who received two injections displayed more taut tongue than those who had received a single injection. However, infants who were given a single injection displayed more brow bulge and deepened nasolabial furrow than infants subjected to two injections. In combination, these findings suggest that the cumulative effect of multiple pain stimuli is complex, defying a simple judgment about the relative intensity of the pain experience in the two groups. The effect of multiple stimuli deserves further study, as it is relevant to the number and frequency of painful medical procedures that should be performed on infants as part of optimal medical practice.

Conclusions

The present study was consistent with previous research in identifying a configuration of facial actions associated with the painful stimulus of immunization. The hypothesis that individual differences in this response were mediated by the negative emotionality dimension of temperament was not confirmed.

Developmental changes in the facial expression of pain were identified. During the "baseline" and "injection" events, 2-month old infants scored higher on pain summary scores than the 4-month old infants (according to both coding systems) and than 6-month old infants (according to the Baby FACS coding system). During the "recovery" period, 4-month old infants scored lower on a pain summary score than did 18-month old infants or 6-month old infants (according to the NFCS coding system). Age-related changes in the individual action units of NFCS Brow Bulge, NFCS Deepened Nasolabial Furrow, and Baby FACS AU9/AU10-Levator Contraction were identified. These changes were roughly consistent with the changes identified in pain summary scores. Such developmental changes may have significance for the assessment of pain in infants.

Limitations of the present study include the inability to separate the experience of pain from its expression. This confound is likely unavoidable. As well, our effort not to interfere with the routine practices of the nurses and parents observed meant that there was variability in the pain stimulus and the conditions surrounding the injection. It was felt that the lack of experimental control was warranted by the increase in external validity. The study is also subject to the limitations of parent report assessments of temperament. Finally, we did not attempt to separate the dimensions of the pain response, such as latency to the peak reaction, latency to quiet, and intensity of facial actions. Future studies may benefit from unpacking these aspects and considering them separately.

A number of questions deserve further examination. The surprising failure to identify a role for temperament suggests that further research will be necessary to delineate the factors underlying individual differences in the expression of pain. Such research would benefit from the an investigation of the stability of pain responses over the first 2 years of life, as well as investigation of a number of situational characteristics. The present findings on age-related changes in facial expression should be replicated and integrated with research on other components of the pain response such as cry and the use of language, physiological variables, and the metabolic stress response.

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APPENDIX A

Background Characteristics Questionnaire

INFANT QUESTIONNAIRE

Subject number: ____________

Today's date: ____________

What is your baby's birth date? ______________________________

Was your baby premature? ______________________________

If so, how many weeks before your due date was he or she born? ______________________________

What was your baby's weight at birth? ______________________________

Is this baby your first-born child? ______________________________

If not, how many older children do you have? ____________

Is your baby generally healthy? ______________________________

If not, what illness or condition does he or she have?
____

Is your baby male _____ or female ______ ?

What is your age? ______________________________

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 so, what?

____ Tylenol

____Other: ______________________

APPENDIX B

Sample Items from the Infant Characteristics Questionnaire (Bates, 1992)

1. How easy or difficult is it for you to calm or soothe your baby when he/she is upset?

1	2	3	4	5	6	7
very easy			about average			difficult

5. How many times per day, on the average, does your baby get fussy and irritable - for either short or long periods of time?

1	2	3	4	5	6	7
never	1-2 times per day	3-4 times per day	5-6 times per day	7-9 times per day	10-14 times per day	more than 15

13. When your baby gets upset (e.g., before feeding, during diapering, etc.), how vigorously or loudly does he/she cry and fuss?

1	2	3	4	5	6	7
very mild intensity or loudness			moderate intensity or loudness			very loud or intense, really cuts loose

APPENDIX C

NFCS Actions
(from Grunau & Craig, 1990)

Action	Description
Brow Bulge	Bulging, creasing, and vertical furrows above and between brows occurring as a result of the lowering and drawing together of the eyebrows.
Eye Squeeze	The squeezing or bulging of the eyelids. Bulging of the fatty pads about the infant's eyes are pronounced.
Deepened Nasolabial Furrow	The pulling upwards and furrow deepening of the nasolabial furrow (a line or wrinkle that begins adjacent to the nostril wings and runs down and outward beyond the lip corners).
Open lips	Any separation of the lips.
Stretch Mouth (Vertical)	A tautness at the lip corners (vertical) coupled with a pronounced downward pull of the jaw. Often seen when an already wide open mouth is opened a fraction further by an extra pull at the jaw.

Stretch mouth (Horizontal)	A distinct horizontal pull at the corners of the mouth.
Lip purse	The lips appear as if an "oo" sound is being pronounced.
Taut tongue	A raised, cupped tongue with sharp tensed edges. The first occurrence of taut tongue is usually easy to see, often occurring with a wide open mouth. After this first occurrence, the mouth may close slightly. Taut tongue is still scoreable on the basis of the still-visible tongue edges.
Chin quiver	An obvious high-frequency, up-down motion of the lower jaw.
Tongue protrusion	Tongue visible between the lips extending beyond the mouth.

APPENDIX D
Baby FACS Actions
(Oster & Rosenstein, 1993)

A. Upper Face Actions

Brow Actions:

AU 1 - Inner Brow Raiser

AU 2 - Outer Brow Raiser

AU 3 - Brow Knitting Alone

AU 4 - Brow Knitting and Lowering

Cheek and Eyelid Actions:

AU 5 - Upper Lid Raiser

AU 6 - Cheek Raiser & Lid Compressor

AU 7 - Lid Tightener

AU 40 - Eyes Normally Open (optional)

AU 41 - Lid Droop

AU 42 - Slit

AU 43 - Eyes Closed

AU 44 - Squint

AU 45 - Blink

AU 46 - Wink

AU 49 - Tears in Eyes

Head and Eye Positions:

AU 47 - Looking at a Designated Person, Object or Event (optional)

AU 48 - Averting the Gaze from a Designated Person, Object, or Event (optional)

AU 51 - Head Turn Left

AU 52 - Head Turn Right

AU 53 - Head Up

AU 54 - Head Down

AU 55 - Head Tilt Left

AU 56 - Head Tilt Right

AU 57 - Head Forward

AU 58 - Head Back

AU 59 - Head Shaking Up and Down

AU 60 - Head Shaking Side-to-Side

AU 61 - Eyes Turn Left

AU 62 - Eyes Turn Right

AU 63 - Eyes Up

AU 64 - Eyes Down

AU 65 - Crosseye

AU 66 - Walleye

AU 67 - Looking Elsewhere, Searching or Looking Around (optional)

AU 84 - Neck Stretches Up

B. Lower Face Actions

Up-Down Actions:

AU 9 - Nose Wrinkling

AU 10 - Upper Lip Raising

AU 15 - Lowered Lip Corners

AU 16 - Lower Lip Pulled Down

AU 17 - Chin Raising

AU 25 - Lips Part

AU 26 - Jaw Drop

AU 27 - Mouth Stretch

AU 80 - Lips Relaxed and Closed (optional)

Horizontal Actions:

AU 14 - Lip Corners Pulled Inward: Dimpler

AU 20 - Lips Stretched Laterally

Oblique Actions:

AU 11 - Upper Lip Raised Obliquely and Flattened

AU 12 - Lip Corners Raised Obliquely: Smiling

AU 13 - Lip Corners Pulled Sharply Upward

Orbital Actions:

AU 8 - Lips Toward Each Other (seen with AU 25, 26, or 27)

AU 18 - Lip Pucker

AU 22 - Lip Funneler

AU 23 - Lips Tight

AU 24 - Lips Press

AU 28 - Lip Suck

Tongue Positions and Shapes:

AU 19 - Tongue Protrusion

AU 37 - Lip Wipe

AU 73 - Tongue in Contact With Lip (not a wiping movement)

AU 74 - Tongue Position in Mouth

AU 75 - Tongue Shape

C. Reflexes and Highly Stereotyped Facial Movements

AU 76 - Rooting

AU 77 - Yawning

AU 78 - Occipito-Frontalis Reflex

AU 79 - Startle

D. Miscellaneous Actions, Physiological Reactions

AU 81 - Chin Trembles

AU 82 - Head/Face Trembles or Shudders

AU 84 - Low-Intensity, Indefinite Mouth Movements: "Munchies"

AU 85 - Sneezes

AU 86 - Coughs

AU 87 - Swallows

AU 88 - Chokes

AU 89 - Nose Runs

AU 91 - Drools or Spits

AU 92 - Throws Up

E. Optional Codes for Facial Stilling and for Skipping Segments of a Record

AU 90 - Facial Stilling (facial muscles relaxed, absence of fleeting, low-level facial activity)

AU 99 - Not Coded (skipping)

APPENDIX E

Results of Preliminary Analyses

Associations Between Background Characteristics and Age Group

Effect	Test statistic	p value
Clinic	χ^2_{12}=14.16256	>.25
Nurse	χ^2_{16}=17.90476	>.25
Parent	χ^2_{4}=4.56349	>.25
Birth Order	χ^2_{16}=18.22271	>.25
Gender	χ^2_{4}=3.41880	>.25
Medication	χ^2_{4}=6.11111	>.15
Prematurity	χ^2_{4}=3.63806	>.25
Time Since Feeding	F(4,70)=0.5029	>.50
Time Since Waking	F(4,70)=0.9395	>.25

Associations Between Background Characteristics and Temperament

Effect	Test statistic	p value
Clinic	F(3,71)=2.0242	>.10
Nurse	F(4,70)=1.2714	>.25
Parent	F(1,73)=1.6096	>.20
Birth Order	F(4,69)=0.2935	>.50
Gender	F(1,73)=3.6800	>.05
Medication	F(1,73)=0.2405	>.50
Prematurity	F(1,73)=0.0687	>.50
Time Since Feeding	r=-.1468	>.20
Time Since Waking	r=-.1239	>.25

APPENDIX F

Frequency of Facial Actions

NFCS Actions

Action Unit	Percent of Segments in Which Action was Observed
Brow Bulge	61
Eye Squeeze	36
Nasolabial Furrow	57
Open lips	83
Vertical Mouth Stretch	4
Horizontal Mouth Stretch	1
Lip Purse	0
Taut Tongue	20
Chin Quiver	0
Tongue Protrusion	2

Baby FACS Actions

Action Unit	Percent of Segments in Which Action was Observed
AU1-Inner Brow Raise	11
AU2-Outer Brow Raise	6
AU3-Brow Knit	53
AU4-Brow Lower	42
AU5-Upper Lid Raise	3

Frequency of Facial Actions (cont.)

Action Unit	Percent of Segments in Which Action was Observed
AU6/AU7-Orbit Tightening	56
AU9/AU10-Levator Contraction	58
AU12-Lip Corners Raised Obliquely	3
AU14-Dimpler	1
AU15-Lowered Lip Corners	0
AU16-Lower Lip Pulled Down	2
AU17-Chin Raise	15
AU18-Lip Pucker	0
AU19-Tongue Protrusion	8
AU20-Lips Stretched Laterally	6
AU22-Lip Funneler	0
AU23-Lips Tight	0
AU24-Lip Press	0
AU26-Jaw Drop	81
AU28-Lip Suck	1
AU33-Blow	0
AU41-Lid Droop	0
AU42-Slit	0

Frequency of Facial Actions (cont.)

Action Unit	Percent of Segments in Which Action was Observed
AU43-Eyes Closed	33
AU44-Squint	11
AU45-Blink	9
AU49-Tears in Eyes	8
AU74b-Tongue Hooked Behind Teeth or Gums	0
AU74c-Tongue Raised	5
AU75b-Tongue Flat	0
AU75c-Tongue Tip Curled	0
AU75c2-Tongue Concave and Relaxed	0
AU75d-Tongue Concave and Tense	16
AU76-Rooting	0
AU81-Chin Trembles	0
AU82-Head/Face Shudders	1
AU85-Sneezes	0
AU86-Coughs	0
AU89-Nose Runs	0
AU91-Drools or Spits	2