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Neonatal pain facial expression: Evaluating the primal face of pain

Martin Schiavenato [a,*], Jacquie F. Byers [b], Paul Scovanner [c], James M. McMahon [a], Yinglin Xia [d], Naiji Lu [e], Hua He [e]

[a] University of Rochester, School of Nursing, 601 Elmwood Ave., Box SON, Rochester, NY 14642-8404, USA
[b] College of Nursing, University of Central Florida, Orlando, FL 32816, USA
[c] School of Electrical Engineering and Computer Science, University of Central Florida, Orlando, FL 32816, USA
[d] Department of Medicine, University of Rochester, Rochester NY 14642, USA
[e] Department of Biostatistics and Computational Biology, University of Rochester, Rochester NY 14642, USA

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Abstract

The primal face of pain (PFP) is postulated to be a common and universal facial expression to pain, hardwired and present at birth. We evaluated its presence by applying a computer-based methodology consisting of "point-pair" comparisons captured from video to measure facial movement in the pain expression by way of change across two images: one image before and one image after a painful stimulus (heel-stick). Similarity of facial expression was analyzed in a sample of 57 neonates representing both sexes and 3 ethnic backgrounds (African American, Caucasian and Hispanic/Latino) while controlling for these extraneous and potentially modulating factors: feeding type (bottle, breast, or both), behavioral state (awake or asleep), and use of epidural and/or other perinatal anesthesia. The PFP is consistent with previous reports of expression of pain in neonates and is characterized by opening of the mouth, drawing in of the brows, and closing of the eyes. Although facial expression was not identical across or among groups, our analyses showed no particular clustering or unique display by sex, or ethnicity. The clinical significance of this commonality of pain display, and of the origin of its potential individual variation begs further evaluation.

Keywords: Neonatal pain; Primal face of pain; Facial expression; Pain assessment; PFP

1. Introduction

The ability to express pain is thought to be present at birth as an adaptation to species survival [34]. An evolutionary view proposes that facial expression of emotions in general is a hardwired ability that is modulated through learned behavior [7,11]. Specifically to pain, Craig and colleagues' [5] *Sociocommunication Model of Infant Pain* proposes that the facial expression of pain in infants is a product of both biological and social factors. That is, it can be theorized that infants are equipped with a "primal face of pain" (PFP), an inborn or biologically determined ability to display distress like pain, which is censored or modulated through various developmental and sociocultural factors [30]. Supporting this is evidence that facial expressions of pain are more consistent in infants than in adults [6]. However, although a consistent display of pain has been observed even across various stimuli [24], evidence supporting a universal display of pain in infants has not been conclusive and remains poorly understood.

Regarding commonality of pain display, much has been written about the role of culture and race/ethnicity in the expression and overall assessment and treatment of pain [13,25,28]. However, it is not clear to what extent

* Corresponding author. Tel.: +1 585 276 4037; fax: +1 585 273 1270.
E-mail address: Martin_Schiavenato@urmc.rochester.edu (M. Schiavenato).

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these are environmental factors such as cultural norms on communication and expression, versus possible inborn genetic differences that govern facial display. Although consistently tracked in medical research, the labels of "race" and "ethnicity" are obscure in meaning at best [36,37]. Similarly, gender/sex differences are reported in pain research and while some can be attributed to social norms [23,27] others, as is the case of studies in newborns, cannot. Guinsburg and colleagues [17] found more facial expression on term and pre-term females, while Holditch-Davis and colleagues [18] found that pre-term males displayed more facial expression. On the other hand, Fuller [12] found no differences between the sexes in facial expression at 2 weeks to 6 months of age; while Grunau and Craig [15] found no sex differences in newborn expression but did find differences in the speed of response with males demonstrating a quicker facial display than females.

Facial expressions form the cornerstone of clinical and research pediatric pain instruments [30]; thus, the evaluation of a common and inherited facial expression for pain, the PFP that an evolutionary view would purport, is critically in question. The purpose of this study was to compare the facial expression of term newborns to a painful stimulus, across sex and ethnic backgrounds, while controlling for possible extraneous confounding effects. Computer methods were applied in an attempt to refine the measurement of facial expression.

2. Methods

2.1. Study design and sample

This prospective observational study used a quota sampling technique to recruit "well" neonates at the newborn nursery of a large metropolitan hospital who were (a) term (37–43 weeks gestation), without gestational or delivery complications, without history of maternal drug use (see Table 1 for inclusion/exclusion criteria), and (b) represented a specific sex and ethnic origin: males and females ascribed as Asian, or African-American, or Caucasian, or Hispanic/Latino. We define ethnicity here as a sociocultural, subjectively assigned and non-genetic attribute. The hospital's convention of assigning the infant's "race" according to the mother's self-ascribed "race" (i.e., that which coincides with our definition and categories for "ethnicity") at the time of admission was applied. Admittedly, this method does not identify infants of multi-ethnic, multi-racial background. To avoid potential confounding effects of cesarean anesthesia, only vaginal births were included. Metabolic screening (e.g. phenylketonuria test) is State-mandated and the heel-stick required for blood collection was chosen as the common pain stimulus in the study. Hospital protocol required the procedure to take place 24 h after beginning oral feeds and before discharge. The heel-stick was carried out by hospital staff per normal protocol using a standard lancet device. The neonate's head and chest were recorded using a tripod digital video camera (Kodak Z740). The picture was focused on the neonate's face; sound was recorded and the staff member was instructed to state "stick" immediately prior to engaging the lancet. Recorded events consisted of a brief baseline prior to the event, the heel-stick, and the immediate reaction following it. Total analyzed video time did not exceed 30 s per newborn.

Table 1
Inclusion/exclusion criteria

1. Vaginal delivery
2. Term pregnancy (37–43 week gestation)
3. No history of pregnancy complications
4. No history/evidence of genetic or congenital disorders
5. No history of substance abuse during pregnancy
6. Apgar scores at 1 and 5 min >6

2.2. Data collection

The study was approved by both university and hospital Institutional Review Boards, and parental consent was obtained in advance. A chart review was performed to derive demographic and medical history data including sex, race/ethnicity, gestational age, postnatal age, birth measurements, Apgar scores, and evidence of pregnancy or delivery complications. Use of epidural and or other perinatal anesthesia was noted for potentially interactive neurobehavioral effects [3,26]. Similarly, feeding type, bottle, breast or both, was tracked to control for potential differences in bonding and/or maternal contact and interaction [35]. Behavioral state is implicated in pain expression with infants that are awake expressing more pain response [1,15,20,32]. Behavioral state was scored at baseline as either asleep, characterized by closed eyes; or awake, characterized by open eyes. Soothing techniques were utilized on fussing/whimpering infants to ensure a non-crying baseline. These infants were coded awake with eyes open or closed.

2.3. Video analysis

Our examination of facial expression led us to the Neonatal Facial Coding System, NFCS [14], a commonly used tool in this population and specifically designed for coding pain action. Facial action coded with the NFCS and consistently associated with pain in term neonates includes brow bulging, eyes squeezed shut, deepening of the nasolabial furrow, open mouth, and taut tongue [4,15,16,31]. These actions are generally coded for presence/absence in video analyses and point to anatomical engagement (e.g. area of facial movement). A scheme was developed that allowed us to measure (a) *gross movement and cry* (taut tongue, chin quiver and cry), and (b) *fine facial activity* (other implicated facial action based on the NFCS as listed above). "Gross movement and cry" were evaluated by the principal investigator (a trained and certified NFCS rater) by viewing digital video recordings played back in real time on a computer with frame by frame manipulation software and noting the presence/absence of chin quiver, taut tongue and/or cry. These actions were looked at independently because of their previous stated involvement in pain expression and because they were not conducive to our computerized image measurement methods.

2.4. Baseline and reaction images

Baseline image was defined as a "neutral" or the non-crying/non-grimacing image immediately before the heel-stick. *Reaction* image was defined as the still picture displaying the initial moment of maximal expression following the heel-stick. *Baseline* instantly preceded heel-stick, and *reaction* occurred almost immediately after heel-stick. Specifically, for reaction, we were careful to capture any facial action after the heel-stick but before any potentially intervening act such as squeezing of heel for blood. Rad Video Tools (Rad Game Tools, Kirkland, WA) was used to convert the digital video file into a series of still images (jpegs) from which to choose baseline and reaction pictures. IrfanView (Irfan Skiljan, www.irfanview.net) was used to examine and select the two images.

2.5. Computerized image measurement

"Fine facial activity" as tracked by this methodology is an innovative attempt at measuring intensity of NFCS associated pain behavior by means of digital image analysis. Recent advances in computer vision are exploring systems with the potential for automatic recognition of facial actions and identification of expressed emotion [2,33]. These computer systems use the Facial Action Coding System (FACS) developed by Ekman and Friesen [10], the oldest and the most widely used tool for coding facial expression in general. The NFCS was derived from the FACS [4,15]. Along this line of research, a technique proposed by Pantic and Patras [21] was attempted to track facial action and measure movement. They proposed using particle filtering to track 20 facial points in a video image assuming a stationary head or small head rotations. In earlier phases of this research, we attempted similar affine transformations to account for minor changes in head movement; however, these affine transformations were prone to error due to the lack of a sufficient number of rigid registration points on the face and to considerable head movement by the infants following the heel-stick. Thus, we devised a "point-pair method" that used facial points but rather than base the measurement on moving video, we used the two captured still images (baseline and reaction) for comparison to help overcome the issue of head movement. This method accounts for rigid transformations in a two dimensional image plane. Thus, manual image selection performed by the principal investigator attempted to minimize movement and approximate position while capturing the fullness of the expression. Head movement, which was common across neonates, was evaluated and considered to introduce random error. This methodology does not completely preclude the subjectiveness associated with current methods in selecting or judging an image. However, it offers a higher level of measurement and precision in terms of movement as compared to current methods.

2.6. Point-pair method

We devised 7 pairs of points (point-pairs) that coincide anatomically with the pain facial actions associated with the NFCS (Table 2). Because nasolabial furrowing or deepening of a portion of the face is difficult to measure in a flat two-dimensional image, a substitute measure was developed (point-pairs 4 and 5). Based on facial action common to both the NFCS and FACS [4], "cheek raise" was used as a proxy for nasolabial furrowing. A point on the infraorbital triangle itself is difficult to obtain because of the relative lack of anatomical landmarks in the area. Therefore, the alar-facial groove was chosen as a readily identifiable landmark, and its movement was anchored at the ipsilateral medial canthus which is an assumed reference point with relative stability in facial expression. The remaining point-pairs

Table 2
NFCS facial action and point-pair comparison

NFCS facial action[a]	Corresponding point-pair
1.Brow bulge	1. Point-pair 1: between the medial borders of the eyebrows; to track horizontal brow movement
2. Eye squeeze	2. Point-pair 2 (right side), point-pair 3 (left side): from mid eyebrow to mid lower eyelid
3. Nasolabial furrow, cheek raise (proxy)	3. Point-pair 4 (right side), point-pair 5 (left side): from medial canthi to alar-facial groove
4. Horizontal mouth/lip movement	4. Point-pair 6: between lip corners
5. Vertical mouth/lip movement	5. Point-pair 7: between medial upper and lower lip vermilion border

[a] [4].

correspond more directly to the facial action associated with the NFCS (Fig. 1).

2.6.1. Computing fine facial activity

The goal was to measure movement, in pixels, in particular facial areas implicated in neonatal pain expression by tracking change between point-pairs. To preclude issues of image size and differences in infant anthropometrics, we chose *percent of facial width* as the standardized unit of measurement. Each child's face-width was measured twice at baseline and twice at reaction, and the average was used to scale all subsequent point-pair pixel measures. Baseline and reaction images maintained similar scales. Measuring and averaging over both images allowed for a second view and more accurate estimation of facial width. The child's hairline or ears (depending on which was best visible) was used at eyebrow height as landmarks for face-width measurement. Point-pair locations were assigned and measured in order at both baseline and reaction pictures (see Table 2 for anatomical locations). All computer measurements were performed by the principal investigator.

2.6.2. Point-pair calculation

Each point-pair is calculated from a pair of points, for example, the fist point-pair (P_1) is measured by the first and the second point on the face. Similarly, the second point-pair is measured by the third and fourth points. The point-pair value itself is determined by the pixel distance between 2 points $X_1 = (x_1,y_1)$ and $X_2 = (x_2,y_2)$ calculated as

$$\mathrm{dist}(X_1, X_2) = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

The final point-point pair output, expressed as a percent of face-width, was the computed distance between the two test points divided by the scale and multiplied by 100:

$$P_i = \frac{100^* \mathrm{dist}(X_{2i-1}, X_{2i})}{\mathrm{dist}(S_1, S_2)}$$

Or,

$$P_i = \frac{100 * \sqrt{(x_{2i-1} - x_{2i})^2 + (y_{2i-1} - y_i)^2}}{\sqrt{(S_{x1} - S_{x2})^2 + (S_{y1} - S_{y2})^2}}$$

where S are the scale points derived from measuring facial width. Point-pairs were calculated for both baseline and reaction images. Point-pair change, net movement between images, was calculated as

$$\Delta P_i = P_i^R - P_i^B$$

where P_{ij}^R is the point-pair value for the reaction image, and P_{ij}^B is the point-pair value for the baseline.

The above calculations were done in Matlab (MathWorks Inc., Natick, MA). Fig. 2 illustrates measurement of all 7 point-pairs at both baseline and reaction.

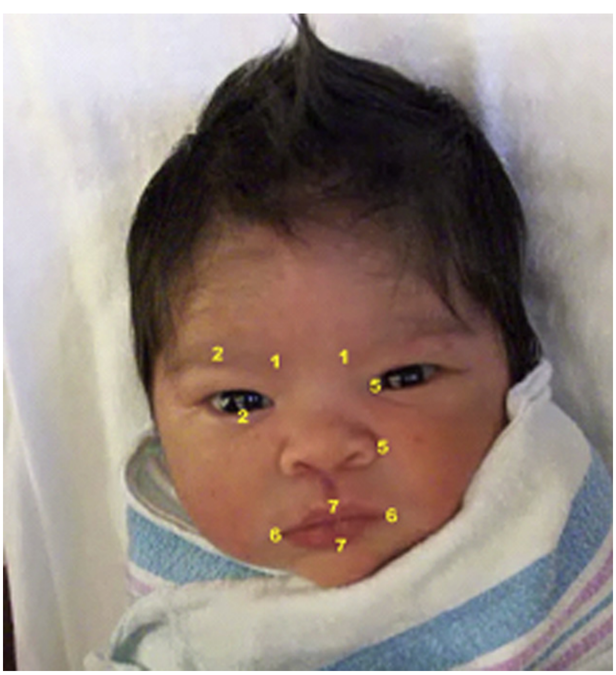

Fig. 1. Point-pairs*. Distance between point-pairs is measured and compared between *baseline* and *reaction* images. *Point-pairs 3 and 4 not shown for graphic clarity but correspond to the opposite side of the face.

2.7. Statistical analyses

Multivariate analysis of covariance (MANCOVA) and cluster analysis (CA) were employed to assess differences and similarities in the facial expression of pain across sex and racial/ethnic groups. Due to the limited sample size ($N = 57$), only large effect sizes (i.e., large point-pair changes) could be detected. In interpreting the findings, we therefore focused on comparing the pattern of means and variances rather than statistical tests of significance (see Figs. 3 and 4). In the MANCOVA, the dependent variables (DVs) consisted of each of the 7 point-pairs and the independent variables (IVs) were sex and race/ethnicity. Several covariates, including behavioral state, type of feeding, and use of medications (epidural and/or other perinatal anesthesia), were added to the model in order to control for extraneous, nongenetic or non-inherited factors. In addition, cluster analysis was used to determine whether neonates could be empirically differentiated on the basis of sex or race/ethnicity on measures of facial expression change. Fundamental to the use of CA is the computation of similarity or distance among the cases (i.e., neonates), which can then be used to identify natural groupings or clusters in the data. These empirically identified clusters are then compared with pre-defined groups (i.e., sex

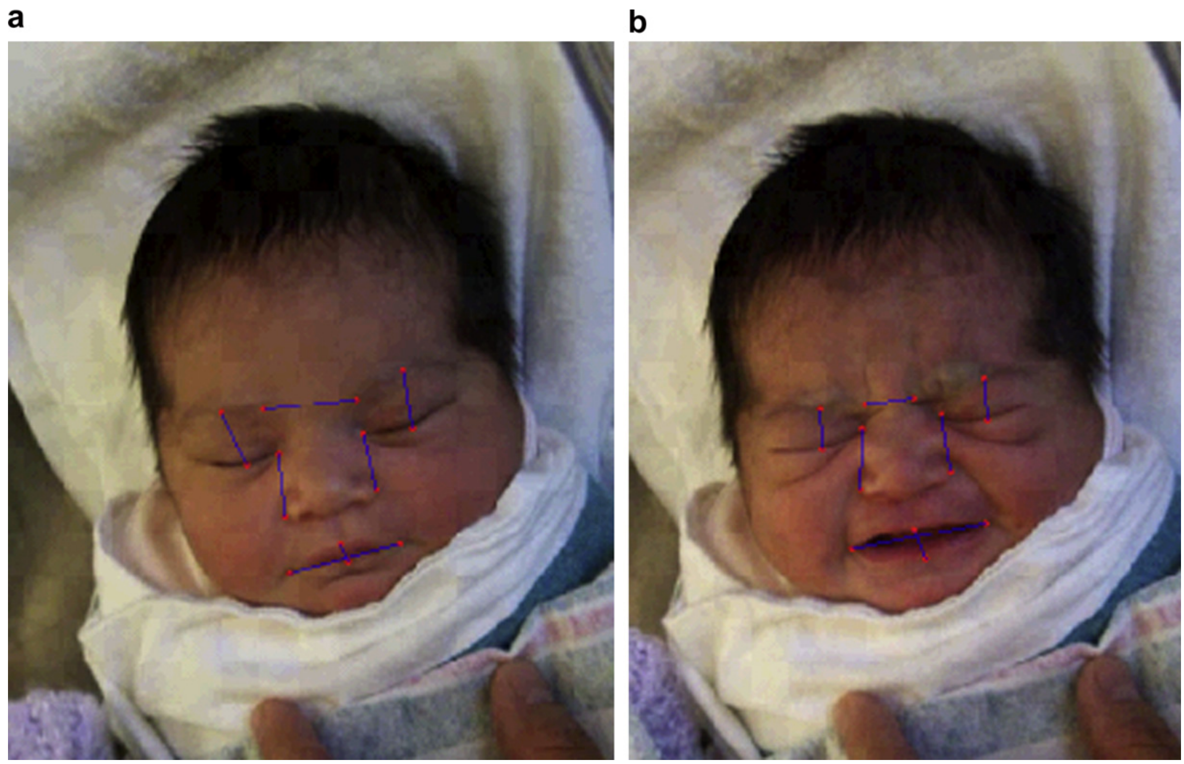

Fig. 2. Sample point-pair measurement. (a) Baseline (b) Reaction.

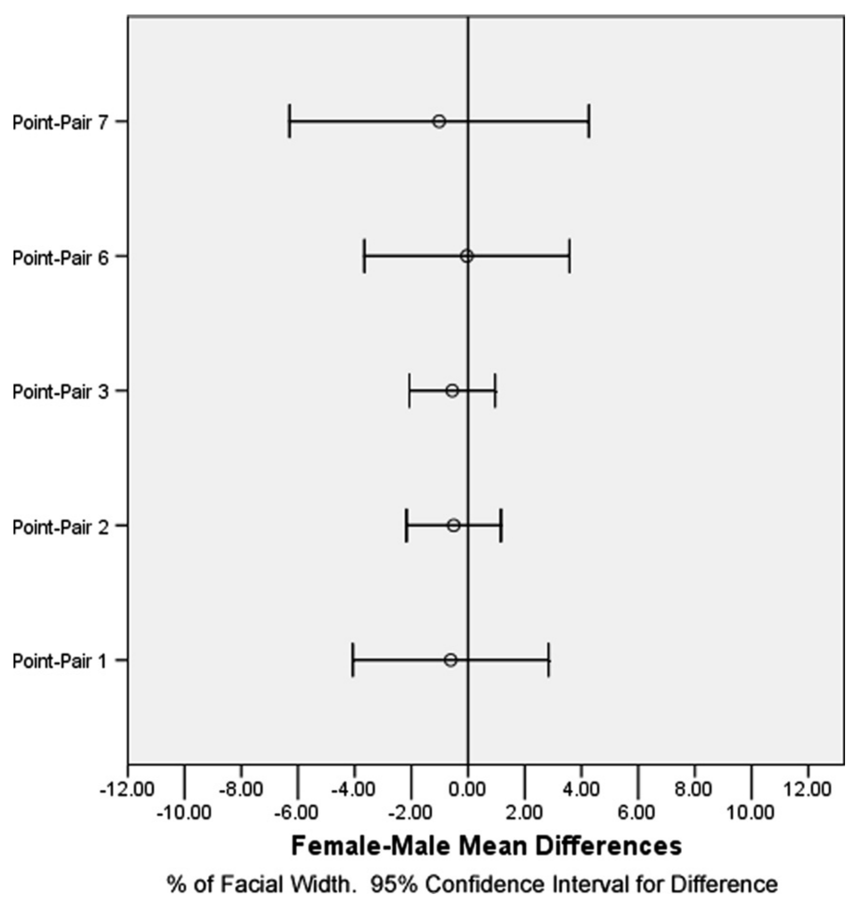

Fig. 3. Female–male mean differences*. *Differences calculated as female minus male score.

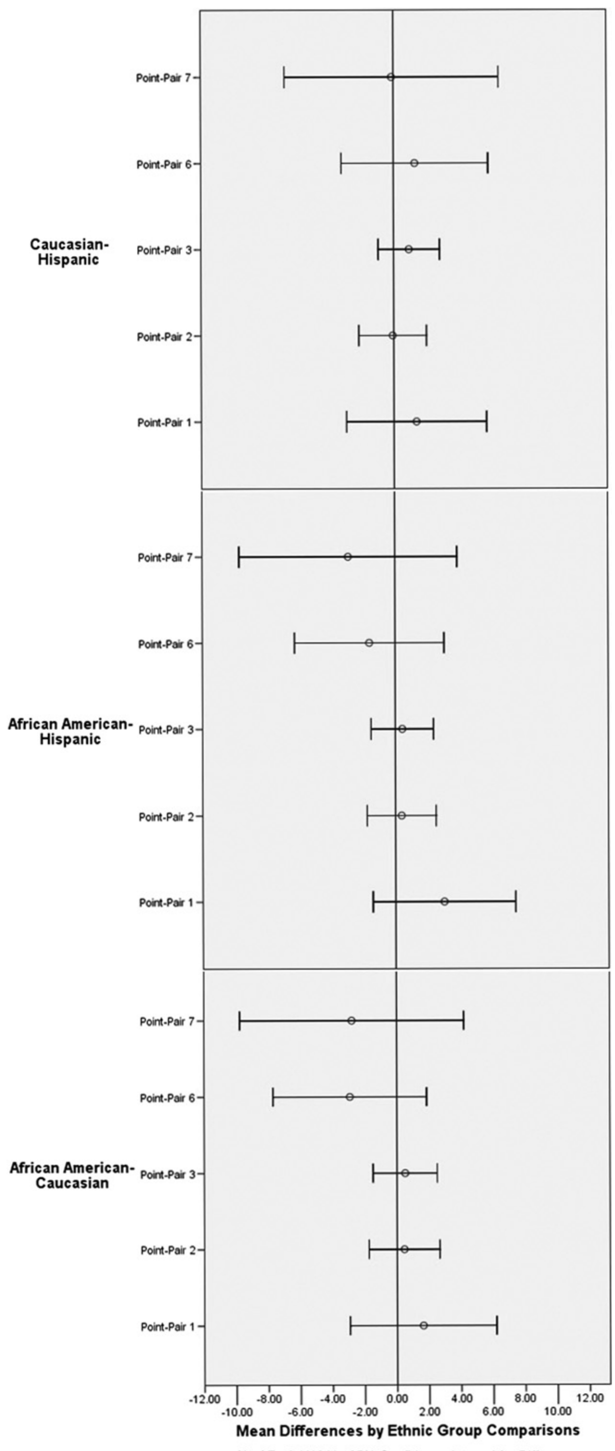

Fig. 4. Mean differences by ethnic group comparisons*. *Differences calculated as first ethnic group minus second ethnic group.

and race/ethnicity) to assess the degree to which these groups form empirical clusters. Most informative for the present analysis is the graphical display of the degree of overlap in pain-induced changes in facial expression among the various groups of neonates plotted in two- or three-dimensions of point-pair change (see Figs. 5 and 6).

Fourteen cases were randomly selected to be rescored 24 h apart to assess intra-rater reliability on measurement of the 7 facial point-pairs. Intraclass correlation coefficients (ICCs) were calculated for reliability measurement of both *baseline and reaction* pictures. Video of these fourteen cases was also evaluated for intra-rater reliability on "gross movement and cry" measurements (Cohen's kappa). Statistical tests were performed on SPSS (SPSS Inc., Chicago, IL) and SAS (SAS Institute Inc., Cary, NC).

3. Results

3.1. Sample characteristics

The exploratory nature and novelty of our methodology precluded a predetermined sample size. A quota sample of 20 participants divided equally by sex was attempted for each of 4 racial/ethnic groups; 19 African American, 19 Caucasian, and 19 Hispanic/Latino neonates were recruited and retained for analysis. However, since only 5 Asian neonates were recruited in the study, these were excluded from the present analysis (Table 3). Characteristics of neonates are presented in Table 4. The mean postnatal age was 36 h, while mean gestational age was 39 weeks. The mean birth weight was 3361 grams. Seventy-seven percent (44) of mothers had epidural anesthesia whereas 10% (6) had another form of anesthesia. The sample infants were 53% (30) awake prior to the heel-stick. Thirty-seven percent (21) of the infants were breastfed, 21% (12) were bottle fed and 42% (24) had a combination breast and bottle feedings.

3.2. Gross movement and cry

Although not originally an assigned variable, "head movement" was conspicuously noted in video analysis and added for coding with 86% (49) of the infants moving their head sideways following the heel-stick. The behavior was displayed more frequently than cry, which was present in 58% (33) of the sample. Two other behaviors previously associated with NFCS measurement were taut-tongue, displayed 49% (27) of the time; and chin-quiver, not noted at all. Cohen's kappa correlations for intra-rater reliability were 0.72 for cry, 0.81 for taut-tongue, and 1.0 for head movement. Chin-quiver was not observed.

3.3. Fine facial activity: point-pairs

Table 5 lists overall means and ranges for point-pairs, and intra-rater reliability correlation coefficients. ICC single measures ranged from 0.37 to 0.95. Two of the three lowest reliability scores were for point-pairs 4 and 5 associated anatomically with the NFCS nasolabial

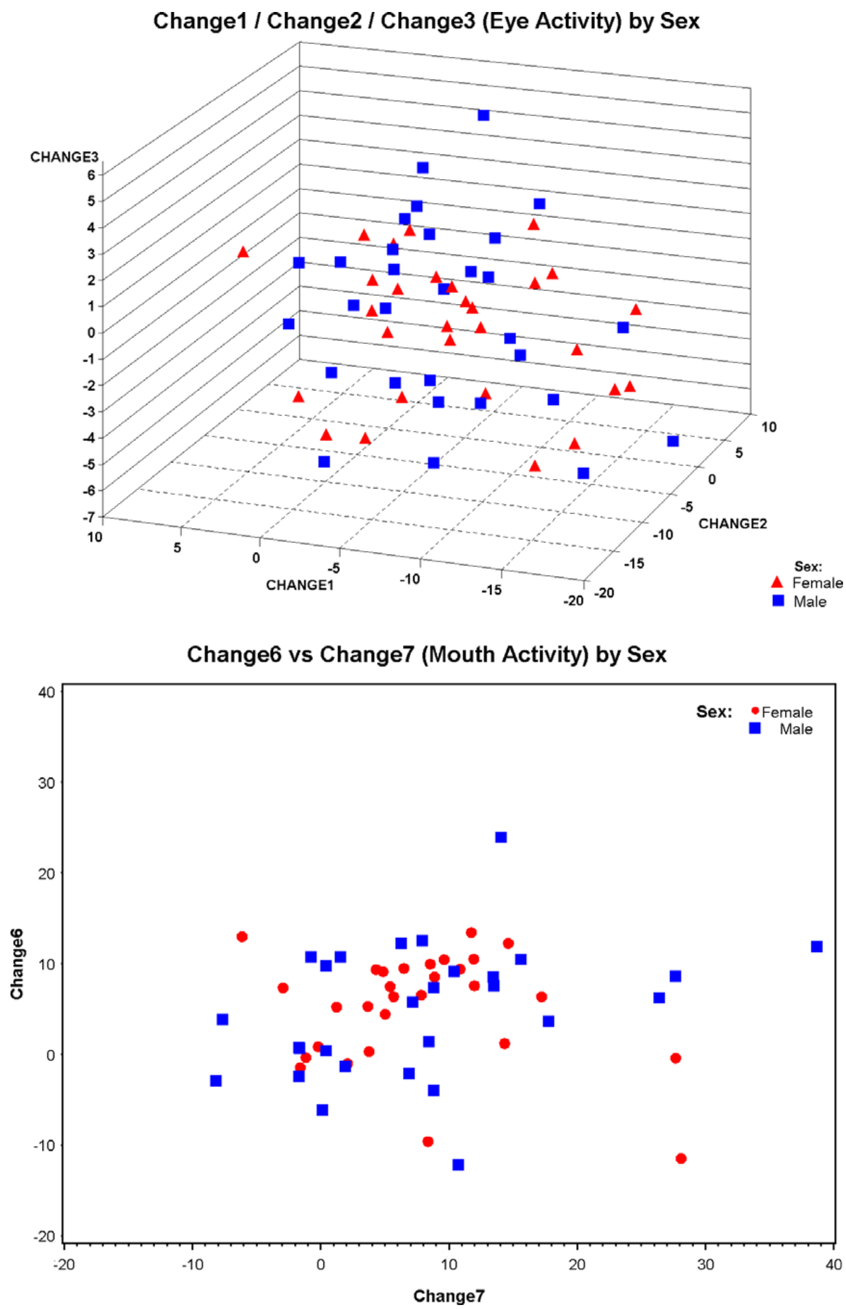

Fig. 5. Cluster analysis: facial pain display by sex.

furrow and our proxy measure of cheek raise. The points' anatomical landmarks were difficult to follow and might have been particularly sensitive to head movement. Poor reliability was especially evident with point-pair 4 (0.37) but since they are bilateral measurements (i.e., both cheeks) both points 4 and 5 were excluded from further analyses. Without them, mean ICC is 0.78 indicating good intra-rater agreement. Table 6 presents means and standard deviations by sex and ethnicity.

Given our small sample and limited power, it was not surprising that MANCOVA analysis revealed no statistically significant differences between sex and racial/ethnic groups (Table 7). Nonetheless, the pattern of estimated group means and variances (controlling for behavioral state, type of feeding, use of epidural anesthesia and use of other perinatal anesthesia), as presented in Figs. 3 and 4, is informative. It can be seen, for example, that the point estimates for mean differences in facial expression change across the point-pairs are small between male and female neonates (Fig. 3). Minimal differences in mean estimates are also apparent across racial/ethnic groups for pair-points 2 and 3 (Fig. 4). Moreover, the 95% confidence intervals are also

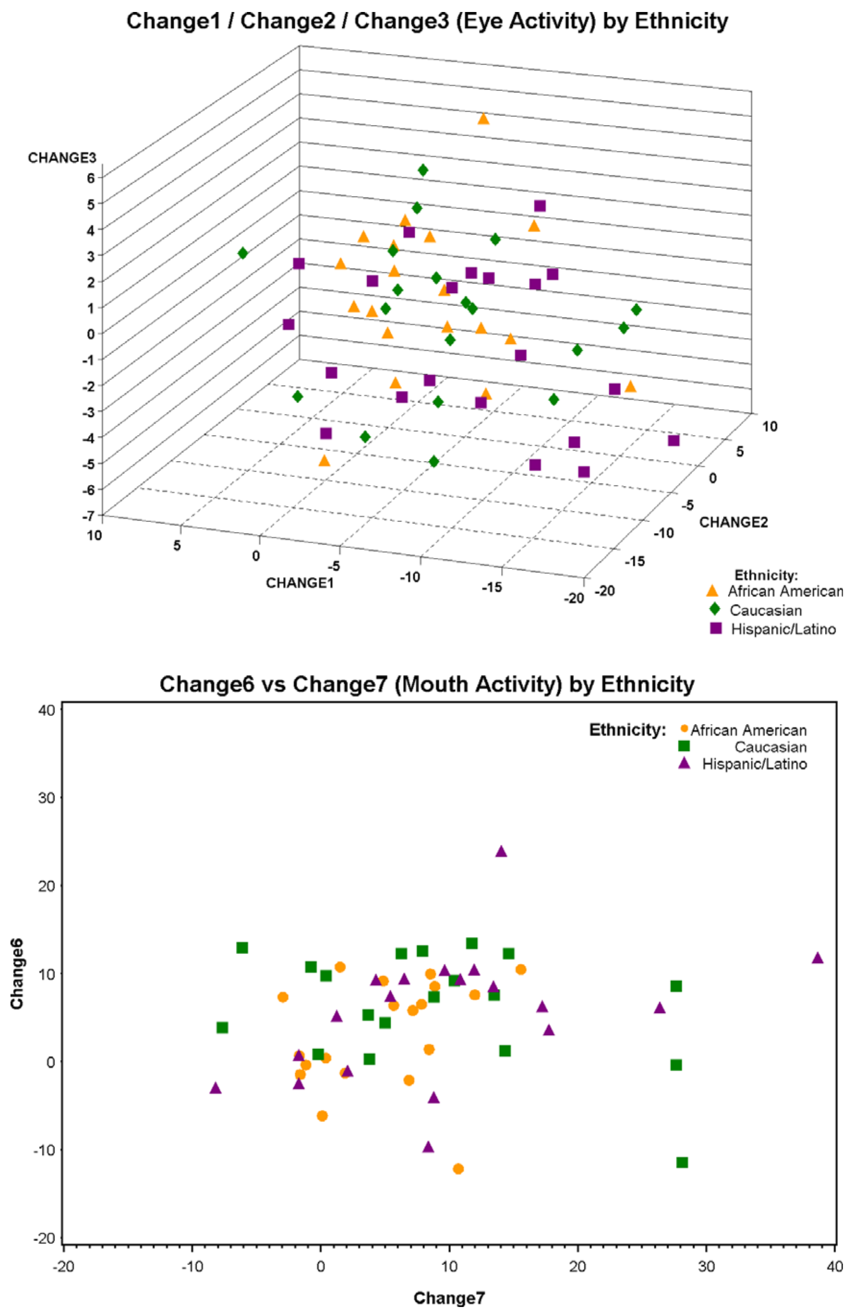

Fig. 6. Cluster analysis: facial pain display by ethnicity.

Table 3
Sample distribution by sex and ethnicity

Ethnicity	Sex		Total
	Female	Male	
African American	9	10	19
Asian[a]	3	2	5
Caucasian	10	9	19
Hispanic Latino	10	9	19
Total	32	30	62

[a] Group excluded from further analyses.

Table 4
Sample characteristics

	Result
Mean gestational age	39 weeks
Mean postnatal age	36 h
Mean birth weight	3361 g
Mothers with epidural anesthesia	77%
Mothers with other perinatal anesthesia	10%
Awake	53%
Breastfeeding	37%
Bottle feeding	21%
Both bottle and breast	42%

Table 5
Point-pair statistics: baseline to reaction differences*

	Minimum	Maximum	Mean	Range	SD	ICC[b]
Point-pair 1	−19.58	7.03	−4.83	26.61	6.08	0.73
Point-pair 2	−9.17	3.83	−1.90	13.00	2.89	0.74
Point-pair 3	−6.85	5.27	−1.93	12.12	2.71	0.60
Point-pair 4[a]	−5.33	2.06	−1.19	7.38	1.84	0.66
Point-pair 5[a]	−8.94	2.65	−1.01	11.60	1.97	0.37
Point-pair 6	−12.18	23.96	5.01	36.14	6.73	0.88
Point-pair 7	−8.16	38.68	7.86	46.84	9.25	0.95
						0.78[c]

*Expressed as percent of facial width.
[a] Point-pairs excluded from further measurement.
[b] Intraclass correlation coefficient, single measures.
[c] Mean intra-rater reliability for point-pairs 1, 2, 3, 6 and 7.

relatively narrow for these three group comparisons. A greater degree of difference in pain-induced facial expression can be observed in the estimated means of racial/ethnic groups for point-pairs 1, 6 and 7, with concomitant wider confidence intervals.

The results of cluster analysis clearly demonstrate substantial overlap in 2-and 3-dimensional space of facial expression change between male and female neonates (Fig. 5) and among racial/ethnic groups (Fig. 6); see Tables 8 and 9 for relevant statistics. The analysis showed no clear differentiation or clustering by sex or race/ethnicity on facial expression change, after controlling for behavioral state, type of feeding, use of epidural anesthesia and use of other perinatal anesthesia.

4. Discussion

The computer-enabled point-pair method described here allows the use of parametric statistics and may enhance current facial coding schemes like the NFCS by progressing from a categorical level of measurement to a continuous measurement level.

To document the PFP, possible extraneous and non-biological factors (e.g. sociocultural and developmental) were controlled for. Our population of study – neonates – inherently limits sociocultural and developmental effects, while we attempted to statistically control additional factors via MANCOVA and cluster analysis. It is important to note that there are differences between point-pair intensities, with subtle but perhaps important variations in range. Table 5 shows that the mouth (point-pairs 6 and 7) has the widest range of movement and that those points are the only ones with positive means – indicating an opening of the mouth or pairs of points moving away from each other. The remaining point-pairs have a negative mean, indicating a drawing in or closing between pairs. That is, as expected, the PFP consists of opening of the mouth, drawing in of the brows, closing of the eyes, and raising of the cheeks. Yet, minimum and maximum measurements for all pairs are across negative (closing or drawing in) and positive

Table 6
Adjusted means and standard deviations by sex and ethnicity

	Sex	Ethnicity	Mean	SD	*N*
Point-pair 1	Female	African American	−4.94	5.91	9
		Caucasian	−4.02	7.08	10
		Hispanic Latino	−6.87	6.44	10
		Total	−5.29	6.40	29
	Male	African American	−1.82	3.68	10
		Caucasian	−5.58	5.48	9
		Hispanic Latino	−5.92	7.52	9
		Total	−4.35	5.82	28
	Total	African American	−3.30	4.99	19
		Caucasian	−4.76	6.25	19
		Hispanic Latino	−6.42	6.79	19
		Total	−4.83	6.08	57
Point-pair 2	Female	African American	−1.45	2.32	9
		Caucasian	−2.49	2.67	10
		Hispanic Latino	−2.72	2.91	10
		Total	−2.25	2.62	29
	Male	African American	−1.21	3.50	10
		Caucasian	−1.81	3.76	9
		Hispanic Latino	−1.62	2.31	9
		Total	−1.54	3.15	28
	Total	African American	−1.32	2.92	19
		Caucasian	−2.17	3.16	19
		Hispanic Latino	−2.20	2.63	19
		Total	−1.90	2.89	57
Point-pair 3	Female	African American	−1.61	2.02	9
		Caucasian	−2.16	2.24	10
		Hispanic Latino	−2.76	2.91	10
		Total	−2.20	2.39	29
	Male	African American	−1.03	3.17	10
		Caucasian	−1.39	3.28	9
		Hispanic Latino	−2.60	2.73	9
		Total	−1.65	3.03	28
	Total	African American	−1.30	2.63	19
		Caucasian	−1.80	2.73	19
		Hispanic Latino	−2.68	2.75	19
		Total	−1.93	2.71	57
Point-pair 6	Female	African American	5.96	4.07	9
		Caucasian	3.89	7.67	10
		Hispanic Latino	5.77	6.41	10
		Total	5.18	6.15	29
	Male	African American	0.78	7.05	10
		Caucasian	9.11	2.71	9
		Hispanic Latino	5.08	8.94	9
		Total	4.84	7.39	28
	Total	African American	3.23	6.27	19
		Caucasian	6.36	6.31	19
		Hispanic Latino	5.44	7.49	19
		Total	5.01	6.73	57
Point-pair 7	Female	African American	4.68	5.34	9
		Caucasian	10.27	11.30	10
		Hispanic Latino	7.76	4.88	10
		Total	7.67	7.88	29
	Male	African American	5.11	5.53	10
		Caucasian	7.40	10.01	9
		Hispanic Latino	11.95	14.79	9
		Total	8.05	10.64	28
	Total	African American	4.91	5.30	19
		Caucasian	8.91	10.52	19
		Hispanic Latino	9.75	10.66	19
		Total	7.86	9.25	57

Table 7
MANCOVA summary table

Effect	Wilks' lambda	F	Hypothesis df	Error df	p Value	Partial eta squared η^2
Intercept	0.82	1.58	6	42	0.18	0.18
Epidural	0.89	0.89	6	42	0.51	0.11
Other anesthesia	0.89	0.88	6	42	0.52	0.11
State	0.90	0.76	6	42	0.61	0.10
Feeding type	0.90	0.79	6	42	0.58	0.10
Sex	0.93	0.57	6	42	0.75	0.08
Ethnicity	0.85	0.61	12	84	0.83	0.08
Sex∗ethnicity	0.79	0.88	12	84	0.57	0.11

Design: intercept + epidural + other + state + feeding + sex + ethnicity + sex∗ethnicity.

Table 8
Sex mean differences female–male

Point-pair	Mean difference	Standard error	Lower bound	Upper bound
Point-pair 1	−0.61	1.72	−4.07	2.84
Point-pair 2	−0.51	0.83	−2.18	1.16
Point-pair 3	−0.56	0.75	−2.07	0.96
Point-pair 6	−0.04	1.80	−3.66	3.58
Point-pair 7	−1.02	2.62	−6.3	4.26

(opening or drawing out) movement. This illustrates either true subtle individual differences in movement of certain areas involved in expression, and/or measurement error. One possible contribution to measurement error is the common occurrence of head turning associated with the pain response, which made the face a moving target and point-pair measurement challenging, particularly with point-pairs 4 and 5 which were dropped. While this additional source of error may have further decreased our power to detect any mean differences among groups by increasing the variance around the means, the random nature of the error would not have affected the close clustering of means or the pattern of group similarity which supports the case for a common facial display. Future refinement in this methodology will have to address the issue. Head-turning behavior may be worth further exploration as a clinical sign since it was more common than cry, and is not broadly reported as an indicator of neonatal pain.

The issue of whether or not facial expression of an emotion is "universal" has a long, contentious history [9,28] and in some ways is reminiscent (and undoubtedly influential in the development) of the *Sociocommunication Model of Infant Pain* [5]. Key in the controversy is the role of biology vs. the role of sociocultural influences. The general agreement is that both have *some* degree of influence. Russell [28], for example, characterizes the dichotomy as a continuum with absolute sociocultural influences at one end and absolute biological (i.e., universal) determinants at the other; expression lying somewhere in between. Ekman [8] similarly speaks of facial expression of emotion (i.e., "basic emotions") as a family, composed of a unique theme with variations. The themes are the product of evolution, while variations the product of learning. In this context "universal" primarily implies biological lineage not necessarily similarity or uniformity of expression; although related, the two concepts are not the same. Our study design and our sample of newborns are an attempt to rule out or control for sociocultural, developmental

Table 9
Paired ethnicity mean differences

Group comparison	Point-pair	Mean difference	Standard error	Lower bound	Upper bound
African American × Caucasian	Point-pair 1	1.63	2.27	−2.94	6.19
African American × Hispanic	Point-pair 1	3.03	2.21	−1.41	7.47
Caucasian × Hispanic	Point-pair 1	1.40	2.17	−2.96	5.76
African American × Caucasian	Point-pair 2	0.45	1.10	−1.75	2.66
African American × Hispanic	Point-pair 2	0.38	1.07	−1.76	2.53
Caucasian × Hispanic	Point-pair 2	−0.07	1.05	−2.18	2.03
African American × Caucasian	Point-pair 3	0.51	0.99	−2.51	1.48
African American × Hispanic	Point-pair 3	0.43	0.97	−1.51	2.38
Caucasian × Hispanic	Point-pair 3	0.95	0.95	−0.96	2.85
African American × Caucasian	Point-pair 6	−2.92	2.38	−7.71	1.86
African American × Hispanic	Point-pair 6	−1.61	2.31	−6.26	3.04
Caucasian × Hispanic	Point-pair 6	1.31	2.27	−3.26	5.88
African American × Caucasian	Point-pair 7	−2.80	3.47	−9.78	4.18
African American × Hispanic	Point-pair 7	−2.92	3.37	−9.71	3.86
Caucasian × Hispanic	Point-pair 7	−0.12	3.31	−6.78	6.54

and other non-biological influences on the expression of pain. In other words, the PFP documented here is an attempt to isolate and capture the universal, inborn, inherited expression associated with a painful stimulus. Based on our preliminary analyses, such a facial display appears to be similar across sex and ethnicity. Or, said differently, no systematic variations in facial pain display were noted between males and females, or between the 3 ethnic groups. This suggests that individual variation in neonatal expression in response to pain may be genetically influenced. The role of genes in determining not just the presence of the display at birth but also potential variations within it deserves further examination [21].

Discernment of what constitutes pain expression is of utmost importance in its assessment and management. The presence of a universal human facial pain display has theoretical and practical consequences in measurement tools like facial pain scales, which are based on a common understanding of facial expression in the evaluation of pain [30]. An important product of this study is the establishment, in terms of our metric, of the effect of a heel-stick on facial expression in our population. Questions that arise from this include, how does expression vary by stimulus intensity? Further, the mechanics of the expression beyond that which is presented here need further evaluation. For example, how does the expression occur or how is it displayed across time? Finally, documenting the nature of the PFP as a baseline expression with increasing precision as shown here may help to quantify the role of possible developmental and sociocultural contributions in sculpting the expression of pain throughout life.

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