Proceedings of the 29th Annual International
Conference of the IEEE EMBS
Cité Internationale, Lyon, France
August 23-26, 2007.

Is there a Primal Face of Pain? A methodology answer

Martin Schiavenato, Jacqueline Byers, Paul Scovanner, Piotr Windyga, Mubarak Shah

Abstract— **Pain assessment is of high priority in the clinical setting. Facial Pain Scales (FPSs) are pain assessment tools generally used with school-aged children. The implicit theoretical bases for the success of FPSs have seldom been explored. Explanations why and how FPSs work (or do not work) have not been addressed. We support the existence of a universal pain expression –the Primal Face of Pain (PFP), which is present at birth, evolved in nature, and modulated through sociocultural factors. We propose it to be key in understanding the applicability of FPSs. We present here the design of a computer-assisted descriptive study that will observe, quantify and model the PFP as present in newborns. Measurement of the PFP will lead to exploration of the theoretical consequences of its existence, particularly as related to pediatric pain assessment and the valid use of FPSs. Further, this work can lay a foundation for the development of a new generation of FPSs.**

I. Introduction

DECADES ago it was proposed that many facial expressions are constant across cultures and serve basic universal communicative functions in the language of emotions [1,2]. The phenomenon of pain itself is construed to have an emotional component [3]. It was also proposed that the experience of pain may in fact result in display of facial expressions universal in nature [4]. These facial displays have been documented in adults, children, and both term and premature neonates. Additionally, the importance of infants' ability to express distress in order to ensure their survival has been postulated [5]. Simply put, those infants equipped to attract help from a parent through their facial expression (i.e., inherited ability of display pain) are more likely to survive than those who are not. This expression of pain requires the parent's ability to recognize it as a call for help [6]. In the matter of recognition of facial pain display, evidence suggests that we are equipped to perceive pain in others when we are as young as 5 years old [7]. The relationship of pain expression to pain recognition seems to be important enough to be formed very early in life. Further evidence supporting the role of pain expression can be found in children suffering environmental deprivation (i.e., the congenitally blind) who nevertheless show full facial expression in spite of the lack of external visual cues [8]. Similarly, research into those suffering from facial paralysis illuminates the functionality and perhaps necessity of facial expression, by noting difficulties in communication and socialization for those unable to fully form facial expressions [9].

Thus, we define as the Primal Face of Pain (PFP) this hardwired original communicative capability, evolved and universal in nature, with the protective function of enlisting aid by expressing distress. But if the PFP exists, what does it look like, how is modulated, and does it vary across ethnicity or sex? The proposition for the existence, and feasible illustration, of the PFP is important in as much as it potentially represents an objective and universal visual and graphic mode of pain expression with clinical consequences in pain assessment.

The purpose of this study, therefore, is to investigate the theory that a universal internal reference is at work in the expression and clinical assessment of pain.

M. Schiavenato is with the College of Nursing, University of Central Florida, 4000 Central Florida Blvd., P.O. Box 162210, Orlando, Florida, USA (e-mail: schiavenato@yahoo.com).

J. Byers is with the College of Nursing, University of Central Florida, 4000 Central Florida Blvd., P.O. Box 162210, Orlando, Florida, USA (e-mail: jbyers@mail.ucf.edu).

P. Windyga is with the School of Electrical Engineering and Computer Science, University of Central Florida, 4000 Central Florida Blvd., P.O. Box 162362, Orlando, Florida, USA (phone: 407 823-3467; fax: 407 823-5419; e-mail: pwindyga@cs.ucf.edu).

P. Scovanner is with the Computer Vision Lab, School of Electrical Engineering and Computer Science, University of Central Florida, 4000 Central Florida Blvd., P.O. Box 162362, Orlando, Florida, USA (e-mail: pscovanner @cs.ucf.edu).

M. Shah is with the Computer Vision Lab, School of Electrical Engineering and Computer Science, University of Central Florida, 4000 Central Florida Blvd., P.O. Box 162362, Orlando, Florida, USA (e-mail: shah@cs.ucf.edu).

II. Background

A. Modulation of facial expressions: the sociocommunication model of infant pain

Facial expressions of pain reportedly are more consistent in infants than in adults [10], leading one to believe that exposure or experience associated with human development may lead to modulation of facial display of pain. A biocultural model to explain this phenomenon, in which hardwired or "involuntary" emotional displays are modulated through learned behavior, was proposed more than thirty years ago [1]. It was later termed the "two factor" model, on one hand comprised of the innate, hardwired behavior and, on the other, censored or modified according to sociocultural conventions [8]. Evidence suggests that such factors as race and ethnicity play a role in both the adult and pediatric exhibition of pain [11,14]. Thus, the exposure to sociocultural environments that comes with experience would appear to potentially modify the original, innate expression (the PFP).

There are theoretical models that depict the interplay of the biological and the sociocultural in the phenomenon of expressing pain. The "neuromatrix" relies heavily on a

1-4244-0788-5/07/$20.00 ©2007 IEEE

comprehensive biological scheme that encompasses even the molecular level, but nevertheless includes environmental and behavioral modifiers [15]. The roles of ethnicity in pain [16] and the sensitivity to cultural factors in the delivery of care to the pediatric patient [17] have also been implicated.

The Sociocommunication Model of Infant Pain [18], which incorporates pain expression, includes biological substrates and personal history affect the pain experience. These variables, to a newborn in particular, would signify his/her physiology and/or prenatal experience (i.e., strictly congenital factors).

Presumably, due to their brief social and cultural exposure, newborns have the least "social context" affecting their facial pain expression. In other words, if there is a genetically programmed display of pain –the PFP– newborns are apt to display it most faithfully due to their lack of sociocultural experience and its consequential behavioral modulation. Thus, the study of a PFP should rely on the investigation of expression of pain in newborns.

B. Facial pain scales (FPSs)

Facial pain scales (FPSs) are used as pain assessment tools to measure and record self-reports of pain in school-aged children. Their use is wide and their validity generally accepted with a preference by users for the cartoon-like depictions such as those in the popular Wong & Baker scale (Figure 1) [19]. Regardless of actual likeness to a "real" human face, these scales appear to work well, even across gender and race/ethnicity. Their success may in part be due to their neutrality.

Yet, little is known as to why or how these scales are successful. Particularly vexing is the fact that although effective as a self-report, they are generally not helpful as "proxy" reports of pain. That is, on those occasions when an observer, generally a parent or clinician, uses a FPS to rate the child's pain [20-22]. Clinically, sometimes this may be the only option in measuring pain in a child who is non-communicative due to a developmental, linguistic, or pathologic state. However, experimentally when a child's report is compared to a parent's or clinician's, the adult's report poorly matches the child's.

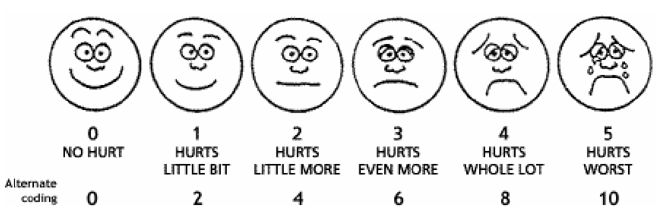

Fig. 1: Wong-Baker FACES pain rating scale

A self-evident factor underlying the success of FPSs is that the graphics in the scales somehow capture and represent the child's experience of pain. That is, the representation of facial expression in the cartoon or picture in the FPS is in some way depicting the personal and complex experience of pain in the child. The key, and only articulated variable in the majority of these scales, is the facial expression itself. Inherent limitations in these FPSs are the fact that they represent a 2D projection of a 3D scene, and are an arbitrary sampling of a continuous event.

C. Facial coding systems

Facial Coding Systems (FCSs) such as the Facial Action Coding System (FACS) [23] use action units (AUs) -muscle movements in specific areas of the face, to classify emotional expression. Although not specific to pain, the FACS has been used with computer imagery to evaluate expression of emotions [24].

At least three other FCSs have been used to document the facial expression of pain, showing some degree of overlapping. The Neonatal FCS (NFCS) [25] was developed for use in both term and premature neonates. It consists of 10 AUs. The Child FCS (CFCS) [26] was developed for use in toddlers and school-aged children. It uses 13 AUs. The Maximally Discriminate Facial Movement Coding System (MAX) [27], used in infants, provides a system for judging brow, eye and mouth movement.

It has been proposed that just four actions carry the bulk of facial information about pain: brow lowering, narrowing and closing of the eyes, nose wrinkling and upper lip [28] (figure 3).

III. METHODOLOGY

We propose to record the facial expression of pain present in newborns and investigate the presence of a common, hardwired expression of pain: the PFP. We propose to observe and quantify facial action involvement in this pain expression, and compare it for commonality across gender and ethnic background.

A. Research postulates and research questions

Three postulates arise from the discussion in section II, offering support to the relevance and potential role of the PFP.

The success of FPSs probably lies in the fact that cartoons highlight (emphasize, exaggerate) certain facial features, stereotyping "a painful expression" with the obvious purpose of cuing the child to their own experienced pain. Their neutrality and bare bones depiction of a complex phenomenon such as pain harkens back to a prototypical and universal expression of pain; that is the PFP.

Postulate 1: *FPSs work because they cue the child to a primal, hardwired mechanism of facial display of pain –the PFP.*

When school-aged children use an FPS, they are attempting to identify their personally experienced pain with the graphic at hand. That is, they are not attempting to match their expressed pain with the scale (we know of no studies that use a mirror to aid the child in comparison or matching of their expression with the FPS).

Postulate 2: *When using FPSs, children match their internal experienced pain against their internal reference, the PFP; and this is what is obtained in a child's pain self-report.*

Based on the Sociocommunication Model of Infant Pain school-aged children –at least 6 years of age [29], the target population in FPSs– have "some" level of sociocultural modulation to their pain expression. It would then follow that school-aged children's facial expressions of pain would not be a valid measure of comparison against an FPS which is in fact cueing onto the PFP. By the same token, the use of FPSs by someone external to the child (a proxy rater) would not be a valid attempt to measure the experienced pain.

Postulate 3: *School-aged children are not likely to express the PFP and proxy use of FPSs on this population is not valid.*

Based on these postulates, our research questions are:
1. Is there a common facial expression upon receiving a painful stimulus among healthy term-newborns?
2. Does this facial expression vary by race/ethnicity or sex?
3. Once observed and quantified, can we accurately reproduce and realistically manipulate this facial expression in a digital environment?

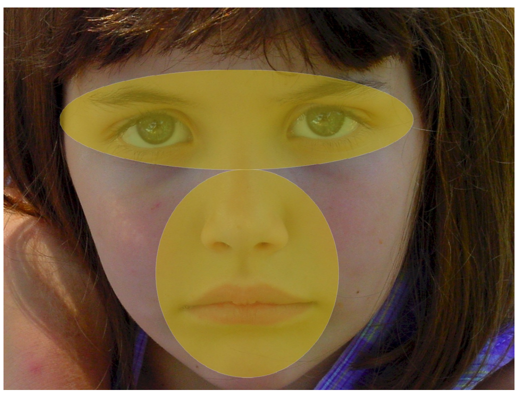

Fig. 2: Main regions of facial activity

B. Pain stimulus mechanism

We propose to take advantage of the widespread administration of the phenylketonuria (PKU) screening test. PKU is an inherited disorder of body chemistry that, if untreated, causes mental retardation [30]. The PKU test is performed during normal course of hospital stay, within 24 hours after starting food intake, and consists of drawing a one time blood sample from a heel stick. Newborns usually show grimace during the PKU test. Since the test is a routine procedure, the proposed study does not represent additional risk.

The heel stick is a painful stimulus and may be followed by a grimace. The grimace is assumed to cycle from a baseline/neutral position (before the stick) to a maximal painful expression (following the stick), and an eventual return to baseline.

C. Facial coding system selection

We propose use of the NFCS as a tool to obtain a rough map to more specific point locations from which we can measure facial action. The NFCS was determined most appropriate due to its established validity, reliability and its focus of pain in neonates. The 10 AU included in the NFCS are: brow lowering, eyes squeezed shut, deepening of naso-labial furrow, open lips, vertical mouth stretch, horizontal mouth stretch, taut tongue, chin quiver, lip purse, and tongue protrusion (as a "no pain" sign in term infants only).

D. Population consideration

Full-term newborn infants, without medical complications should make up the sample. The inclusion/exclusion criteria, aimed at minimizing potentially pathological and/or intervening factors, should include: (a) 38-40 weeks gestation, (b) vaginal delivery, (c) no history of present maternal pregnancy complications, (d) no history or evidence of genetic or congenital disorders, (e) no evidence of birth distress (Apgar scores [30] at one and five minutes > 6), and (f) no history of substance abuse during pregnancy.

To compare commonality of facial expression across ethnic background, the study should include infants from each of the major four ethnic groups (White/Caucasian non-Hispanic, African-American non-Hispanic, Hispanic/ Latino, and Asian), as self-assigned by the mother, equally divided by sex. Likely, the study will translate into testing a number of sub-hypothesis. Due to this, considerations should be made regarding the sample size to obtain strong statistical significance (e.g., α=0.05, β=0.90). This suggests a minimum requirement of 30 patients per group, resulting in a total of 240 (30x4x2) neonates.

E. Data Collection

A real-time 3D scanner should be used to capture the newborn's facial expression during the PKU heel stick procedure performed by the hospital staff. Normal room/crib lighting should be used in the recording, which should occur from shortly before preparing the heel for the stick (baseline), through the stick (painful stimulus) and shortly after it (recovery). Total time of recording should be 2 minutes maximum per participant, with at least 15 samples per second. Image-quality assessment algorithms should be used to validate the datasets. The infant should be placed on a crib as per usual procedure. Additional infant data includes demographic information and birth height/weight measurements to be obtained from medical records.

Since a 2D projection of the 3D scene in question can still be of great value, a 2D complementary/alternative study using a video camera should be considered. In addition, some bio-signals can potentially help in several aspects of the study, for example, in detecting peaks of pain expression. Consequently, recording these signals (e.g., facial heat mapping) is advised toward reinforcing findings.

All scene recordings are to be evaluated for facial action movement and intensity, and these data would be used to develop a graphic model of the facial expression. The intensity measurements derived here can then be used in the development of a graphic illustration of the PFP.

F. Data Analysis/Statistical Evaluation

Scene data should be analyzed for facial action using the NFCS as a validation mechanism and a link to the state-of the art FAC. This will allow for isolating, documenting and comparing facial action in response to a painful stimulus. Nevertheless, a higher resolution movement tracking is needed for modeling purposes. We propose to track a set of 23 facial points plus 4 reference points [24], as indicated in Figure 3. After coding for exhibited facial action, multivariate analyses of variance should be performed on the data to compare commonality of facial expression across sex and ethnic differences. Isolated facial actions involved should be analyzed for degree of motion or intensity in the facial expression with the usage of a 3D/2D editing tools. Provisions should be made to identify and correct artifact movement provoked by head movement. Finally, this tracking data should be utilized to reproduce a graphic model through photograph editing software and/or modeling and animation software that is anatomically representative of the PFP. The goal is to lay the foundation for the development of facial pain scales in a digital environment that is faithful to the PFP if such common expression is indeed found.

Fig. 3: Tracking points for facial action assessment

IV. CONCLUSION

Assessment of pain is key for quality pediatric care. A generic tool could be developed upon isolation of a common denominator for facial pain manifestations. Published works hint the existence of a primal Face of Pain (PFP). The documentation and illustration of the PFP can lead toward the development of modern FPSs.

REFERENCES

[1] A. J. Fridlund, Human facial expression: An evolutionary view. San Diego: Ekman, P. (1977). Biological and cultural contributions to body and facial movements. In J. Blacking (Ed.), *The anthropology of the body*. London: Academic Press, 1994.

[2] P. Ekman, "Facial expressions." In T. Dalgleish & M. Power (Eds.), *Handbook of cognition and emotion*. John Wiley & Sons, 1999.

[3] IASP. "Pain terms: A list with definitions and notes on usage." *Pain*, vol. 6, pp. 249-252, 1979.

[4] K. M. Prkachin, "The consistency of facial expressions of pain: a comparison across modalities." *Pain*, vol. 51(3), pp. 297-306, 1992.

[5] A. C. Williams, "Facial expression of pain: An evolutionary account." *Behavioral and brain sciences*, vol. 25, pp. 439-488, 2002.J. Soltis,

[6] "The signal functions of early infant crying." *Behav Brain Sci,* vol. 27(4), pp. 443-458; discussion 459-490, 2004 .

[7] K. S. Deyo, "Development of sensitivity to facial expression of pain." *Pain*, vol. 107(1-2), pp. 16-21, 2004.

[8] A. J. Fridlund, *Human facial expression: An evolutionary view.* San Diego: Academic Press, 1994.

[9] P. Ekman, "Basic emotions." In T. Dalgleish & M. Power (Eds.), 1999. *Handbook of cognition and emotion*. New York: John Wiley & Sons.

[10] K. D. Craig, "The facial expression of pain." In D. C. Turk & R. Melzack (Eds.), *Handbook of pain assessment (2nd ed.).* New York: The Guilford Press, 2001.

[11] S. A. Ibrahim, "Older patients' perceptions of quality of chronic knee or hip pain: differences by ethnicity and relationship to clinical variables." *The journals of gerontology Series A, Biological sciences and medical sciences*, vol. 58(5), pp. M472-477, 2003.

[12] C. E. Munoz, *Ethnicity and pain coping behavior trends among children with acute lymphocytic leukemia.*, Univ Microfilms International, 2004 .

[13] R. K. Portenoy, "Population-based survey of pain in the United States: differences among white, African American, and Hispanic subjects." *Journal of Pain*, vol. 5(6), pp. 317-328, 2004.

[14] C. Rosmus, "Pain response in Chinese and non-Chinese Canadian infants: is there a difference?" *Social Science & Medicine*, vol. 51(2), p.175, 2000.

[15] R. Melzack, "From the gate to the neuromatrix." *Pain*, vol. 6(suppl), pp. S121-S126, 1999.

[16] M. S. Bates, "Ethnicity and pain: A biocultural model." *Social Science and Medicine*, vol. 24(1), pp. 47-50, 1987.

[17] R. Davidhizar, "Assessing culturally diverse pediatric clients." *Pediatric Nursing*, vol. 25(4), p. 371, 1999 .

[18] K. D. Craig, "Challenges of judging pain in vulnerable infants." *Clin Perinatol*, vol. 29, pp. 445-457, 2002.

[19] R. Luffy, "Examining the validity, reliability, and preference of three pediatric pain measurement tools in African-American children." *Pediatric Nursing*, vol. 29(1), pp. 54-59, 2003.

[20] C. Chambers, "A comparison of faces scales for the measurement of pediatric pain: Children's and parents' ratings." *Pain*, vol. 83(1), p. 25, 1999.

[21] T. St-Laurent-Gagnon, "Pain evaluation in preschool children and by their parents." *Acta Paediatrica*, vol. 88, pp. 422-427, 1999.

[22] A. J. Singer, "Parents and practitioners are poor judges of young children's pain severity." *Academic emergency medicine: official journal of the Society for Academic Emergency Medicine,* vol. 9(6), pp. 609-612, 2002.

[23] P. Ekman and W. V. Friesen, Facial action coding system. Palo Alto: Consulting Psychologists Press, 1987.

[24] M. Pantic, I Patras. "Detecting facial actions and their temporal segments in nearly frontal-view face image sequences." IEEE ICSMC, 2005. pp. 3358-3363.

[25] R. V. Grunau, and K. D. Craig, "Pain expression in neonates: facial action and cry," *Pain*, vol. 28(3), pp. 395-410, 1987.

[26] C. A. Gilbert, C. M. Lilley and K. D. Craig, "Postoperative pain expression in preschool children: validation of the child facial coding system." *Clin J Pain*, vol. 15(3), pp. 192-200, 1999.

[27] C. E. Izard, *The maximally discriminative facial movement coding system.* Revised edition. Newark: Instructional Resources Center, University of Delaware, 1983.

[28] K. M. Prkachin, "The consistency of facial expressions of pain: a comparison across modalities." *Pain*, vol. 51(3), pp. 297-306, 1992.

[29] E. A. Stanford, C. T. Chambers and K. D. Craig, "The role of developmental factors in predicting young children's use of a self-report scale for pain," *Pain*, vol. 120(1-2), pp. 16-23, 2006.

[30] Mosby's Medical, Nursing and Allied Health Dictionary. 2002. 6th Edition. Mosby.