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The consistency of facial expressions of pain: a comparison across modalities

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Summary A number of facial actions have been found to be associated with pain. However, the consistency with which these actions occur during pain of different types has not been examined. This paper focuses on the consistency of facial expressions during pain induced by several modalities of nociceptive stimulation. Forty-one subjects were exposed to pain induced by electric shock, cold, pressure and ischemia. Facial actions during painful and pain-free periods were measured with the Facial Action Coding System. Four actions showed evidence of a consistent association with pain, increasing in likelihood, intensity or duration across all modalities: brow lowering, tightening and closing of the eye lids and nose wrinkling/upper lip raising. Factor analyses suggested that the facial actions reflected a general factor with a reasonably consistent pattern across modalities which could be combined into a sensitive single measure of pain expression. The findings suggest that the 4 actions identified carry the bulk of facial information about pain. They also provide evidence for the existence of a universal facial expression of pain. Implications of the findings for the measurement of pain expression are discussed.

Key words: Facial expression; Nociceptive stimulation; Facial Action Coding System; Pain

Introduction

People in pain communicate their experience in many ways (Craig and Prkachin 1983). These communications, often subsumed by the label 'pain behavior' (Fordyce 1988), are the basis on which most inferences about pain are drawn in clinical and research settings. Because the consequences of pain are profound, it would be adaptive if the behaviors evoked were consistent and in the service of comparable ends such as survival or the reduction of suffering. It has been suggested that one of the primary functions of pain behavior is to enlist the aid of others (Prkachin et al. 1983).

Implicit in the use of the single term 'pain behavior' to refer to several events is the assumption that different indicators of pain have similar effects and determinants. However, disparate phenomena called pain behavior may serve multiple functions or be influenced by different variables (Prkachin 1986). To understand the roles of different pain behaviors, it is necessary to study their properties both separately and in relation to one another.

The present study focused on properties of 1 specific form of pain behavior: facial expression. People in pain often show changes in facial expression that are readily observable to others. Clinicians and laypeople place great emphasis on the credibility of these behaviors and view them as especially reliable indicators of the quality and intensity of a sufferer's pain (Craig et al. in press), however, the nature of information about pain carried by facial expression is not comprehensively understood. In order to interpret the meaning of facial changes during pain effectively, clinicians and researchers alike need answers to such questions as whether specific facial actions provide clear clues to pain states, whether cues to pain are common to all pain states or specific to only some, and whether an overt expression of pain relates faithfully to the subjective experience. Answers to these questions are dependent on understanding the function and determinants of pain expression.

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The salience of facial changes suggests that they may be especially adapted to a communicative role (Prkachin 1986). This is consistent with theories of non-verbal communication which suggest that some facial configurations have evolved to serve a 'signal' function (Redican 1982). If expressions of pain resemble these other forms of facial behavior, they should have similar properties. Of particular interest is whether facial expressions during pain, like expressions of fundamental emotions, are universal (Ekman and Friesen 1971; Ekman and Oster 1982). If a universal expression of pain could be identified, clinicians and researchers might then be able to incorporate investigation of facial expression into the assessment of a variety of pain states, an ability that could have advantages in several situations (Craig et al. in press).

The notion of universality implies the existence of a pain signal that is consistent across stimulus conditions and cultures. The present study was addressed to the first of these attributes. Is there a set of facial changes that appears consistently when pain is induced by different methods? Several studies are relevant to this issue.

Facial actions that appear to be correlated with pain have been identified by a number of researchers. Table I summarizes findings from studies which have employed the Facial Action Coding System (FACS) (Ekman and Friesen 1978a), a precise measurement technique, to analyze pain expressions. In most studies, a core of actions is likely to occur or to increase in intensity when people are in pain. The core consists of movements of corrugator and orbicularis oculi, which lower the eyebrows, narrow the eye opening and raise the cheeks. Various other movements appear with some frequency, notably actions of levator labii superioris (which raise the upper lip, deepen the nasolabial furrow, or wrinkle the nose), eyelid closing and mouth opening. Other actions (e.g., oblique pulling of the lip corners, opening and horizontal stretching of the mouth) appear with less consistency. Thus, available evidence suggests that a number of facial actions encode pain information. However, previous studies have not determined whether facial actions are consistent during different types of pain because they have employed single stimulus modalities or types of clinical pain.

A second purpose of the present study was to examine the structure of pain expressiveness relative to other measures of pain sensitivity. Interest in pain expression has emerged, in part, because of the need to develop new ways of measuring and assessing pain (Chapman et al. 1985). Measures of pain expression may be valuable because they provide information that is different from that available in other channels. Indeed, several studies have reported that facial expressions during pain are independent of or modestly related to other pain measures, suggesting that they carry unique information (Patrick et al. 1986; LeResche and Dworkin 1988; Prkachin and Mercer 1989). In the present study, facial expressions of pain were compared with verbal, pain threshold and pain tolerance measures to determine the degree of overlap among these indices.

The final purpose of the present study was a practical one. In studies of pain expression to date, it has been necessary to employ the FACS in a comprehensive manner to avoid the possibility of overlooking meaningful actions. This is an extremely laborious procedure, often requiring a coding time/real time ratio of 100:1. Consequently, widespread use of facial measurement in the study of pain has been impractical. If a subset of facial actions that occur consistently across a

TABLE I

FACIAL ACTIONS THAT HAVE SHOWN SIGNIFICANT RELATIONSHIPS WITH PAIN IN PREVIOUS RESEARCH WITH ADULTS

Action		Study
AU4	Brow lower	Craig et al. (1991)
		LeResche (1982)
		LeResche and Dworkin (1988)
		Patrick et al. (1986)
		Prkachin and Mercer (1989)
AU6	Cheek raise	Craig et al. (1991)
		Craig and Patrick (1985)
		LeResche (1982)
		LeResche and Dworkin (1988)
		Patrick et al. (1986)
		Prkachin and Mercer (1989)
AU7	Lid tighten	Craig et al. (1991)
		Craig and Patrick (1985)
		LeResche (1982)
		LeResche and Dworkin (1988)
		Prkachin and Mercer (1989)
AU9	Nose wrinkle	LeResche and Dworkin (1988)
		Prkachin and Mercer (1989)
AU10	Upper lip raise	Craig et al. (1991)
		Craig and Patrick (1985)
		LeResche and Dworkin (1988)
		Patrick et al. (1986)
		Prkachin and Mercer (1989)
AU12	Oblique lip raise	Craig and Patrick (1985)
		Prkachin and Mercer (1989)
AU20	Lip stretch	LeResche (1982)
		Prkachin and Mercer (1989)
AU25	Mouth open	Craig et al. (1991)
AU26	Jaw drop	Craig and Patrick (1985)
AU27	Mouth stretch	LeResche (1982)
		Prkachin and Mercer (1989)
AU43	Eyes close	Craig et al. (1991)
		LeResche (1982)
		Craig and Patrick (1985)
		Prkachin and Mercer (1989)
AU45	Blink	Craig and Patrick (1985)
		Patrick et al. (1986)
		LeResche and Dworkin (1988)

variety of types of pain can be identified, coding time could be reduced thus making application of facial analysis more practical. Even if such a core of actions could be identified, however, it would leave open the question of how best to weigh the information available from different movements to quantify the pain signal. For example, when an expression containing 2 or more pain-related actions takes place, is the information from those movements redundant or unique? Answers to such questions have important implications for the scaling of pain expressions. A final purpose of the present study was to explore the structure of facial movements occurring during pain with multivariate methods in order to determine how optimally to combine the information they provide.

Method

Subjects

Twenty male (mean age: 20.8, S.D.: 2.02) and 21 female (mean age: 19.86, S.D.: 1.28) University of Waterloo undergraduates took part. None had taken any analgesic medication for at least 24 h prior to the test session.

Apparatus and materials

Subjects were exposed to 4 types of stimulation: electric shock, cold, pressure and muscle ischemia. Isolated, monophasic currents pulsed at 40 Hz were delivered by a Pulsar 6b stimulator (F. Haer and Co., Brunswick, ME) to the volar surface of subjects' right forearms through a pair of silver–silver chloride electrodes 8 mm in diameter. Cold stimulation was produced with the cold pressor test. A styrofoam tank contained water and ice, maintained at a temperature between 0 and 1°C. An aquarium pump (Aquaclear Power Head 200) placed in the tank circulated the water to prevent local warming during the test. Mechanical pressure was applied with a specially constructed stimulator (Forgione and Barber 1971). This device applied steady pressure to a plexiglass wedge. The wedge was attached to a lever with a 100-g weight resting on its end. A rubber bandage, a standard mercury sphygmomanometer cuff and a hand dynamometer (Takei Kiki Kogyo) were used to produce ischemic pain.

Procedure

The experiment was conducted in a laboratory room adjacent to a control room. A male and a female experimenter conducted the study. The experimenter responsible for procedures in the experimental room was always the same gender as the subject. During testing this experimenter was isolated from the subject by a curtain. An intercom system allowed audio communication between the control and experimental rooms. Proceedings in the experimental room could be viewed through a 1-way mirror, which was partially obscured using corkboards and notices to allay the subject's potential suspicions about being observed. The face of the subject, seated in a reclining chair facing the mirror, was videotaped in black-and-white on VHS videotape, although the subject was not aware of this.

A box containing 2 buttons, marked 'painful' and 'intolerable' was located at the subject's left side. The buttons were connected to 2 lights in front of the experimenter and to a buzzer in the control room. In this way, the subject could indicate when pain threshold and tolerance had been reached.

Electric stimulation consisted of 3-sec currents delivered to the volar surface of the subject's right forearm. Stimuli were presented in ascending intensity, beginning at 0 mA and increasing in 0.5-mA steps. During cold stimulation, the subject immersed the right arm in water up to the elbow. During pressure stimulation the stimulator was applied to the 1st phalange of the 3rd digit of the right hand. Ischemic pain was produced according to the procedures described by Petrovaara et al. (1984) except that the subject squeezed the hand dynamometer at 75% rather than 70% maximal contraction.

The study was described as dealing with subjective responses to electric shock, cold, pressure and ischemia. Subjects were told that the maximum pain they experienced would be up to them and that they were free to terminate stimulation and the experiment at any time. They were also told that the tests would be terminated in any case well before the point at which tissue damage could occur.

Stimuli were presented in 1 of 4 orders. For each modality, the subject pressed a button marked 'painful' when pain was first experienced and a button marked 'intolerable' to indicate the point at which stimulation should cease. At the end of each test, the subject used categorical and ratio scales of affective and sensory descriptors (Heft et al. 1980) to describe the maximum pain experienced.

For all modalities, stimulation continued until the subject terminated the test or the cut-off intensity or time was reached. The cut-off points were 14.0 mA for shock, 3 min for cold and pressure pain and 15 min for ischemia.

Before being debriefed, the subject completed a questionnaire indicating the proportion of time during each modality that he/she engaged in catastrophic or coping cognitions. At this point the fact that videotaping had taken place was disclosed, and the subject was given the opportunity to have the tape erased. No one elected this option. Thereafter the subject completed another form giving consent for further use to be made of the videotapes.

Measurement of facial action

Facial expressions were measured with the FACS, allowing observers to 'dissect' any facial movement into its muscular bases, thereby determining which of 44 specific actions had taken place. Coding was performed by 3 observers, each of whom had undergone FACS training and passed the test of proficiency devised by the developers of the system.

For each modality, facial actions were scored during a period when subjects were not being exposed to the stimulus (baseline) and immediately prior to pain tolerance. Coding varied slightly, depending on the modality. For tonic pain (cold, pressure, ischemia), actions were scored in 10-sec intervals. Baseline intervals were coded from the 10-sec period that occurred immediately before the stimulus was applied. Pain intervals were coded from the 10-sec period immediately before the subject indicated that pain tolerance had been reached.

The episodic pain of electric shock was scored in 3-sec intervals. Baseline observations consisted of the two 3-sec intervals prior to the 1st shock. Pain intervals were coded from the shock that resulted in a pain tolerance rating and the shock immediately preceding that one. These stimuli were each coded for the 3-sec period during which shock was applied. Data from these 2 intervals were then combined to yield a measure of pain expression during 6 sec of exposure to electric shock-induced pain.

For each modality, if the subject did not request termination by the time the cut-off point had been reached, the maximal level attained was taken as pain tolerance.

Occasionally, technical problems resulted in the baseline segment not being available. In such cases, a segment was selected from portions of the video record that were comparable to the baseline. These intervals were selected only if there was no pain stimulation occurring to the subject at the time, and for the preceding and the following 6 sec.

The time of onset, peak intensity, and offset of each facial action were identified. Only actions with an onset during the interval in question were scored. Thus, if an action began prior to, and was present throughout, the interval, it was not coded, even if it was strong, endured for a substantial time or increased dramatically in intensity during the interval. Ten seconds was set as the maximum duration for any action.

Most actions were rated on a 6-point intensity scale (Friesen 1988) which varied from 'no action' (0) through 'minimal action' (a 'trace', coded as 1) to 'maximal action' (5). Those actions that did not lend themselves to an intensity rating (e.g., AU38 – nostril dilate) were coded in a binary format (present/absent).

Three sets of actions were combined. AU6 (cheek raise) and AU7 (lid tighten) were combined into 1 variable (orbit tightening) because the forms and muscular bases of the movements are similar. There is precedent in the FACS literature for performing this combination (Ekman et al. 1985). AU9 and AU10, were also combined into 1 action (levator contraction). These actions involve contractions of different strands of the levator labii muscles, resemble each other and have been hypothesized to represent different stages of the same expression (Prkachin and Mercer 1989). There is also precedent for considering these actions as elements of a unitary expression (Ekman and Friesen 1978b). AU25, AU26 and AU27, which represent varying degrees of mouth opening, were combined into a 4-point scale consisting of 3 increasing degrees of mouth openness (AU25, AU26 and AU27, coded as 1, 2 and 3) and mouth closure (coded as 0) (cf., Prkachin and Mercer 1989).

Scoring reliability was assessed by comparing the 2 coders' data to that of the author on 116 intervals. Reliability, assessed by Ekman and Friesen's (1978b) formula was 0.75, which is comparable to that observed in other FACS studies (cf., Craig et al. 1991).

Statistical analysis

An action was selected for further analysis if (1) it had been reported in previous studies to be associated with pain, or (2) its frequency was greater than 1% of the total sample of actions coded.

The actions selected for further analysis have different properties. Some are binary (present or absent), others vary in frequency, and several vary in intensity. All can be quantified according to their duration. Table II presents the metric properties of the selected actions.

Because of these variations in metric properties, different analytic strategies were employed as appropriate. Binary variables were analyzed with Cochran's Q test, a non-parametric technique for evaluating differences in related categorical variables. Frequency, intensity or duration measures were analyzed with analysis of variance (ANOVA) procedures. Those actions for which a-priori evidence of an association with pain existed were analyzed in univariate factorial 2 (gender)$\times$4 (modalities)$\times$2 (epochs: baseline vs. pain) ANOVAs. When these analyses indicated a significant epochs effect or epochs$\times$modalities interaction, the significance of differences from baseline to pain interval were determined with planned orthogonal t tests (2-tailed; alpha < 0.05) for each modality. Differences between modalities were analyzed with the Tukey *HSD* post-hoc test since there was no prior reason to predict modality differences. Those actions for which a-priori evidence of an association with pain did not exist were analyzed in a multivariate analysis of variance (MANOVA) of the same form. Duration data were analyzed in the same way.

TABLE II

FACIAL ACTIONS SELECTED FOR FURTHER ANALYSIS

Percent denotes the percentage of all AUs coded in the entire data set.

Action	Description	Percent	Coding
AU1	Inner brow raise	2.0	Intensity
AU2	Outer brow raise	1.9	Intensity
AU4	Brow lower	3.2	Intensity
AU6	Cheek raise	4.5	Intensity
AU7	Lid tighten	5.4	Intensity
AU9	Nose wrinkle	2.2	Intensity
AU10	Upper lip raise	1.6	Intensity
AU12	Oblique lip pull	5.1	Intensity
AU14	Dimple	2.3	Intensity
AU17	Chin raise	4.1	Intensity
AU20	Lip stretch	0.7 *	Intensity
AU24	Lip press	2.7	Intensity
AU25	Lips part	2.1	Binary
AU26	Jaw drop	2.9	Binary
AU27	Mouth stretch	0.1 *	Binary
AU38	Nostrils flare	1.4	Binary
AU41	Lids droop	2.9	Binary
AU43	Eyes close	2.8	Binary
AU45	Blink	34.5	Frequency

* Action included because of prior evidence of an association with pain.

Results

Categorical analyses

Categorical analyses revealed no significant differences in the likelihood of AU38 (nostril dilation) between baseline and pain states. Eye closing occurred during 20% of pain intervals and 0% of baseline intervals during electric shock, a difference that was significant (Q (1) = 7.00, $P < 0.01$). There was also a tendency for eye closing to be more likely during pain than during baseline intervals for cold and pressure pain ($P < 0.10$).

Intensity analyses

The intensity scores for each action were summed separately for baseline and pain intervals in the 4 modalities. Eight subjects (3 male and 5 female) had missing data on 1 of the variables, either because a trial had not been videotaped or a baseline segment was unavailable. Although this represented only 0.03% of the data, it had the effect of censoring the entire case from repeated measures analyses. Therefore, the data were analyzed in 2 ways. The first employed only subjects with complete data. In the second, a conservative assumption was made that the action in question did not occur at all during the missing intervals and zeros were entered for the missing data. In no case was the outcome of these secondary analyses different from the original; therefore they will not be reported.

In the analyses of AUs for which there was a-priori evidence of a relationship with pain, several actions varied reliably with pain. For brow lowering (AU4), orbital tightening (AU6/AU7), levator contraction (AU9/AU10) and oblique lip pulling (AU12) there were significant epoch effects (Fs (1, 31) ranging from

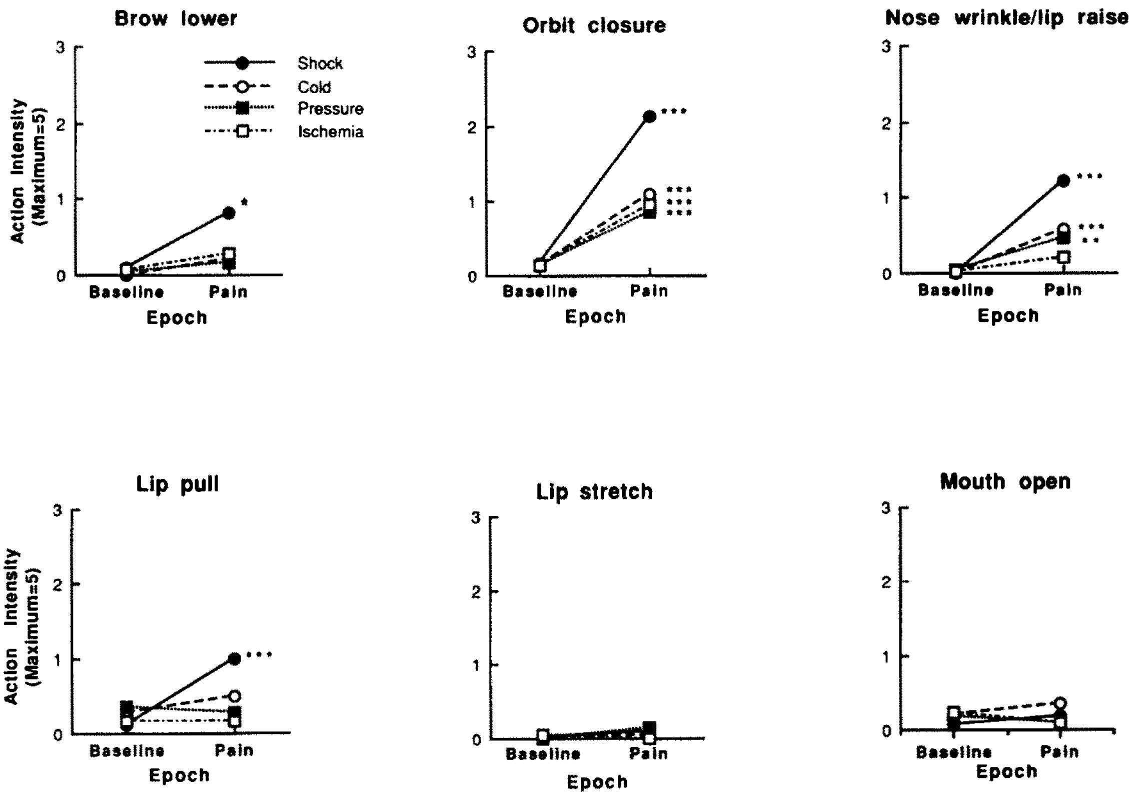

Fig. 1. Differences in the intensity of facial actions from baseline to pain tolerance.

7.25, $P = 0.01$ to 49.28, $P < 0.001$). For brow lowering and orbital tightening there were also significant stimulus × epochs interactions (Geisser-Greenhouse Fs (3, 29) = 3.22, $P < 0.05$, and 3.86, $P < 0.01$, respectively). The results of these analyses are presented in Fig. 1. There, it can be seen that the intensity of orbital tightening increased significantly with pain for all, and the intensity of levator contraction increased significantly with 3 of 4 modalities. Although brow lowering increased with pain during all modalities the differences were only significant for shock. Oblique lip pulling and mouth opening increased significantly with shock; however, they were *less* intense during pain for some modalities. Brow lowering, orbit tightening and levator contraction were more intense for electric shock than the other modalities.

Analyses of actions for which there was no a-priori evidence of association with pain yielded no significant effects.

Frequency analyses

Analysis of blinking frequency revealed a significant epoch effect (F (1, 31) = 16.26, $P < 0.01$). There was no modalities × epoch interaction. Fig. 2 reveals that, contrary to expectations, blinking rate *decreased* during pain across modalities, significantly so for pressure and ischemic pain.

Duration analysis

Comparable analyses of the total durations of facial actions were conducted on all coded AUs. Eye closure (AU 43) and blinking (AU 45) were analyzed in the univariate data set because of pre-existing evidence that these actions are associated with pain. AU 38 was

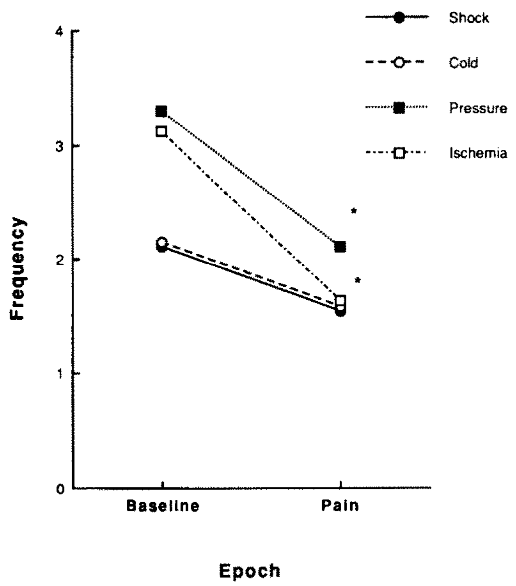

Fig. 2. Differences in blinking frequency from baseline to pain tolerance.

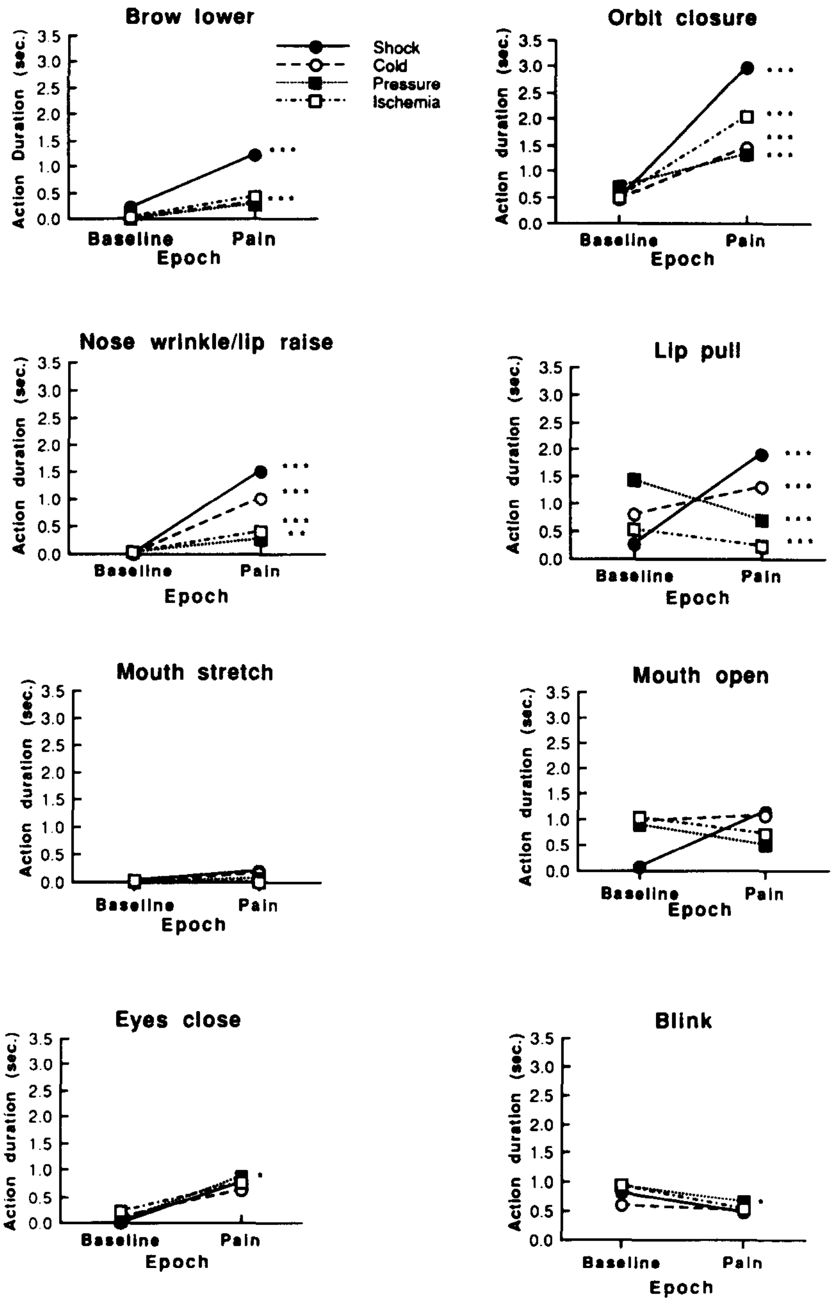

Fig. 3. Differences in the duration of facial actions from baseline to pain tolerance.

included in the multivariate analyses because it did not meet this criterion.

The results are summarized in Fig. 3. The findings were comparable to those for intensity. The durations of brow lowering (AU4), orbit tightening (AU6/AU7), and levator contraction (AU9/AU10) increased reliably during pain across all modalities. Duration of eye closure (AU43) was greater during pain for all modalities, but only significantly so for shock and pressure pain. Duration of lip pulling (AU12) varied significantly with pain, but the direction of the relationship varied from one modality to another: for shock and cold it was longer, and for pressure and ischemia it was shorter during pain. For shock and ischemia, the duration of blinking was significantly related to pain, but in the direction opposite to that predicted.

The MANOVA of facial actions for which there was no a-priori evidence of a relationship with pain revealed no further systematic effects.

Combining facial actions

Although several studies have examined facial expressions of pain, few have considered the problem of weighting separate actions to most effectively capture

TABLE III

RESULTS OF PRINCIPAL COMPONENTS FACTOR ANALYSES OF INTENSITIES OF FOUR FACIAL ACTIONS DURING SHOCK, COLD, PRESSURE AND ISCHEMIC PAIN

	Factor loadings					
	Shock	Cold		Pressure		Ischemia
	I	I	II	I	II	I
Brow	0.59	0.52	0.78	0.25	0.96	0.66
Lid/cheek	0.88	0.91	−0.24	0.82	−0.31	0.75
Nose/lip	0.91	0.76	−0.57	0.66	−0.10	0.74
Eyes	0.82	0.83	0.29	0.90	0.09	0.74
Eigenvalue	2.63	2.38	1.08	1.97	1.03	2.09
% variance	65.8	59.5	26.9	49.3	25.8	52.2

Factor-score coefficients: Brow 0.22; Lid/cheek 0.33; Nose/lip 0.35; and Eyes 0.31.

the information they provide about the construct they are intended to assess. Factor analysis was employed to ascertain how the separate pain-related actions interrelate empirically and to derive weights that reflect that natural ordering. The foregoing analyses provided evidence that no more than 4 actions were consistently related to pain in categorical, intensity or duration analyses. Intensity scores for brow lowering, orbit tightening, levator contraction and a variable consisting of the number of eye closures (not blinks) were entered into principal component factor analyses.[1] Separate analyses were performed for each modality. An eigenvalue greater than 1 was necessary to be retained as a factor. The results are presented in Table III. For each modality, the analysis revealed a large 1st factor, accounting for 49–65% of the variance in AU intensities. Analyses for cold and pressure pain also revealed smaller 2nd factors. The structures of the 1st factor in all modalities were generally similar. In each case orbit tightening, levator contraction and eye closure loaded substantially on this factor. Brow lowering also loaded on the 1st factor for all but pressure pain.

These findings imply that the 4 actions reflect a general pain expression factor. Sensitivity of a measure based on such a factor was tested by weighting and combining facial-action intensity scores to reflect the factor structure derived from the foregoing analysis. Since factor analyses yielded structures and factor-score coefficients that were unique to their own distributions, it was necessary to decide on a common metric by which all modalities could be compared. Because the initial analyses indicated that response to electric shock was the clearest and most intense, the weighting coefficients from the shock factor analysis were used as

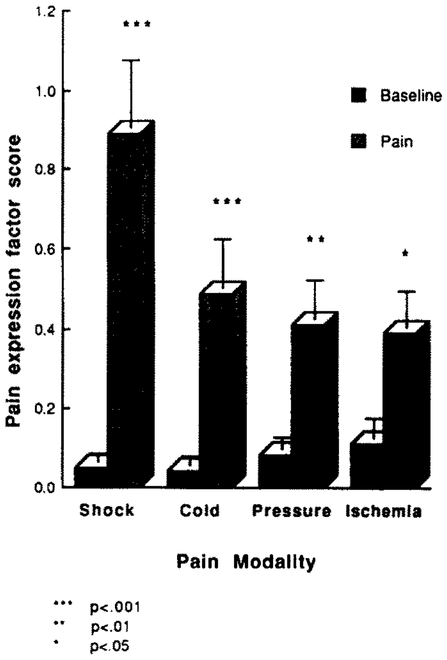

Fig. 4. Differences in pain expression factor scores from baseline to pain tolerance.

the basis for conversion. These weights are presented in Table III. Intensity scores for each action at baseline and during pain for each modality were then converted to standard scores relative to the shock distribution and multiplied by their factor-score coefficient. The resultant values were then summed to create a weighted composite pain-expression score. Since, due to standardization, the resulting scores could be less than zero, a constant representing the standard score for no action in the shock analyses was added so that a final score of zero represented no action. These values were entered into a 2 (gender) × 4 (modalities) × 2 (epochs) ANOVA. The results are presented in Fig. 4. Significant epoch (F (1, 31) = 34.32, $P < 0.001$), modalities (F (3, 93) = 3.94, $P < 0.05$), and modalities × epochs effects (F (3, 93) = 4.23, $P < 0.01$) were obtained. Planned t tests revealed that factor scores at pain for all modalities were significantly greater than those at baseline. Comparisons across modalities by Tukey *HSD* indicated that the mean factor score during shock pain was greater than that for all other modalities. There were no other significant differences.

TABLE IV

INTERCORRELATIONS AMONG PAIN EXPRESSION FACTOR SCORES FOR ALL MODALITIES

	Cold	Pressure	Ischemia
Shock	0.39 *	0.29	0.33 *
Cold		0.32 *	−0.02
Pressure			0.33 *

* $P < 0.05$.

[1] The same analysis of duration data yielded comparable results. These may be obtained by writing the author.

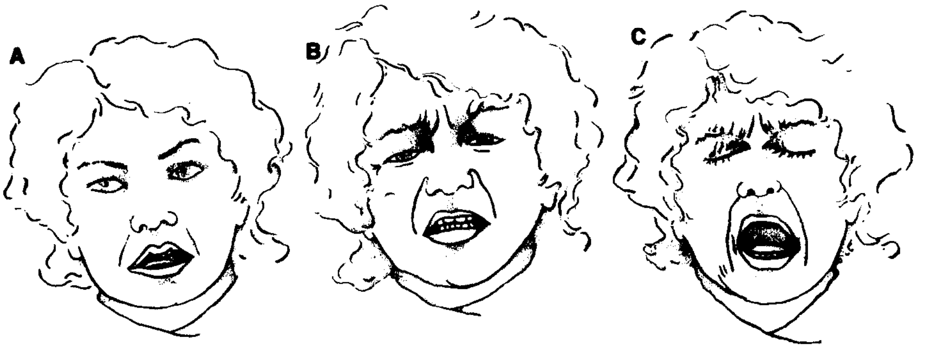

Fig. 5. A sequence of facial changes showing the emergence of the 4 principal facial actions. A: onset of action. B: brow lowering (AU4), orbit tightening (AU6) and levator contraction (AU10) C: brow lowering, orbit tightening (AU7) and eyelid closing (AU43) Also shown is mouth stretch (AU27) which was not consistently related to pain.

Table IV presents the intercorrelations among factor scores for all modalities. With the exception of the relationship between cold and ischemic pain and between shock and pressure pain, these measures tended to be modestly and significantly related. Factor scores for each modality were also correlated with the subject's pain threshold and tolerance scores on that modality, the subjective ratings of maximal pain due to that modality on categorical, sensory and affective scales, and the rating of the amount of coping and catastrophizing engaged in during that modality. Of 28 correlations performed, only 2 were significant, a value that is only marginally greater than that which would be expected by chance. Therefore, it appeared that the pain-expression factor scores were largely unrelated to pain threshold, tolerance, subjective pain ratings and measures of cognitive activity during pain.

Discussion

Although more than 6 facial actions have been reported to occur with pain, there has been some inconsistency in the actions which have been identified. In the present study, brow lowering, orbit tightening and levator contraction were consistently related to pain. The intensity of orbit closure and levator contraction was significantly greater and the duration of both actions longer during pain for all modalities. The duration of brow lowering was significantly longer during pain than at baseline across all modalities, and its intensity was increased during pain, significantly so for electric shock. Eye closure was more likely during pain than baseline for electric shock, marginally more likely during cold and pressure and its duration was greater during pain than baseline for electric shock and pressure.

Consistency of association across different types of pain is a stringent, yet useful, criterion for designating an action pain related. Applying this criterion to the present results suggests that the list of potentially pain-related facial actions can be narrowed. It would appear that the bulk of information about pain conveyed by facial expression is represented by 4 actions: brow lowering, orbit tightening, levator contraction and eye closure. Indeed, the factor-analytic results suggest that, even within this subset, the greatest amount of variance is accounted for by orbital and levator action. This suggests that the 4 actions comprise a basic 'signal' (see Fig. 5) that may be universal to different types of pain. Although the present findings were obtained with experimental pain stimuli, the same actions have been associated with pain in most other analyses of facial expression including studies of time-limited, discrete, experimental pain (Craig and Patrick 1985; Patrick et al. 1986), and of pain patients (LeResche 1982; LeResche and Dworkin 1988; Prkachin and Mercer 1989; Craig et al. 1991). Thus, the conclusion that this signal is general and common to a variety of states, including clinical pain, appears to be sustainable.

This is not to say that the 4 actions comprise the only pain signal or that other movements may not show a unique and consistent relationship to pain. It is possible that clinical pain states may evoke further actions, especially when pain intensity becomes severe and exceeds the limits that it is possible to impose in experimental studies (LeResche 1982; Prkachin and Mercer 1989). For example, horizontal stretching of the lips produced by risorius (AU20) has been reported to be associated with pain in some studies (LeResche 1982; Prkachin and Mercer 1989). Nevertheless, available studies would suggest that even in such circumstances the actions identified here would often be present.

Of course, a consistent relationship between facial expressions and appropriate eliciting conditions is only 1 criterion for establishment of universality. Universality also implies cross-cultural consistency (Ekman and Friesen 1971). Future research should examine this issue.

Three actions that have been associated with pain in previous studies bore peculiar relationships to it in the present study. Oblique pulling of the lips (AU12) was significantly more intense during the pain of electric shock and cold than at baseline, confirming previous observations (Craig and Patrick 1985; Prkachin and Mercer 1989). However, during pressure and ischemic pain, this action was less intense and its duration shorter during pain than at baseline. Similarly, mouth opening was more intense during shock and cold but less intense during pressure. Blinking rate and duration actually decreased during all pain modalities, a finding that is in direct contrast to some previous studies (Craig and Patrick 1985; Patrick et al. 1986), but which is similar to results reported by Craig et al. (1991) and Prkachin and Mercer (1989). Analyses of actions that have not been identified in previous research to bear a relationship to pain uncovered no new candidates to consider as potentially pain related.

That some actions are more likely or more intense during only some pain modalities and not others may be evidence for stimulus specificity. Alternatively, these actions may reflect the occurrence of secondary processes such as coping or self-observation. For example, a parsimonious explanation of why blinking rate is only occasionally associated with pain derives from examining factors confounded with pain in different studies. In studies in which pain has been accompanied by an increased blinking rate, the pain has been of sudden onset (as in electric shock) or in its early stages (as in cold pressor). As noted by Prkachin and Mercer (1989), these conditions are likely to produce the confounded experience of startle which other research has found to produce blinking (Ekman et al. 1985). Thus, it seems likely that those actions which bear an inconsistent relationship with pain across modalities may represent the occurrence of processes that may be confounded with pain.

It would appear that clinicians and investigators interested in assessing pain via facial expression could safely restrict themselves to the investigation of brow lowering, lid tightening/cheek raising, nose wrinkling/lip raising and eye closing. This should simplify the process of measurement in this field considerably. The present data also imply that oblique lip pulling, mouth opening and blinking should *not* be considered actions that carry information specific to pain, and therefore investigators who are uninterested in the potential information that these actions might carry could safely ignore them. The factor analytic results imply, however, that it would be important to measure all the 'core' actions comprehensively. Although data from each modality yielded evidence that the collection of 4 facial changes represented a general reaction in the sense that they were correlated, it was also clear that the information provided by separate actions was not completely redundant. Indeed, each action made substantial contribution to a composite index of pain expression. As shown in Fig. 4, this index provides quite sensitive discrimination of pain and non-pain conditions. Researchers interested in obtaining a measure of pain expression might profitably make use of this index in the future.

Pain expressions were not correlated with pain threshold, pain tolerance or reports of pain intensity. This independence among measures may have been artifactually introduced by the methodology employed, since pain expression and subjective intensity measurements were both taken at the point when subjects were exposed to the maximum pain they would tolerate. With most subjects experiencing substantial pain, and indicating so both verbally and non-verbally, there may not have been enough variation in pain state to effectively determine whether subjective and expressed pain levels were consistent with one another. On the other hand, the outcome is consistent with other findings (LeResche and Dworkin 1988), indicating that facial expressions provide evidence about pain processes that is different from that available in other measures.

In conclusion, the results of this study support 2 major generalizations. First, a relatively small subset of actions convey the bulk of information about pain that is available in facial expression. Second, the occurrence of those actions is fairly consistent across different types of pain. These findings are consistent with the suggestion that pain expressions may be universal. The present data provide some suggestions for how these phenomena may be profitably quantified in future studies.

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