

Voluntary Facial Displays of Pain Increase Suffering in Response to Nociceptive Stimulation

Tim V. Salomons,^{*,†} James A. Coan,^{*,||} S. Matthew Hunt,^{*} Misha-Miroslav Backonja,[§] and Richard J. Davidson^{*,†,‡}

^{*}Waisman Laboratory for Brain Imaging and Behavior, Waisman Center,

[†]Department of Psychology,

[‡]Department of Psychiatry, and

[§]Department of Neurology, the University of Wisconsin-Madison, Madison, Wisconsin; and

^{||}University of Virginia Department of Psychology, Charlottesville, Virginia.

Abstract: Facial expressions of pain are an important part of the pain response, signaling distress to others and eliciting social support. To evaluate how voluntary modulation of this response contributes to the pain experience, 29 subjects were exposed to thermal stimulation while making standardized pain, control, or relaxed faces. Dependent measures were self-reported negative affect (valence and arousal) as well as the intensity of nociceptive stimulation required to reach a given subjective level of pain. No direct social feedback was given by the experimenter. Although the amount of nociceptive stimulation did not differ across face conditions, subjects reported more negative effects in response to painful stimulation while holding the pain face. Subsequent analyses suggested the effects were not due to preexisting differences in the difficulty or unpleasantness of making the pain face. These results suggest that voluntary pain expressions have no positively reinforcing (pain attenuating) qualities, at least in the absence of external contingencies such as social reinforcement, and that such expressions may indeed be associated with higher levels of negative affect in response to similar nociceptive input.

Perspective: This study demonstrates that making a standardized pain face increases negative affect in response to nociceptive stimulation, even in the absence of social feedback. This suggests that exaggerated facial displays of pain, although often socially reinforced, may also have unintended aversive consequences.

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Key words: Pain, facial displays, directed facial action task.

Facial displays are one of the clearest indicators that an individual is experiencing pain. Precise characterization of these facial displays has facilitated their use as a complementary indicator of pain in clinical settings, particularly in infants or adults with limited linguistic ability.⁸

Considerable research has been dedicated to understanding the origin and maintenance of facial expressions

of pain. The operant model of pain behavior,¹⁴ for example, has emphasized the role of reinforcement in the establishment and maintenance of pain behaviors including facial displays. Within this framework, the positive social reinforcement elicited by facial displays of pain is viewed as a primary factor in their etiology and continuance. Based on observations of pain displays in a wide variety of species and in infants as young as 25 days, Williams¹⁹ has compellingly argued that many of the morphological characteristics of facial pain displays are reflexive and have evolutionary origins. Nevertheless, actions that are not voluntary or explicitly social in nature can be recruited for instrumental purposes,^{8,9} suggesting that pain displays may include a component that is voluntary, or at least under the control of social contingencies consistent with the operant model, as this may confer advantages such as increased social support or decreased suffering.

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Address reprint requests to: Tim Salomons, Waisman Laboratory for Brain Imaging and Behavior, Waisman Center, 1500 Highland Drive, A-132, Madison, WI 53705. E-mail: tsalomons@wisc.edu
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From a clinical perspective, the critical question that arises is the degree to which deliberate augmentation of a particular pain behavior is an adaptive strategy for coping with pain. Operant treatments for chronic pain seek to identify the specific reinforcers and punishments associated with each behavior. Although social feedback may represent a reinforcer, it is possible that there are negative consequences of this behavior that counteract these benefits. To properly assess this question in a laboratory setting, the effect of pain behaviors on the subjective experience of pain must be disentangled from the effect of positive reinforcers such as social support. Toward this goal, the present study tests the effect of a voluntary facial display of pain on the affective response to pain in the absence of social reinforcement.

In addition to limiting social reinforcement, this study aimed to reduce demand characteristics by using standardized facial movements. Previous studies that have examined this question^{7,15,17} have instructed subjects to exaggerate or inhibit their response to a pain stimulus. Although this technique has the advantage of external validity (as the manipulation is based upon the subject's own natural response to pain), it may lead to biased results due to the effect of demand characteristics, as instructions to exaggerate the facial response to pain may implicitly suggest to the subject that pain ratings should also be increased.

The present study used the Directed Facial Action (DFA) Task,¹⁰ a set of instructions developed to guide subjects through the voluntary performance of discrete muscle movements, or Action Units (AUs), from the Facial Action Coding System (FACS).^{11,12} Using AUs commonly associated with pain,^{8,19} we compared a "pain face" with a standard "control face" to determine the effect of the pain face on pain tolerance and subjective reports of distress in the absence of social reinforcement.

Previous studies of the effects of voluntary facial expressions on emotional responding have been criticized for paying insufficient attention to the impact of preexisting differences between facial expressions on results.¹ To address this issue, we have also assessed the degree to which pre-existing differences between the faces (ie, face specific difficulty and unpleasantness ratings) could account for their effects on pain perception.

Materials and Methods

Participants

Twenty-nine participants (19 female, mean age/SD = 23/4.16) provided informed consent and completed the study. Subjects were screened for medications and medical or psychiatric conditions that could alter pain perception.

Facial Action Training

Subjects were trained to make the pain and control faces (Fig 1) based on AUs of the FACS.⁶ The pain face consisted of 5 AUs: Brow lower (AU4), cheek raise (AU6), upper lip raise (AU10), lip corner pull (AU20), and lips apart (AU25).⁸ The control face was valence-neutral and matched with the pain face in numbers of AUs: Brow raise (AU1 and AU2), one eye closed (Unilateral AU43), lips puckered (AU18), and cheeks filled (AU34). In addition to these 2 faces, subjects also received thermal stimulation while sitting calmly (referred to subsequently as the "relaxed face").

Subjects were given no information about the faces, which were referred to by number throughout the experiment (eg, "make face #2"). No feedback other than repetition of the standardized instruction script was provided. Immediately after facial training, participants

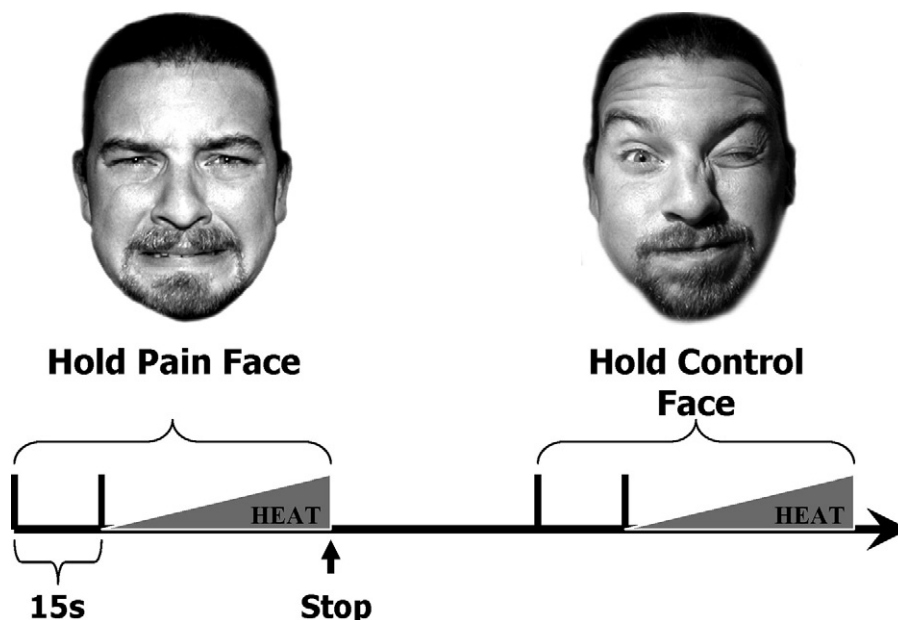


Figure 1. Subjects held the pain face (left) or control face (right) for 15 seconds before the onset of thermal stimulation. Subjects stopped the stimulus themselves when it reached a predetermined level. (Figure printed with permission.)

Table 1. Effects of 3 Repeated-Measures ANOVAs, With Face (Control, Pain, and Relaxed), Time, and Their Interaction, Predicting Pain Trial Unpleasantness Ratings

	DF	F	P	η^2
Pain Trial Unpleasantness				
Face	2, 56	12.34	.00	0.31
Time	3, 84	6.72	.00	0.19
Face by Time	6, 168	1.85	.10	0.06

rated the difficulty and unpleasantness of the faces on a 7-point scale (0 = not at all difficult or unpleasant, respectively; 6 = extremely difficult or unpleasant, respectively). These ratings formed the basis of the analysis of preexisting differences between the faces (see Results section).

Heat Stimulus

Heat stimuli were generated by a thermal stimulator (TSA-II; Medoc Advanced Medical Systems, Haifa, Israel) through a 30 × 30-mm Peltier device that was attached to the subject's nondominant forearm. Stimulation began at 34°C and increased by 0.3°C/s. Subjects were asked to stop the stimulation by pressing a button when their pain reached an 8 on a standard 11-point numeric pain scale, (0 = "no pain", 10 = "the worst pain imaginable"). To obtain baseline threshold temperatures, this procedure was repeated 4 times before the experiment. Subjects who reached the maximum temperature allowed in the experiment (49°C) were eliminated from the study.

Experimental Trials and Assessment

The experiment took place in a windowless room. To prevent unintentional social feedback from the experimenter, subjects were instructed to focus on a small piece of colored paper on the wall.

Before the onset of the thermal stimulus, subjects were instructed which face to make. When the desired AUs were present, subjects held the face for 15 seconds before heat onset and for the duration of thermal stimulation.

The experimenter observed the participants face for the duration of the trial and rated the face accuracy on completion. Accuracy ratings were made on a 7-point scale (0 = completely wrong, 6 = perfect). To assess interrater reliability, 2 trained raters were present for a subset ($n = 5$) of the study participants. Cronbach's α was 0.67, consistent with reliabilities observed in similar studies.⁶

Thirty seconds after pain offset, emotional valence and arousal were assessed using the Self-Assessment Manikin, an experimentally validated measure of affective responding (SAM).² The SAM measures valence and arousal on separate scales ranging from 1 to 5 for each dimension.

Subjects received 4 presentations of the thermal stimulus under each of the 3 face conditions (pain, control, and relaxed faces) in quasirandom order.

The study was approved by the Health Sciences Institutional Review Board at the University of Wisconsin-Madison.

Results

Three repeated-measures ANOVAs were conducted for the purpose of assessing the effects of Face (control, pain, relaxed) and Time (measurements 1 through 4) on pain tolerance and ratings of valence and arousal on each pain trial (Table 1). Where appropriate, tests were Huynh-Feldt-adjusted to correct for violated assumptions of sphericity.

Temperature

There were no effects of Face on pain tolerance [mean (SD) for pain face = 47.16 (1.27)°C, control face = 47.12 (1.26) °C, resting condition = 47.03 (1.41)°C; all P 's for planned comparisons ≥ 0.1]. The effect of Time was also not significant but approached significance, $F(3, 84) = 3.52$, $P < .06$, $\eta^2 = .11$, $\varepsilon = .42$, with pain tolerance increasing from times 1 through 4 (means, 46.92°C, 46.93°C, 47.21°C, and 47.35°C, respectively). There was no significant Face by Time interaction.

Perceived Aversiveness (Valence Ratings)

There was a significant main effect of Face on valence ratings [$F(2, 56) = 12.34$, $P < .00$, $\eta^2 = .31$, $\varepsilon = .95$], with pain face trials rated as more aversive than control face trials ($P < .01$), and both face trials more aversive than relaxed face trials (all $P < .03$) (Table 1). Planned comparisons revealed that pain face trials were rated as more aversive than control face trials ($P < .01$) and that both types of faces were rated as more aversive than relaxed face trials (all $P < .03$; Fig 2). The effect of time was also significant [$F(3, 84) = 6.72$, $P < .01$], with all trials becoming

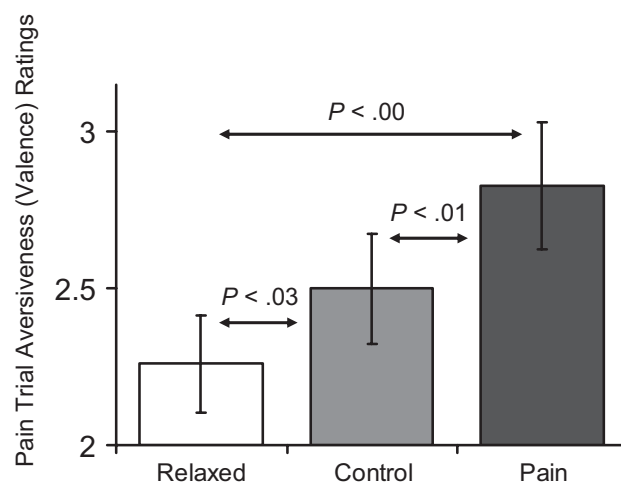


Figure 2. Main effect of face on pain trial aversiveness (valence) ratings [$F(2, 56) = 12.34$, $P < .00$, $\eta^2 = .31$, $\varepsilon = .95$], with pairwise comparisons.

Table 2. Pre-existing Differences Between the Faces in Difficulty and Unpleasantness and Differences in the Accuracy With Which the Subjects Made the Two Faces During the Experiment

	PAIN FACE		CONTROL FACE		<i>F</i> (1,28)	<i>P</i>
	MEAN	SD	MEAN	SD		
Difficulty	4.35	.24	3.07	.20	24.47	< .01
Unpleasantness	3.69	.21	2.59	.24	37.04	< .01
Accuracy	5.00	.48	4.56	.59	20.04	< .01

ing more unpleasant with time. This finding is noteworthy given the trend toward increased tolerance over time. A possible explanation for this potentially inconsistent finding is that because of reduced peripheral sensitivity over time, subjects required more stimulation to achieve the same level of pain but that this pain was perceived as more unpleasant due to the cumulative effort of making the faces. The Face by Time interaction was not significant.

To ensure that these effects could not be accounted for by temperature differences, we ran a hierarchical linear model (see below for methodological details), with temperature entered first. Even after accounting for Temperature, the effect of Face was still highly significant [$F(2,227) = 9.47, P = .00$].

Emotional Arousal (Arousal Ratings)

There were no significant effects on arousal, although the effect of Face approached significance [$F(2, 56) = 2.72, P < .09$], with a trend toward both the pain and control faces being more arousing than the relaxed face.

Covariate Analyses of Nuisance Variables

As demonstrated in Table 2, there were significant differences between the faces in difficulty and unpleasantness (both measured before the experiment) as well as the accuracy with which they made the faces (measured during the experiment). The degree to which effects on valence ratings were due to these differences was assessed. Because the SPSS (SPSS, Inc., Chicago, IL) GLM module does not handle changing covariates, covariate analyses were performed with the use of SPSS Mixed Model utility. Importantly, all covariate models were specified hierarchically using a Type 1 sum of squares,

with the nuisance variable entered first. This method prioritized shared variance to the nuisance covariates, making this a very conservative set of analyses. As indicated in Table 3, in all models in which face was entered with 1 of the nuisance variables, the nuisance variable was significant but the effect of face remained even after accounting for this effect. There were no significant interactions, which is somewhat surprising in the case of face accuracy, as effects of DFA tasks are frequently dependent on face performance (Ekman, personal communication with J.A.C., March 22, 2005). Restriction of range on the performance variable may explain this finding.

In addition to the 3 models presented in Table 3, an additional model was calculated with all nuisance variables (face unpleasantness, face difficulty, and face performance) entered in the same model. This was a highly conservative test of the robustness of the face effect. With all nuisance variables in the model, main effects of difficulty, unpleasantness, and performance fall away, but main effects of face [$F(1,14) = 11.88, P < .01$] and time [$F(1,57) = 9.06, P < .01$] remain. In this model, no interaction effects were observed.

The fact that the effects of face on valence ratings remains even after accounting for the effects of nuisance variables in these models strongly suggests that these effects cannot be accounted for by preexisting differences between the faces in unpleasantness or difficulty or by differences in the accuracy of subjects' facial expressions.

Discussion

Using the Directed Facial Action task, we found that in the absence of social reinforcement a voluntary facial display of pain altered the affective response to painful stimulation but not the stimulus intensity required to reach a particular subjective level of pain (8 of 10). In addition to providing no experimenter feedback and having subjects focus on a spot on the wall, the effect of social feedback was controlled in 2 ways. First, by having subjects make and hold an extreme facial display before the onset of pain, we obviated the facial information conveyed during the actual pain experience. Finally, by allowing subjects to control the duration and temperature of the nociceptive stimulus, we were able to limit the need for subjects to use social support as a means of gaining control over their pain experience.

Our findings indicate that in the absence of social reinforcement, voluntary facial displays of pain increase the negative affect resulting from nociceptive input. By

Table 3. Results of Covariate Analyses, Entering Face, and a Nuisance Variable in a Model Predicting Valence Ratings

NUISANCE VARIABLE	EFFECT OF NUISANCE VARIABLE WITHIN MODEL	EFFECT OF FACE WITHIN MODEL, <i>F</i> (DF)	FACE *NUISANCE VARIABLE INTERACTION
Difficulty	$F(1, 52) = 4.15, P < .05$	$F(1, 75) = 12.18, P < .01$	NS
Unpleasantness	$F(1, 157) = 6.98, P < .01$	$F(1, 169) = 4.60, P = .03$	NS
Accuracy	$F(1, 156) = 5.02, P = .03$	$F(1, 178) = 19.29, P < .01$	NS

Note that denominator degrees of freedom are estimated from Satterthwaite approximations without exact *F* distributions.

indicating that voluntary facial displays of pain incur costs in terms of increased negative affect, these results argue against the notion that the operant properties of voluntary pain displays are determined solely by social contingencies. For example, while social contingencies may reinforce the facial expression of pain, these benefits may be offset by an increase in subjective suffering. From a clinical standpoint, this suggests that increasing or exaggerating pain behaviors may be a maladaptive strategy for pain control, particularly for individuals who are highly sensitive to social reinforcement or who are otherwise strongly reinforced for expressing pain.

One difficulty with drawing conclusions from the DFA task concerns the degree to which pre-existing differences between the faces are responsible for results obtained. We found, for example, that control and pain faces differed in terms of both difficulty and unpleasantness, even in the absence of concomitant painful stimuli. Similar differences are common in DFA tasks, with previous investigators observing differences between faces in both subjective ratings and autonomic nervous system activation.¹⁰ These findings have generated some controversy as to whether effects observed in DFA experiments are better explained by variables such as face difficulty (Boiten,¹ 1996; and rebuttal by Levenson and Ekman,¹⁶ 2002). In the present study, effects of face on valence ratings survived conservative covariate analyses testing the effects of face-specific difficulty, unpleasantness, and accuracy, both singly and in combination, suggesting that the effect of the pain face on the subjective experience of pain cannot be solely attributed to any of these pre-existing differences between the faces.

These results ultimately suggest that voluntary facial displays of pain increase the negativity of the affective response to painful stimulation and that these effects cannot be accounted for by the difficulty or unpleasantness of making such a face in the absence of nociceptive input. Nevertheless, there are some caveats that should be considered in the interpretation of these data. For example, although the present experiment limited the impact of demand characteristics by making the instructions opaque with respect to the experimental question and using an archetypal pain face that was unlikely to mimic the subject's own natural facial response, it is difficult to completely eliminate such effects due to the possibility that some subjects may have inferred that it was an approximation of a facial pain response.

The conclusions drawn from these data would also be strengthened by future study determining their specificity to the pain face. The control face used in this preliminary investigation was affectively neutral and matched the pain face only in terms of the number of movements. A logical next step will be to compare the pain face to other negatively valenced, but not pain-specific, faces (eg, fear).

Although the present study found no effect of the pain face on pain tolerance, future study may investigate these effects further with more comprehensive testing, not only of tolerance but pain threshold, which might be more sensitive to such effects. Performing such testing might also help to clarify the suggestion made by these data that voluntary facial expressions of pain seem to affect the affective response to pain while having no effect on sensory processing.

If findings such as those reported here are found to be specific to biologically relevant facial displays of pain, future work must determine the mechanisms by which they affect subjective responses to pain stimuli. Several theorists have considered this question, proposing direct feedback from facial afferents as well as central connections between motor cortex and other neural centers directing peripheral pain responses,¹⁰ but none of these potential explanations have been conclusively supported experimentally. A small number of studies suggest that voluntary emotional facial expressions can alter CNS functioning in ways that are consistent with the emotional valence of those expressions. For example, Ekman and Davidson¹³ observed that voluntary smiles, including flexion of the orbicularis muscle surrounding the eye, corresponded with increases in left prefrontal cortex (PFC) activity, a pattern often observed to follow the elicitation positive affect.¹⁸ Similarly, Coan et al⁵ observed that voluntary facial expressions of fear and sadness resulted in decreases in left, and increases in right, PFC activity, a pattern of PFC activity that has long been associated with both anxiety and depression.³ Importantly, Coan and Allen⁴ reported that changes in PFC activity appeared to mediate associations between voluntary facial movement and self-reported emotional experience for both positive and negative emotions. Future studies, combining measures of CNS activation (eg, EEG, ERP, and fMRI) and peripheral autonomic nervous system arousal may clarify the way voluntary facial displays of pain affect the neural processing and subjective experience of pain.

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