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The power of smiles: mitigating pain through facial expression

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'Of all the medicines in the inner life, a smile is by far the best medicine'. With these words, spiritual leader Sri Chinmoy inspired mankind to navigate life's difficulties with a smile, alluding to the idea that smiling is a simple, yet effective coping mechanism when enduring hardship and pain. But why?

Smiling, a common facial expression observed in populations enduring acute pain (Kunz et al., 2009) and distress (Keltner & Bonanno, 1997), may possess stress-buffering effects with the potential to expedite recovery from physiological stress (Finan & Garland, 2015; Levenson et al., 1990). One conceivable mechanism by which smiling may reduce heart rate during a stressor like acute pain and enhance psychological responses to pain, is the Facial Feedback Hypothesis, which posits that facial muscle activation can alter, enhance, or attenuate emotional experiences (Tourangeau & Ellsworth, 1979). Evidence for the Facial Feedback Hypothesis , partnered with research connecting physiological benefits to the experience of positive emotions (e.g. Pressman & Cohen, 2005), point to the possibility that smiling can lead to downstream benefits physiologically and psychologically, possibly even during adverse, painful experiences. The current study explored the role of spontaneous smiling[1] expressions in regulating physiological and psychological responses to pain and their connection with positive emotions.[2]

Smiling during pain

Facial expressions can nonverbally communicate a range of emotions, such as happiness, anger, sadness, and fear (Ruys & Stapel, 2008), but may not necessarily be as straightforward as they seem. People may mask or disguise their expressions, whether it is to cope with adversity, garner social acceptance, regulate intense emotions, or handle a difficult situation (Crivelli & Fridlund, 2018; Ekman & Friesen, 1982). For example, certain facial expressions, such as smiling or contentment, are required by employers or societal norms, which may be masking one's true emotions (Kotchemidova, 2005; Pham et al., 2022). In this regard, facial expressions do not always perfectly map onto the actual emotional experience, suggesting that facial expressions potentially hold other, more complex functions besides conveying one's emotional experiences (Fridlund & Russell, 2006; Schmidt & Cohn, 2001).

A key example of this phenomenon is smiling. While smiling can be used to express positive emotions, such as joy and excitement, it also serves an important function when experiencing negative emotions, pain, and distress (Ansfield, 2007; Ekman & Friesen, 1982; Finan & Garland, 2015; Fredrickson & Levenson, 1998; Pressman et al., 2021). For instance, smiling activates facial muscles that wrinkle the corner of the eyes and lift the cheeks (Ekman et al., 1990), and has shown to improve emotion during negative experiences when compared to other

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facial expressions that can occur during pain such as grimacing (Ekman & Friesen, 1982; Pressman et al., 2021), despite activating some but not all of the same muscle groups. Smiling is a particularly beneficial facial expression that can buffer cognitive and affective responses to pain while promoting resilience and self-management (Finan & Garland, 2015). Research also suggests that smiling is associated with decreased experiences of acute pain and stress, as indicated by lower self-reports of pain and faster cardiovascular recovery towards resting levels of function (Fredrickson & Levenson, 1998; Levenson et al., 1990; Pressman et al., 2021; Soussignan, 2002). As such, one type of smile includes miserable smiles, which occur in the context of negative situations including acute pain (Ekman & Friesen, 1982). These smiles are thought to be beneficial because they improve both stress-related perceptions and physiological arousal during unpleasant experiences (Cross, Acevedo, Leger, et al., 2023; Pressman et al., 2021). Smiling during distress is quite common, with one study reporting that about one-third of individuals responded to laboratory-induced painful stimulation with a spontaneous smile (often called 'smiles of pain' or 'miserable smiles'; Kunz et al., 2009). Given how often smiling facial expressions spontaneously occur during pain, it is important to better understand whether this naturally occurring behavior is associated with pain-relevant outcomes.

How can smiling alter painful experiences?

Two studies have examined whether experimentally manipulating smiling influences cardiovascular and affective responses to laboratory-induced stressors. The first, a study by Kraft and Pressman (2012), randomized participants to complete laboratory-induced stress tasks (i.e., star-tracing and cold pressor tasks) while holding chopsticks in their mouths to produce different smiles or a neutral expression. Results indicated that participants who smiled had lower heart rates during stress recovery, with the strongest effects in the Duchenne smiling condition (Kraft & Pressman, 2012). Consistent with these results, Pressman et al. (2021) found that compared with those assigned to make a neutral facial expression, experimentally induced smiling during a vaccination-like needle injection was associated with lower levels of self-reported pain, as well as attenuated heart rate and skin conductance (a measure of physiological arousal) responses to pain during reactivity and recovery.

These two study findings of experimentally manipulated smiles are in line with the Undoing Hypothesis (Fredrickson & Levenson, 1998), which posits that positive emotion 'undoes' stress and hastens recovery specifically. Fredrickson and Levenson's (1998) classic study on the Undoing Hypothesis found that participants who spontaneously smiled while viewing a sadness-eliciting film exhibited faster cardiovascular recovery after the film was over compared to those who did not smile. Thus, the current study builds on these findings by testing whether spontaneous smiling in the context of acute pain also results in psychological or physiological benefits. This will not only add confidence to the general finding that smiles are beneficial during acute stress, but will allow us to test whether this is an adaptive coping strategy tied to pain related benefits. Many people smile spontaneously during distress and pain (Kunz et al., 2009), but few studies have examined whether there are benefits to this behavior.

Current study

Our primary objective was to examine whether spontaneous smiles during a painful task influence physiological (i.e., heart rate) and/or psychological responses (i.e., self-reported pain and affect). To induce pain, we used the standardized cold pressor task (Lamotte et al., 2021; Lovallo, 1975), where participants were exposed to a controlled cold temperature for a brief period of time via submerging their hand in a bucket of cold water. We hypothesized that spontaneous smiling during the cold pressor task would be associated with lower heart rate responses, lower self-reported pain and distress, and higher self-reported state positive affect as compared to those who do not smile spontaneously during the cold pressor task. The results of this study will contribute to our understanding of the complex interplay between smiling facial expressions and pain regulation, and help to better understand the commonly observed phenomenon of smiling during different types of distress.

Method

Participants

Fifty-seven participants3 were recruited through the Psychology department research subject pool or via flyers posted around the University of California, Irvine. Participants were excluded if they had a history of or were currently diagnosed with a psychological disorder, cardiovascular disease, connective tissue disease, or facial musculature disorder. Participants were also excluded if they were not fluent in English. Participants' demographic characteristics are summarized in Table 1. None of the participants reported that they smoked (i.e., cigarettes, cigars, pipes) on a regular basis. Participants received class credit or $20 USD as

Table 1. Descriptive statistics for analytic samples.

	Smile (n = 21)	No Smile (n = 36)	Total Sample (n = 57)
Age (M_{years}, SD)	20.4 (1.3)	21.0 (3.6)	21.3 (5.0)
Body Mass Index (M, SD)	26.7 (6.9)	23.7 (4.0)	24.7 (5.3)
Sex (% female)	77.3	80.0	77.4
Ethnicity (%)			
Asian	45.5	43.2	44.4
Latino	27.3	29.7	28.6
White	18.2	13.5	15.9
Biracial/Multiracial	9.1	2.7	4.8
Black	0.0	2.7	1.6
Other	0.0	8.1	4.8
Average Smile Duration ($M_{seconds}$, SD)	6.7 (9.3)	0.0 (0.0)	2.5 (6.5)

Columns for ethnicity may not add up to 100% due to rounding.

compensation. This study was approved by the university's institutional review board.

Procedure

After providing informed consent, participants' height and weight were measured using a medical grade scale with the participant facing away from the numbers on the scale. Participants completed baseline questionnaires that assessed characteristics including demographics, self-reported state affect, and stress levels. Next, electrocardiogram (ECG) sensors were placed on participants' torsos using a Lead II configuration and connected to the recording unit. Then, video and physiological recording commenced. After completing a five-minute resting baseline period, participants wrote about a neutral topic for 5 minutes (i.e., their typical morning routine), then answered a questionnaire regarding their state affect.[4] Next, participants submerged their non-dominant hand into a bucket of almost freezing water (between 3.8°C to 4.2°C) past their wrist. In order to maintain a stable temperature, water was circulated continuously by an electric pump. Participants were asked to keep their hand in the water for as long as they could, with an uninformed ceiling of two minutes. The experimenter remained in the room with the participant, but they were intentionally positioned behind and to one side of the participant while the participant faced a computer. After two minutes (or when they reached their pain tolerance), they removed their hand from the bucket, the experimenter left the room with the bucket, and the participant sat quietly for a five-minute recovery period. They then completed more questionnaires that asked about their pain experience, levels of distress, and state affect during the cold pressor task. Lastly, participants completed one more set of questionnaires and were debriefed. For full details of the procedures and information on other aspects of the larger study, see Acevedo et al., 2022.

Measures and materials

Demographic and anthropometric measures

Age (years), sex (female/male), and racial/ethnic background (Asian, Black, Biracial/Multiracial, Latino, other, White)[5] were measured through self-report. Body mass index (BMI; kg/m^2) was calculated by measuring height and weight with a medical-grade scale upon study entry.

Self-reported pain and distress measure

After the recovery period of the cold pressor task, participants were asked 'What was the maximum level of pain you experienced?' and 'Please rate the distress you experienced during the cold-water task'. Participants rated their pain and distress on a scale of 0–100, where 0 indicated no pain/distress at all, and 100 indicated the highest level of pain/distress possible.

Self-reported state positive affect measure

State affect was measured multiple times (at baseline before the writing task, after the writing task, and after the recovery from the cold pressor task) throughout the study using the Subcomponents of Affect Scale (Jenkins et al., 2023).[6] Participants were asked to consider how they were feeling 'right now' and evaluate items reflecting state affect (e.g., happy, cheerful) on a scale of 0 to 4, where 0 indicated 'not at all accurate' and 4 indicated 'extremely accurate'. Positive affect was calculated by averaging state affect items (i.e., relaxed, calm, happy, cheerful, lively, enthusiastic) relevant to this subscale. The positive affect subscale was reliable in our study (Cronbach's $\alpha = .85$).

Smiling expression coding

The Noldus Facereader 6 software coded 20 action units (i.e., distinct groups of muscles in the face) in order to track the different facial muscles activated by a participant (Noldus, n.d.). For a full list, description, and illustration of the specific action units analyzed by Noldus Facereader, refer to: https://www.noldus.com/applications/facial-action-coding-system. This software classified facial expressions based on their representation of certain emotions (i.e., happiness, sadness, surprise, anger, fear, disgust, neutral), but more specific and nuanced types of expressions (e.g. Duchenne smiles versus non-Duchenne smiles) were not differentiated. In addition, Noldus Facereader determined the duration of facial expressions (in seconds), as well as their average intensity, which is expressed as a value between 0 and 1. For this study, we specifically analyzed facial expression duration during the cold pressor task. This variable was not normally distributed and had a positive skew. Given that we were also interested in the presence of smiling, we dichotomized smiling such that duration scores greater than 0 seconds were coded as smiling during pain, and scores equal to 0 were coded as not smiling during pain ($n_{yes} = 21$; $n_{no} = 36$). About 36.8% of participants exhibited a smile during pain.[7] The average smile duration among individuals who smiled during pain was 6.70 seconds (SD = 9.25).

Heart rate

Using BioLab 3.0.13, heart rate was recorded as beat-to-beat intervals. ECG data were transferred to Mindware HRV 3.0.22 software, which was used to identify each heartbeat throughout the study and derive heart rate in beats per minute. Trained researchers visually inspected the data to ensure only heartbeats were marked and removed segments when electrical artifacts (due to movement or sensors falling off) prevented R peak identification. For this study, we took the heart rate at each minute and averaged across minutes for each task time period: baseline (5 minutes), writing task (3 minutes), cold pressor (2 minutes), and recovery (5 minutes). For more information on how heart rate was recorded and calculated, see Acevedo et al., 2022.

Data analytic plan

Preliminary analyses

Covariates that were assessed included age, sex, BMI, and race/ethnicity. Pearson's *r* correlations were conducted between key study variables. Independent samples *t*-tests were used to test for sex differences in heart rate. To test whether smiling during pain was associated with differences in age or BMI, independent samples *t*-tests were also used. Lastly, chi-square tests examined whether there were sex or racial/ethnic differences among those who smiled (versus not) during pain. To maintain parsimony, only variables that were significantly associated with the independent or dependent variables were included as covariates in hypothesis testing. For details of the descriptive statistics of the analytic sample, see Table 1.

Hypothesis testing

To test the first hypothesis examining the influence of smiling on heart rate responses throughout the study, repeated measures ANOVA tests were conducted. Simple comparisons were conducted for significant omnibus repeated measure ANOVA tests. Additionally, four separate linear regressions were conducted to test whether smile duration during the cold pressor task was associated with average heart rate at baseline, writing task, cold pressor, and recovery, after adjusting for covariates. To test the second and third hypotheses, independent samples *t*-tests were conducted to examine the differences between the smiling and non-smiling groups in self-reported pain, distress, and positive affect. Additionally, three linear regressions were conducted to test whether smile duration during the cold pressor task was associated with self-reported pain, distress, and positive affect.

Results

Preliminary analyses

No potential covariates were significantly associated with smiling during the cold pressor task, *p's* $> .05$ (see Table 2). Significant sex differences in heart rate were found during the cold pressor task ($t(58) = 2.42$, $p = .018$, $M_{diff} = 8.63$, 95% CI [1.50, 15.76], $d = .74$) and during recovery ($t(58) = 2.57$, $p = .013$, $M_{diff} = 7.71$, 95% CI [1.71, 13.70], $d = .79$), such that males had lower heart rate than females during and after the cold pressor task. Therefore, only sex was used as a covariate in adjusted analyses.[8] See Tables 2 and 3 for more details.

Table 2. Preliminary assessment of potential covariates associated with smiling during cold pressor task.

			95% Confidence Interval	
	t	*p*	Lower	Upper
Age	0.51	.612	−2.06	3.46
BMI	−0.29	.774	−3.28	2.45
	X^2	*p*		
Sex	1.43	.232		
Ethnicity	0.21	.901		

Table 3. Correlation matrix.

	M	SD	1	2	3	4	5	6	7	8
1.Smile duration	2.54	6.50								
2. Pain	67.47	25.23	−.19							
3. Distress	59.95	26.95	−.13	.59***						
4. PA Baseline	1.76	.81	.38**	−.00	−.18					
5. PA ColdRec	1.08	.85	.29*	−.23	−.42***	.71***				
6. HR Baseline	70.77	10.30	−.06	.00	−.19	−.02	.14			
7. HR Cold	78.47	12.04	−.18	.10	.05	.02	.10	.76***		
8. HR Rec	68.80	10.18	−.11	.05	−.13	−.01	.18	.91***	.82***	
9. BMI	24.64	5.69	.11	−.04	−.07	.10	.09	−.25*	−.22	−.18

PA = Positive Affect; Cold = Cold Pressor Task; HR = Heart Rate; Rec = Recovery; ColdRec = After Recovery Period of Cold Pressor Task.
*$p \le .05$; **$p < .01$; ***$p \le .001$.

Does smiling influence heart rate during acute pain?

Consistent with our hypothesis, unadjusted repeated measures ANOVA indicated a between-subjects effect of smiling on heart rate responses, $F(1, 54) = 7.48$, $p = .008$, $\eta^2_p = .12$. On average, those who smiled during the cold pressor task had lower heart rate throughout the study (see Figure 1(a)).

In simple comparison analyses of heart rate at each time point, there were significant group differences (baseline: $t(55) = 2.51$, $p = .015$, $d = .69$; writing task: $t(55) = 2.44$, $p = .018$, $d = .67$; cold pressor: $t(55) = 2.62$, $p = .011$, $d = .72$; recovery: $t(55) = 2.74$, $p = .008$, $d = .75$). Specifically, those who smiled during the painful cold pressor task on average had lower heart rates throughout each part of the study when compared to those who did not smile: 6.78 beats per minute (bpm) lower ($SE_{dif\,f} = 2.70$) at baseline, 6.17 bpm lower ($SE_{diff} = 2.53$) at writing task, 8.09 bpm lower ($SE_{diff} = 3.09$) at cold pressor, and 7.15 bpm lower ($SE_{diff} = 2.61$) at recovery. After adjusting for the influence of sex, results remained largely the same (see Figure 1(b)).

Regression models examining smile duration during the cold pressor task suggested that time spent smiling was not statistically significantly associated with heart rate throughout the study after adjusting for sex (baseline: $R^2 = .06$, $R^2_{adj} = .03$, $b = -0.08$, SE = .21, $t(54) = -0.40$, $p = .691$, 95% CI [−0.50, 0.33], writing task: $R^2 = .06$, $R^2_{adj} = .03$, $b = -0.07$, SE = .19, $t(54) = -0.38$, $p = .706$, 95% CI [−0.46, 0.31], cold pressor: $R^2 = .15$, $R^2_{adj} = .11$, $b = -0.33$, SE = .23, $t(54) = -1.44$, $p = .156$, 95% CI [−0.78, 0.13], recovery: $R^2 = .14$, $R^2_{adj} = .11$, $b = -0.17$, SE = .19, $t(54) = -0.86$, $p = .396$, 95% CI [−0.55, 0.22]).

Is smiling associated with self-reported pain and distress?

Smiling was not associated with self-reported pain (dichotomous smiling: $t(54) = 0.68$, $p = .50$, $M_{diff} = 4.13$, SE = 6.11, 95% CI [−8.11, 16.38]; smile duration: $R^2 = .04$, $R^2_{adj} = -.001$, $b = -0.63$, SE = .46, $t(54) = -1.39$, $p = .171$, 95% CI [−1.54, 0.28]) or distress (dichotomous smiling: $t(55) = 0.67$, $p = .50$, $M_{diff} = 4.94$, SE = 7.33, 95% CI [−9.75, 19.64]; smiling duration: $R^2 = .03$, $R^2_{adj} = -.01$, $b = -0.52$, SE = .55, $t(54) = -0.94$, $p = .350$, 95% CI [−1.62, 0.59]).

Is smiling associated with self-reported positive affect?

Smiling was only associated with self-reported positive affect following the recovery period of the cold pressor task when smile duration was examined (dichotomous smiling: $t(56) = -.25$, $p = .81$, $M_{diff} = -0.06$, SE = 0.24, 95% CI [−0.54, 0.42]; smile duration: $R^2 = .09$, $R^2_{adj} = .06$, $b = 0.04$, SE = .02, $t(54) = 2.22$, $p = .031$, 95% CI [0.00, 0.07]).

Discussion

The current study examined the influence of spontaneously smiling during acute cold exposure to the hand on the physiological and psychological response to pain. We found that spontaneously smiling during a cold pressor pain task was associated with lower heart rate over the course of the study, echoing past findings showing that the presence of spontaneous smiling aids heart rate recovery (Fredrickson & Levenson, 1998) as well as studies showing that experimentally induced smiling reduces heart rate responses to stressful and pain inducing tasks (Kraft & Pressman, 2012; Pressman et al., 2021). However, how long these smiles lasted was not associated with heart rate. We also found that neither spontaneously smiling during pain nor smile duration were associated with lower self-reported pain or distress from the cold pressor, as was the case with needle pain in past research (Pressman et al., 2021). While spontaneously smiling during pain was not associated with higher positive affect, smile duration did predict self-reported positive affect following the recovery period of the cold pressor task. These findings contribute to the literature on the benefits of spontaneously smiling during distressing experiences and add to the overall literature on the

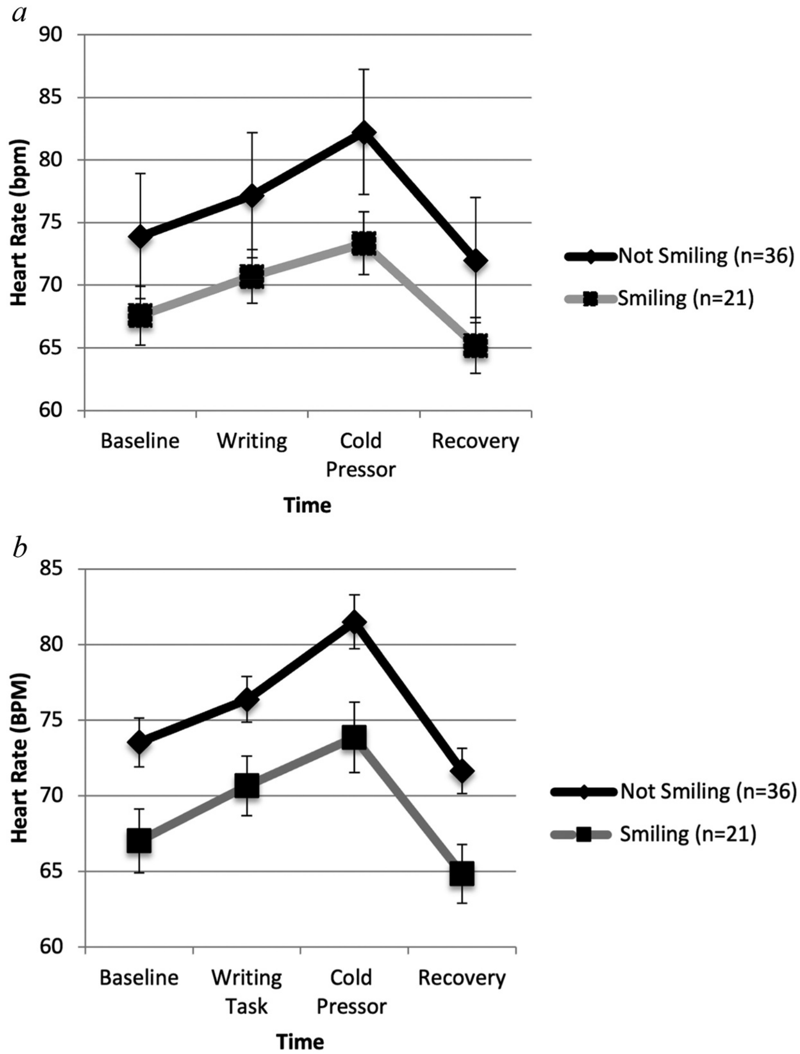

Figure 1. (a) Unadjusted model. (b) Adjusted model. Figure 1a shows that participants who smiled during the cold pressor task had lower heart rates throughout the study compared to those who did not smile. Figure 1b shows that after adjusting for sex, participants who smiled during the cold pressor task had lower heart rates throughout the study compared to those who did not smile.

possible health benefits of smiling more generally (Cross, Acevedo, Leger, et al., 2023).

Although smile duration was not associated with heart rate, the results of our first hypothesis suggest that any occurance of spontaneously smiling during pain was associated with lower heart rate throughout the study, even before the cold pressor task occurred. Perhaps the influence of a smile on heart rate may lie more in its presence rather than in how long it lasts. The association between spontaneously smiling and heart rate during and following the cold pressor task is consistent with the Undoing Hypothesis mentioned earlier (Fredrickson & Levenson, 1998). One potential mechanism through which the Undoing Hypothesis may work is through triggering the oculocardiac reflex. This reflex is instigated when the muscles around the eyes are activated, which may occur during smiling (Cross, 2020; Cross, Acevedo, Leger, et al., 2023), in turn stimulating the vagus nerve, subsequently reducing heart rate (Cross, Acevedo, Leger, et al., 2023; Dunville et al., 2018). While we are unable to confirm whether the oculocardiac reflex was activated among those who spontaneously smiled during pain, future studies could explore these possibilities by monitoring neural and facial muscle activation during smiling and pain studies, as well as by doing more repeated assessment of emotional responses.

However, the undoing hypothesis and the oculocardiac reflex do not explain why spontaneously smiling during pain would be associated with heart rate *before* pain occurred. There may be something different about the type of individual who smiles during acute pain. For instance, those who spontaneously smile during acute pain self-reported higher levels of positive affect at baseline (Table 3). This is compatible with the idea that positive affect is helpful when coping with stress (Folkman & Moskowitz, 2000). Also, this is in line with the Positive Affect Stress Buffering Model, which posits that positive emotions improve perceptions and physiological reactivity to stress, as well as recovery from stress (Pressman & Cohen, 2005). This provides a reason smiling may influence the pain experience, but only to the degree that smiling actually represents or induces felt positive emotions (e.g. Bostock et al., 2011; Heponiemi et al., 2006; Ong et al., 2006). Therefore, individuals who self-reported higher levels of positive affect at baseline were more likely to smile during the cold pressor task and those who smiled had lower heart rates throughout the study.

Contrary to our second hypothesis, spontaneously smiling during pain and smile duration were not associated with lower self-reported pain. This finding differs from previous research examining associations between smiling and pain, where smiling was associated with lower self-reported pain (Pressman et al., 2021). There may be important methodological differences that contributed to the variation in these findings. In the current study, we measured self-reported pain five minutes after the pain task had concluded in order to obtain a measure of physiological recovery mitigating carryover effects. Retroactively reporting on pain may not be as accurate as real-time pain measurements (Gendreau et al., 2003), which may have contributed to findings that were not significant. Future studies should seek to assess pain multiple times throughout the study or throughout the pain task to enhance our understanding of the trajectory of pain experienced throughout the study.

Contrary to our third hypothesis, those who smiled during pain did not report greater self-reported positive affect after the recovery period of the cold pressor task compared to those who did not smile. Nonetheless, we found that smile duration was associated with self-reported positive affect after the recovery period of the cold pressor task. Much of previous literature suggests that smiling can increase positive affect (Coles et al., 2019, 2022) by activating various facial muscles that influence emotional experience (Davis et al., 2009; Söderkvist et al., 2018) and in this case, influence affective responses to stressful events like acute pain. This is supported by the Facial Feedback Hypothesis, which suggests that certain facial muscle activation can influence emotional experiences (Tourangeau & Ellsworth, 1979). By smiling, participants activated facial muscles that may have influenced their emotional experience following the cold pressor task, shaping this stressor into something more manageable and positive. However, since smiling during the cold pressor task was also positively associated with positive affect during baseline (see Table 3), it is important to consider the possibility that participants who felt greater positive affect during baseline were more likely to smile during pain, to have lower reactivity, and to report more positive affect after the cold pressor task was completed. It should also be considered that we were underpowered to detect group differences in self-reported pain and positive affect, and when examining smiling as a continuous variable (duration), we were able to detect effects. However, future studies should take these factors into consideration and tease out whether smiling or positive affect is driving this finding.

Limitations and future directions

This study had a few limitations. First, the sample size for this study was relatively small. While we had sufficient power to detect effects for heart rate, statistical power was lower for the self-reported pain and positive affect outcomes. Therefore, future studies should seek to replicate this finding in larger samples to increase statistical power and detect potential effects that may have been limited in the current study. Another limitation was that the sample was majority female. There are important sex differences in the experience of stress, coping strategies, emotional expressiveness, pain expressiveness, and physiological responses (Dao & LeResche, 2000; Sullivan et al., 2000), where females are often more expressive in their facial expressions (Deng et al., 2016), feel negative affect more frequently (Fujita et al., 1991), and tend to have lower physiological responses to stress (Verma et al., 2011) than males (although our sample did not reflect this trend and showed the inverse). Future studies should include a more representative sample by including more males and other sex/gender identities in order to acquire a more comprehensive and accurate understanding of stress and pain experiences. It is also crucial to consider individual and group differences (e.g. race/ethnicity) in pain tolerance (Rahim-Williams et al., 2012). Future studies should be mindful of such differences, because variation in pain sensitivity could create different interpretations of the pain experience. Additionally, the facial expression coding software used for this study limited our ability to identify different types of smiles (e.g. Duchenne versus non-Duchenne). To address this, future studies should measure the degree and intensity of smiles, as well as differentiate between the various types of smiles (e.g. Ambadar et al., 2009; Frank & Ekman, 1993; Gunnery & Ruben, 2016). Researchers should also explore other potential reasons for smiling during pain that were not examined in the current study, such as social motives (e.g. reinforcing social bonds, garnering social support, communicating to others that the pain is manageable; Kunz et al., 2009, 2013).

Despite the limitations above, this study contributes important new findings and expands on past literature on experimentally induced facial expressions influencing responses to pain (Kraft & Pressman, 2012; Pressman et al., 2021) by examining how spontaneous smiling influences responses to pain. Examining spontaneous smiles rather than experimentally inducing them allows for an ecologically valid way of observing and understanding pain and the facial expressions made during the experience of pain. Furthermore, this approach evades any complications or extra steps that commonly occur alongside experimental manipulations, such as adjusting for participant adherence and ensuring participants are blinded to hypotheses. An additional strength of this study is the racial/ethnic diversity of the sample, with a large portion of the sample identifying with racial/ethnic populations that are understudied and underrepresented in research, particularly East Asian and Latino individuals. It is important to recognize that there are cultural differences in facial expressions and the pain experience (Jack et al., 2012; Rahavard et al., 2017), and future studies should continue to recruit diverse samples to gain a fuller and more complete picture.

Pain is a shared human experience, encountered by nearly all individuals at some juncture in their lives (Dahlhamer et al., 2018). An examination of both the physiological and psychological dimensions of pain is of paramount importance, as it can offer valuable insights into how we can enhance our capacity to assist people in managing and coping with pain. Overall, the current study contributes to the positive psychology and pain literature by showing that smiling during a painful task is associated with physiological benefits, as well as promises for psychological outcomes, although additional research is needed. By furthering research in this area, important discoveries can be made about the function and potential benefits of different spontaneous facial expressions during common stressors such as acute pain, with implications for the field of positive psychology. Smiling, especially when in the face of adversity, has repeatedly been shown to be beneficial for enduring and recovering from acute pain (Barnes, 2005; Papa & Bonanno, 2008). With a better understanding of how smiling plays a role in coping during acute pain, we can improve the pain experience and bolster resilience.

Notes

1. Spontaneous smiling refers to a naturally-occuring facial expression produced by a participant. This differs from experimentally manipulated smiling (common in Facial Feedback Hypothesis research), which is a lab-induced facial expression that often requires a participant to hold devices (e.g. pens or chopsticks) in their mouths in order to activate facial muscles associated with smiling or mimic an expression intentionally (e.g. Cross et al., 2019).
2. In this paper, we refer to 'emotions' as broad psychological states and subjective experiences usually accompanied by physiological and/or behavioral changes. Contrast this to 'affect', which is defined in this paper as a more *specific* component of emotion that reflects an *immediate* response to a stimulus.
3. Only participants in the control condition of a larger study were included in the present analyses ($n = 57$) because of emotion manipulations in participants randomized into experimental conditions (*Acevedo et al., 2022*). The larger study had 283 participants.
4. Participants did not experience any significant change in state affect following the neutral writing task.
5. Participants were asked to select one of the six racial/ethnic background options that they felt best described them. If they selected 'other', they were given a chance to specify.
6. Our analyses will focus on the last measurement of state affect in the study, taken after the recovery period from the cold pressor task.
7. The occurrence of smiles during pain in this sample is comparable to (and slightly higher than) past studies, which have typically ranged from 21–33% of participants exhibiting a smile during pain (Kunz et al., 2009, 2013).
8. A negative association between baseline heart rate and BMI was found, $r(61) = -.25$, $p = .050$. One participant had a BMI that was an outlier, and thus we conducted a sensitivity analysis to examine the correlation without this participant's data. Baseline heart rate was not significantly associated with BMI, $r(60) = -.21$, $p = .108$.

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Data availability statement

Study data will be made available upon reasonable request.

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