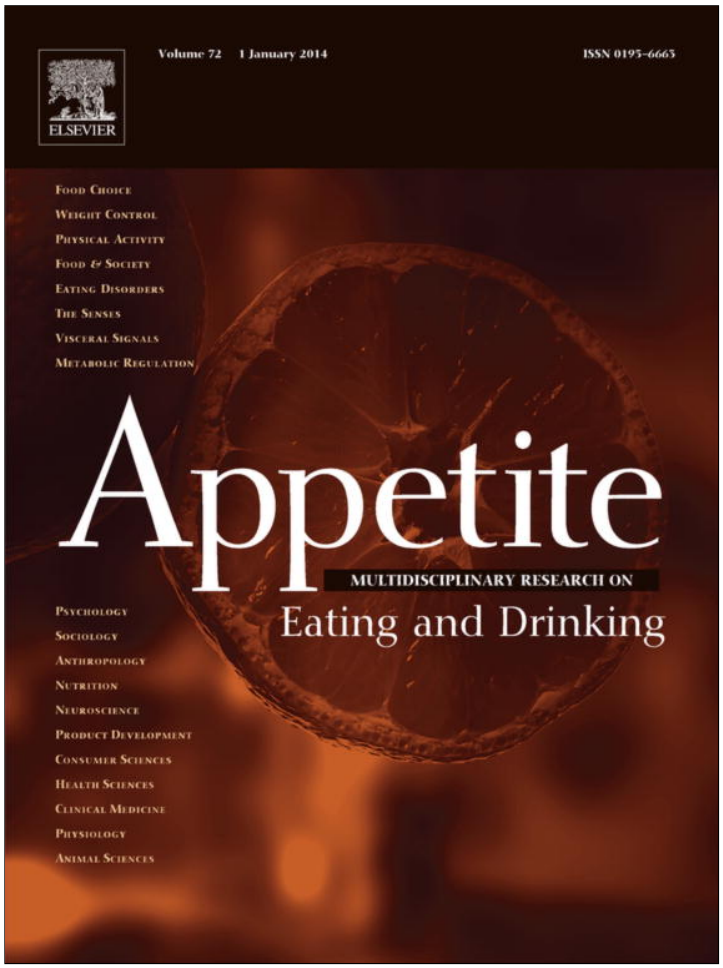

Appetite 72 (2014) 150–155

Contents lists available at ScienceDirect

Appetite

journal homepage: www.elsevier.com/locate/appet

Research report

# Gustatory pleasure and pain. The offset of acute physical pain enhances responsiveness to taste ☆

Brock Bastian *, Jolanda Jetten, Matthew J. Hornsey

*School of Psychology, University of Queensland, St. Lucia, QLD 4072, Australia*

ARTICLE INFO

*Article history:*
Received 9 August 2013
Received in revised form 14 October 2013
Accepted 15 October 2013
Available online 25 October 2013

*Keywords:*
Physical pain
Pleasure
Taste
Enjoyment
Sensory experience

ABSTRACT

The idea that pain may serve to produce pleasurable states has been noted by theorists and, more recently, substantiated by empirical findings. We explored the possibility that, beyond producing positive hedonic states, the offset of pain may serve to enhance the capacity for gustatory pleasure. Across three studies we examined whether pain offset may enhance responsiveness to taste. In Study 1 participants enjoyed chocolate more after the experience of pain compared to completing a similar but non-painful task. In Study 2, pain offset increased the perceived intensity of a range of tastes, both pleasant and unpleasant, indicating that the effects of pain offset are not limited to the processing of positive hedonic stimuli. In Study 3, pain offset increased sensitivity to different flavors. The findings suggest that the offset of acute pain increases awareness of, and therefore sensitivity to, gustatory input, thereby enhancing the capacity for gustatory pleasure.



## Introduction

Philosophers have often mused about the relationship between pain and pleasure. The romantic view of pain was that it provides depth to life and reveals true beauty (Morris, 1991). Others have argued that pain provides an important contrast for pleasure, and that the experience of pleasure is defined by the experience of pain (Verri, 1781; cited in Guidi (1994)). It is perhaps for this reason that people the world over enjoy the consumption of chili pepper (Rozin, 1990, 1999; Rozin & Schiller, 1980) or choose to engage in other painful activities such as intense exercise, ice-swimming, painful religious rituals, masochistic sexual practice, and even self-harm (Baumeister, 1988; Glucklich, 2001; Le Breton, 2000; Morris, 1991; Nock, 2010a, 2010b; O'Connor & Cook, 1999; Zenner, De Decker, & Clement, 1980).

Providing some insights into the links between pain and pleasure, research suggests that pain may be experienced as rewarding in some contexts (Becerra, Breiter, Wise, Gonzalez, & Borsook, 2001; Gear, Aley, & Levine, 1999; Leknes & Tracey, 2008; Zubieta et al., 2001), that experiences of pain may regulate negative affective states (Chapman, Gratz, & Brown, 2006; Claes, Klonsky, Muehlenkamp, Kuppens, & Vandereycken, 2010; Franklin et al., 2010) and may even produce positive affective states (Boecker et al., 2008; Franklin, Lee, Hanna, & Prinstein, 2013; Klonsky, 2009; Leknes, Brooks, Wiech, & Tracey, 2008). More broadly, it appears that people gain pleasure from all manner of innately negative experiences (Rozin, Guillot, Fincher, Rozin, & Tsukayama, 2013). Here we investigate another way in which the experience of pain may be rewarding; that in addition to producing positive hedonic states, pain offset may also change people's enjoyment of subsequent stimuli.

A number of studies have investigated how pain may change the value attached to subsequent stimuli. These conditioning studies have shown that pairing pain offset with neutral stimuli results in approach toward/liking of those stimuli (see e.g., Andreatta, Mühlberger, Yarali, Gerber, & Pauli, 2010; Smith & Buchanan, 1954; Tanimoto, Heisenberg, & Gerber, 2004; Zanna, Kiesler, & Pilkonis, 1970). These findings are consistent with research showing that pain offset may produce positive affective states (Franklin, Lee, et al., 2013; Franklin, Puzia, et al., 2013; Leknes et al., 2008). That is, the positive affective states produced by pain offset relief become associated with subsequent stimuli, thereby increasing liking for those stimuli. What has never been addressed, however, is how stimuli themselves may be processed close to the offset of pain. Specifically, we examine whether the offset of painful experiences may increase sensitivity to, and therefore enhance the capacity to enjoy, pleasant tastes.

One possibility is that positive affective states associated with pain offset not only become linked to gustatory input via associative learning, but also change how gustatory stimuli are processed. Research on pain's capacity to regulate affect suggests that pain commandeers neural regions associated with both pain and affect

☆ *Acknowledgments:* We would like to thank Michelle Ting and Elizabeth Stewart for their assistance with data collection and Siri Leknes, Jason Mattingley and Bill von Hippel for their helpful comments on earlier drafts.

* Corresponding author.
*E-mail address:* b.bastian@uq.edu.au (B. Bastian).

0195-6663/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.appet.2013.10.011

(Barrett & Bliss-Moreau, 2009; Lindquist, Wager, Kober, Bliss-Moreau, & Barrett, 2012), allowing relief from pain to incidentally generate emotional relief (Franklin, Puzia, et al., 2013). Taste also activates neural regions overlapping with pain (see also Small & Apkarian, 2006), suggesting that pain relief may also incidentally affect how taste is processed, increasing the pleasantness of gustatory stimuli.

A related possibility is that pain activates the opioid system (Leknes & Tracey, 2008). Activation of this system has been shown to enhance the pleasantness of sweet tastes and decrease the aversiveness of bitter foods in rodents (Berridge, 2002; Doyle, Berridge, & Gosnell, 1993; Parker, Maier, Rennie, & Crebolder, 1992; Pecina & Berridge, 1995, 2000; Rideout & Parker, 1996). It has also been linked to the greater enjoyment of sexual behavior (Murphy, Checkley, Seckl, & Lightman, 1990). Moreover, the opioid system remains activated after the cessation of pain (Sprenger et al., 2006) and has been linked to positive affective states arising after pain has ceased (e.g., Boecker et al., 2008). This suggests that the neurobiological correlates of pain may serve to enhance enjoyment of subsequent stimuli, and specifically the enjoyment of pleasant tastes.

Both proceeding possibilities indicate that pain may shift the hedonic value of gustatory stimuli in a positive direction. Another possibility is that pain may increase sensitivity to both pleasant *and* unpleasant tastes. Pain is a primary threat signaling system that serves to indicate tissue damage and therefore recruits resources aimed at action and escape (Eccleston & Crombez, 1999; Legrain et al., 2009; Shackman et al., 2011). As such, physical pain is a powerful source of arousal (Garey et al., 2003; Pfaff, 2006; Price, 2000; Weil, Zhang, Hornung, Blizard, & Pfaff, 2010) that serves to capture attention and focus awareness on immediate sensory experience (Craig, 2002, 2003, 2009; Eccleston & Crombez, 1999). This evolved response serves to heighten awareness of the immediate sensory experience of pain. It may also, however, have implications for how other sensory experiences, occurring close to the offset of pain, are processed and responded to. We argue that the body remains in a vigilant state after pain, serving to maintain increased arousal and awareness of further physiological and environmental threat. During this state, awareness is generalized to focus on the physiological condition of the body, and this increases receptivity, and therefore sensitivity, to sensory experiences more broadly.

The possibility that pain may enhance sensory processing sensitivity is consistent with research demonstrating that arousal enhances responsiveness to goal-relevant or high-priority stimuli (Mather & Sutherland, 2011). For example, under conditions of high arousal participants are faster to respond to goal-relevant stimuli and are better able to direct attention to prioritized stimulus characteristics (Chajut & Algom, 2003; Cornsweet, 1969). This prediction is also consistent with the work on pain offset which shows that self-injurers who were exposed to pain (cold-pressor task) showed enhanced quality of information processing (Franklin et al., 2010).

We directly examined the possibility that pain may increase sensitvity to taste across three studies. In order to determine whether pain increases enjoyment of pleasant tastes, in Study 1 we asked people to rate their enjoyment of pleasant tasting stimuli (chocolate) after the experience of pain (vs. control). We also aimed to provide insight into possible pathways through which this increased enjoyment might occur. If enhanced gustatory pleasure is evident due to the positive affect arising from pain or activation of the opioid system, we would expect to see intensity ratings of pleasurable tastes increase, but intensity ratings of unpleasant tastes decrease. If enhanced pleasure is due to increased sensitivity to, and awareness of, the body's physiological state, then intensity ratings of both pleasant and unpleasant stimuli should increase. We tested these possibilities in Study 2. Finally, in Study 3, we directly investigated the possibility that pain increases awareness of, and therefore sensitivity to, subsequent stimuli by examining whether participants were more accurate in their sensory perception after pain.

## Study 1 – Method

Thirty-six participants (28 women, $M_{age} = 23.69$, $SD = 4.97$) were drawn from an on-line research participation pool and paid $10. They were allocated to either a pain condition ($n = 19$) or a no-pain condition ($n = 17$). To induce pain we used a modified version of the cold-pressor task (see Bastian, Jetten, & Fasoli, 2011; Bastian, Jetten, & Stewart, 2013). Participants were required to insert their hand into a container filled with ice-water (0–2 °C). Inside there was another small container with a hole in it and a number of loose metal balls in the bottom. Participants were required to pick up the metal balls and place them in the container one at a time for as long as they could. In order to ensure that all participants had sufficient exposure to the painful stimulus, we asked those who withdrew their hand within a 1 min period to re-insert their hand when ready until one minute had passed. In the control condition participants completed the same task except in room temperature water (~20 °C) for 90 s. Tasks were designed to be equivalent in length, purpose, required compliance and sense of achievement.

All participants were then invited to participate in a separate 'consumer study'. They were asked to sample a chocolate biscuit and to rate the extent to which they enjoyed eating the biscuit and how pleasant they found the flavor to be. Ratings of pleasure and enjoyment were highly correlated ($r = .75$, $p < .001$) and thus were combined to form a measure of enjoyment. Participants completed the 20-item version of the positive and negative affect scale (PANAS: Watson, Clark, & Tellegen, 1988) both prior to the pain/no-pain induction and also at the end of the taste test. Participants also rated how painful their experience was on the Wong–Baker Pain Scale (Wong & Baker, 1988) (0 = *no hurt* to 5 = *hurts worst*). They were debriefed using a funnel debriefing procedure which involved a series of increasingly specific questions regarding the purpose of the study. No participant demonstrated any insight into the study's hypotheses.

### *Results and discussion*

One participant left their hand submerged in the ice bath for an unusually long period of time (>7 min; more than 3 standard deviations above the mean). This participant was removed, leaving $n = 18$ in the pain condition. Participants in the pain condition kept their hand in the bath for an average of 98 s ($SD = 1.36$). A manipulation check revealed that participants in the pain condition rated the physical task as significantly more painful ($M = 2.69$, $SD = 1.10$) than those in the control condition ($M = 0.06$, $SD = .06$), $t(33) = 9.65$, $p < .001$. There were no differences in positive ($\alpha = .88$) or negative mood ($\alpha = .78$) at either Time 1 ($ts < 1.06$, $ps > .298$) or Time 2 ($ts < .79$, $ps > .436$). An ANOVA revealed a significant effect of condition on enjoyment, $F(1,33) = 6.26$, $p = .017$, $\eta^2 = .16$. Participants in the pain condition rated the chocolate biscuit as more enjoyable ($M = 6.03$, $SD = 0.85$) than participants in the no-pain condition ($M = 4.97$, $SD = 1.57$). This effect remained when separately controlling for gender, the amount of time taken when completing the physical task, and positive and negative affect after the taste test.

Providing direct support for our main research questions, the findings of Study 1 indicate that physical pain offset increases

the pleasantness and the enjoyment derived from the consumption of chocolate.

## Study 2

As we note above, pain offset may increase gustatory pleasure in two ways. First, it could be that pain enhances the positive hedonic value of gustatory stimuli by producing positive affective states or activating the opioid system. This would mean that pleasant tastes become more pleasant and unpleasant tastes become less unpleasant. Another possibility is that pain increases awareness of the body's physiological state. From this perspective not only pleasant tastes would be experienced more intensely, but so would unpleasant tastes.

One way to tease apart these possible pathways is to move from a focus on enjoyment of pleasant tasting stimuli to a focus on the intensity of a range of tastes (both pleasant and unpleasant). In Study 2 we aimed to demonstrate that, beyond being associated with enhanced *enjoyment* of pleasant/rewarding tastes (as in Study 1), pain is associated with the enhanced *intensity* of all tastes. Furthermore, rather than focusing only on sweet tastes, we investigated whether physical pain may increase the intensity of four tastes, some of which can be interpreted as more pleasant than others: sweetness, bitterness, sourness and saltiness. In this study we therefore aimed to determine whether the effects of pain offset on sensory information processing are due to a shift in the positive hedonic value of subsequent stimuli, or whether increased awareness of the body's physiological state during pain offset may play a role. If this second possibility is true, then we would expect that, after pain, participants would rate all four tastes as more intense.

In addition, in this study we aimed to demonstrate that any increase in taste intensity should be most apparent immediately after pain, when the effects of pain offset remain acute. As such, rather than using a no-pain control condition, we varied the time-line between pain and the taste ratings. This had the added advantage of ensuring that all participants completed exactly the same tasks, and therefore any effects could not be due to any uncontrolled variance in the manipulation procedure. In line with our argument that taste intensity should increase as a function of increased awareness of the physiological condition of the body during pain offset, we predicted that taste intensity should be greater close to the cessation of pain as compared to after a delay.

### *Method*

Thirty-four[1] participants (21 women, $M_{age} = 22.29$, $SD = 3.04$) were recruited similarly to Study 1 and were all exposed to painful stimulation. However, we varied the timeline between painful stimulation and our test of taste intensity. One group completed the modified cold pressor task (as in Study 1) and then spent ten minutes writing about an average weekday (delay control condition = 17). The other group completed the essay first and then did the cold pressor task (pain condition = 17). After completing the cold pressor task, all participants were invited to participate in a separate experiment on sensory experience. They were shown four cups filled with approximately 15 ml of prepared liquid solution. There were four different solutions. The sweet solution was prepared by mixing ¼ cup of sugar (white sugar) with 1.5 l of water. The sour solution was prepared by mixing ¼ cup of store-bought lemon concentrate ('Lemon Squeeze'), with 1.5 l of water. The salty solution was prepared by mixing ½ tablespoon of salt (table salt) mixed with 1.5 l of water. Finally, the bitter solution was store bought tonic water containing quinine. The order of the cups was randomized for each participant and participants were provided with a drink of water to rinse their mouth after each tasting. After they had consumed the entire contents of the cup, participants were asked to rate each taste for its intensity on two questions (i.e., 'how intense is the taste' and 'how sweet/salty/sour/bitter is the taste'). Responses were made on a 7-point scale from '*not at all*' (1) to '*very much so*' (7). Ratings for the two questions relating to intensity were highly correlated ($rs > .50$, $ps < .003$) so they were collapsed to form a measure of intensity for each taste. At the end participants rated how painful the physical acuity task was on the Wong–Baker Pain Scale (Wong & Baker, 1988) (0 = *no hurt* to 5 = *hurts worst*), and reported their affect on 4 items (positive affect: relaxed, happy: $r = .58$, $p < .001$; negative affect: angry, sad: $r = .63$, $p < .001$) on a scale from 1 (*not at all*) to 10 (*very much so*). Participants were debriefed using a funnel debriefing procedure (described above) with no participant demonstrating any insight into the study's hypotheses.

### *Results and discussion*

There were no differences in the rated painfulness of the physical task in either the pain ($M = 3.35$, $SD = .70$) or delay condition ($M = 3.00$, $SD = 1.12$), $t(32) = 1.10$, $p = .279$. There were also no differences in ratings of how unpleasant, challenging, or frustrating the tasks were ($ts < 1.45$, $ps > .156$). A mixed model ANOVA was used with the intensity ratings for each of the four tastes as the within-subjects factor and immediacy of the offset of the painful stimulus as the between subjects factor. Consistent with predictions, all tastes were rated as more intense when consumed immediately after pain, $F(1,32) = 4.87$, $p = .035$, $\eta^2 = .13$ (see Fig. 1). Participants in the pain condition rated each of the tastes as more intense (sweet: $M = 4.15$, $SD = .84$; salty: $M = 4.65$, $SD = 1.77$; sour: $M = 4.09$, $SD = 1.08$; bitter: $M = 4.94$, $SD = 1.67$) than when consumed after a 10 min break (sweet: $M = 3.35$, $SD = 1.06$; salty: $M = 3.65$, $SD = 1.46$; sour: $M = 3.59$, $SD = 1.08$; bitter: $M = 4.24$, $SD = 1.24$). There was no interaction of the different tastes with condition, $F(1,32) = .22$, $p = .884$, $\eta^2 = .02$, indicating that the increased intensity in the pain as compared to the no-pain conditions was equivalent for all four tastes. This effect remained when separately controlling for gender, the total amount of time taken when completing the ice-bucket task, and positive or negative affective states.

Study 2 builds on Study 1 by demonstrating that pain offset enhances the perceived intensity of all tastes, some of which are more pleasant than others. In this way, Study 2 provides evidence that the effects of pain offset on sensory processing extend beyond the influence of pain on enhancing the positive hedonic value of

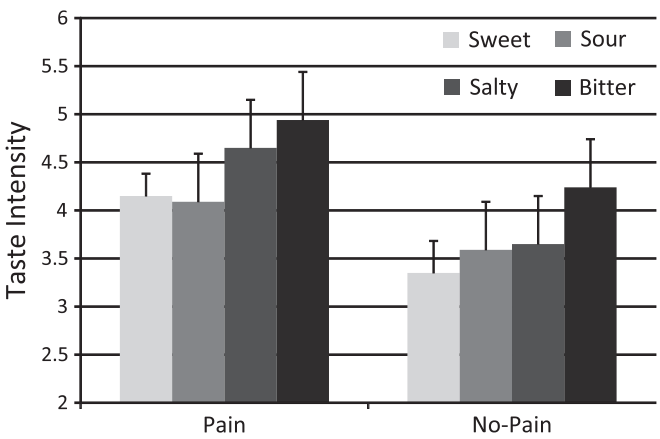


**Fig. 1.** Intensity ratings for different tastes across condition, Study 2.

[1] One participant was excluded in the pain condition due to experimental error: the ice-water was not sufficiently cold.

gustatory stimuli. Pain offset not only increases the intensity of pleasant tastes, but also increases the intensity of unpleasant tastes. This suggests that during pain offset, increased awareness of the body's physiological state enhances sensitivity to taste. This effect of pain offset, in turn, facilitates the capacity to derive enjoyment from pleasant tasting stimuli. Study 2 also provides an important insight into the nature of these effects: that they are most apparent close to the offset of pain.

## Study 3

By showing that both pleasant/rewarding and unpleasant/non-rewarding stimuli are experienced as more intense after pain, the findings of Study 2 go some way to demonstrate that the effects of pain offset on taste are due to increased awareness of the body's physiological state. To this extent, pain offset appears to promote increased sensitivity to gustatory stimuli. Still, we have only provided indirect support for this argument. In Study 3 we aimed to directly examine the effect of pain on sensitivity to subsequent gustatory stimuli. Specifically, we examined if people are better able to detect and distinguish different flavors after experiencing pain. We used flavorings that were unsweetened and therefore represented relatively neutral stimuli in terms of pleasantness or reward.

### *Method*

Thirty-three participants (23 women, $M_{age} = 21.82$; $SD = 3.25$) recruited similarly to Study 1 were invited to taste six different cups of water mixed with food-grade industrial flavorings. These flavors were obtained from an industrial flavor manufacturer and included chocolate (Code: ES0586), ginger (Code: ES0815), peppermint (Code: ES0787), apple (Code: ES0388), coconut (Code: ES0750), and orange (Code: ES0790). Given the strength of the flavors two phases were used to prepare the tasting solutions: an initial flavor solution was prepared by adding 6 ml of each flavor to 250 ml of water which was then mixed with 10 ml of water in the final tasting cup. This represented a relatively strong mixture, the purpose of which was to familiarize participants with each flavor. Participants were told the name of each flavor they tasted to ensure they were able to pair the flavor with the appropriate label.

The experimental phase was next. This first involved exposing participants to the pain induction (modified cold-pressor: $n = 16$) or the control condition (room temperature water: $n = 17$) used in Study 1. This physical task was framed as a separate experiment to the tasting task they had just completed. Participants where then told they would be completing a second phase of the taste task. This represented our primary dependent variable measuring taste sensitivity. Participants were seated in front of three rows of ten cups each with between 10 and 11 ml of clear liquid in them. They were informed that the cups in each row may contain either no flavor, or they may contain one of two flavors with which they had just familiarized themselves. The two possible flavors were written on a card in front of each row and included coconut or orange, apple or peppermint, and ginger or chocolate. Participants were told that if the cups contained flavor, it would be of increasing intensity starting with the 1st cup and ending with the 10th cup. They were instructed to report whether there was a flavor present—and which flavor it was—when they felt reasonably confident. No feedback was provided and the experimenter recorded when the participant named the correct flavor (if no flavor was identified after tasting all 10 cups participants received a score of 11). In reality there was no flavor in each of the first three cups, and the next seven cups in each row contained apple, chocolate, or coconut in mixed order of presentation and with increasing intensity across the seven cups. Again, two phases were used to prepare the tasting solutions. An initial flavor solution was prepared by adding 1 ml of each flavor to 250 ml of water. In the fourth cup (the first containing flavor) 0.5 ml of this prepared flavor solution was mixed with 10 ml of water, this increased to 0.10 ml of prepared flavor solution in the fifth cup, 0.15 ml in the sixth cup, and so on with each cup increasing by 0.05 ml increments of prepared flavor solution. The tenth cup had 0.35 ml of prepared flavor solution. Flavors were chosen that were most easily differentiated from each other. Responses were averaged across all three trials.

To ensure that our findings were not influenced by other confounding factors, participants indicated whether they had eaten or drunk anything in the last hour. They also indicated whether they were a smoker, had used chewing gum in the past hour, had a cold, or were sick in any way or had any other medical conditions. Participants were debriefed using a funnel debriefing procedure (described earlier) with no participant demonstrating any insight into the study's hypotheses.

### *Results and discussion*

One participant indicated they were a smoker and no participants reported using chewing gum in the past hour. Inspection of food and drink consumed did not reveal any substance that would impact on flavor sensitivity. No participants reported any medical conditions and five participants indicated they had only mild symptoms of sickness. Inspection of the sensitivity measure indicated that one participant guessed the correct flavor at cup 1 (before any flavor was present) and so was excluded from further analyses leaving $n = 16$ in each condition. All other participants did not identify the correct flavor until after the 4th cup.

To determine whether there were any differences in guessing between the two groups we created a false alarm index for each flavor. A score of zero was given to participants (a) who named the correct flavor on their first response and did not change their minds, and (b) who never indicated the presence of any flavor. A score of 1 was given to participants whose first response was incorrect. Scores were summed across the three flavors. This revealed no differences between groups in the tendency to guess (pain: $M = 0.19$, $SD = 0.24$; no-pain $M = 0.21$, $SD = 0.24$), $t(30) = 0.24$, $p = .809$.

Scores for the point at which participants first gave the correct answer were averaged across all three trials. An ANOVA on the measure of sensitivity revealed an effect of condition, $F(1,30) = 7.85$, $p = .009$, $\eta^2 = .21$. Participants who experienced pain were quicker to name the correct flavor ($M = 8.17$, $SD = 1.95$) than participants who did not experience pain ($M = 9.83$, $SD = 1.36$). This effect remained when separately controlling for gender, the total amount of time taken when completing the physical task, whether the participants were sick, were a smoker, or for false alarms.

## General discussion

We aimed to determine whether the offset of acute pain may enhance enjoyment of subsequent gustatory experiences. Study 1 provided direct support for this notion, showing that the offset of pain increased participants' enjoyment of chocolate. Study 2 revealed that the offset of pain increased the intensity of a range of tastes, both pleasant and unpleasant, thus suggesting that pain serves to enhance responsiveness to a range of gustatory experiences. Finally, Study 3 demonstrates that the offset of pain served to increase sensitivity to different flavors on an objective measure of sensory discrimination. Together, these three studies demonstrate that the offset of pain serves to enhance sensitivity to gustatory stimuli.

Although there is now an emerging body of work focusing on the role of pain in producing pleasant experiences (Boecker et al., 2008; Franklin, Lee, et al., 2013; Leknes et al., 2008), little work has examined whether pain offset may shape how people experience the qualities of subsequent stimuli. We outline two plausible pathways through which pain may increase enjoyment of subsequent gustatory experiences. The first relies on the role of pain in enhancing the hedonic value to subsequent stimuli, either by producing positive hedonic states or by activating the release of endogenous opioids. The second relies on increased awareness of the body's physiological state, thereby increasing sensitivity to gustatory input. Both pathways would predict that pain offset might increase enjoyment of pleasant tastes (Study 1). Critically, however, only increased awareness would predict that pain might increase the intensity of both pleasant/rewarding and unpleasant/non-rewarding tastes (Study 2) and would increase sensitivity to different flavors (Study 3).

Our findings suggest a novel pathway through which pain may produce pleasurable experiences. Previous work has demonstrated that positive affect associated with pain offset relief may play a role in increasing liking of neutral stimuli encountered during this state (e.g., Andreatta et al., 2010). What has never been investigated is how stimuli may be processed close to pain offset. As we note, it is possible that positive affective states, as well as endogenous opioid release, may be involved in enhanced processing of the positive hedonic qualities of gustatory stimuli encountered close to pain offset. Our findings suggest, however, that the effects of pain offset on taste extend beyond enhancing positive hedonic qualities, and may increase sensitivity to both the pleasant/rewarding and negative/non-rewarding aspects of gustatory stimuli.

Engagement with and enjoyment of our immediate sensory experience is a desirable state that is often sought out through therapeutic practices such as yoga, meditation, and mindfulness (Brown & Ryan, 2003). Indeed mindfulness based interventions are used for treating eating disorders due to their ability to enhance awareness of taste and thereby increase the capacity to savor food (Kristeller, Baer, & Wolever, 2006). Our findings highlight that the experience of physical pain may not only produce pleasant hedonic states, but may also increase responsiveness to sensory input, thereby enhancing sensory perception and providing an alternate avenue for enriching sensory experience. By uncovering this potentially positive consequence of pain, our findings provide direct insight into the ways in which the experience of pain may serve to enhance the experience of gustatory pleasure.

## References


Andreatta, M., Mühlberger, A., Yarali, A., Gerber, B., & Pauli, P. (2010). A rift between implicit and explicit conditioned valence in human pain relief learning. *Proceedings of the Royal Society B, 277*, 2411–2416.

Barrett, L. F., & Bliss-Moreau, E. (2009). Affect as a psychological primitive. *Advances in Experimental Social Psychology, 41*, 167–218.

Bastian, B., Jetten, J., & Fasoli, F. (2011). Cleansing the soul by hurting the flesh. The guilt reducing effect of pain. *Psychological Science, 22*, 334–335.

Bastian, B., Jetten, J., & Stewart, E. (2013). Physical pain and guilty pleasures. *Social Psychological and Personality Science, 4*, 215–219.

Baumeister, R. F. (1988). Masochism as escape from self. *Journal of Sex Research, 25*, 28–59.

Becerra, L., Breiter, H. C., Wise, R., Gonzalez, R. G., & Borsook, D. (2001). Reward circuitry activation by noxious thermal stimuli. *Neuron, 32*, 927–946.

Berridge, K. C. (2002). Pleasures of the brain. *Brain and Cognition, 52*, 106–128.

Boecker, H., Sprenger, T., Spilker, M. E., Henriksen, G., Koppenhoefer, M., Wagner, K. J., et al. (2008). The runner's high. Opioidergic mechanisms in the human brain. *Cerebral Cortex, 18*, 2523–2531.

Brown, K. W., & Ryan, R. M. (2003). The benefits of being present. Mindfulness and its role in psychological wellbeing. *Journal of Personality and Social Psychology, 84*, 822–848.

Chajut, E., & Algom, D. (2003). Selective attention improves under stress. Implications for theories of social cognition. *Journal of Personality and Social Psychology, 85*, 231–248.

Chapman, A. L., Gratz, K. L., & Brown, M. Z. (2006). Solving the puzzle of deliberate self-harm. The experiential avoidance model. *Behavior Research and Therapy, 44*, 371–394.

Claes, L., Klonsky, E. D., Muehlenkamp, J., Kuppens, P., & Vandereycken, W. (2010). The affect-regulation function of nonsuicidal self-injury in eating-disordered patients. Which affect states are regulated? *Comprehensive Psychiatry, 51*, 386–392.

Cornsweet, D. M. (1969). Use of cues in visual periphery under conditions of arousal. *Journal of Experimental Psychology, 80*, 14–18.

Craig, A. D. (2002). How do you feel? Interoception. The sense of the physiological condition of the body. *Nature Reviews Neuroscience, 3*, 655–666.

Craig, A. D. (2003). A new view of pain as a homeostatic emotion. *Trends in Neurosciences, 26*, 303–307.

Craig, A. D. (2009). How do you feel – now? The anterior insula and human awareness. *Nature Reviews Neuroscience, 10*, 59–70.

Doyle, T. G., Berridge, K. C., & Gosnell, B. A. (1993). Morphine enhances hedonic taste palatability in rats. *Pharmacological Biochemistry and Behavior, 46*, 745–749.

Eccleston, C., & Crombez, G. (1999). Pain demands attention. A cognitive-affective model of the interruptive function of pain. *Psychological Bulletin, 125*, 356–366.

Franklin, J. C., Hessel, E. T., Aaron, R. V., Arthur, M. S., Heilbron, N., & Prinstein, M. J. (2010). The functions of nonsuicidal self-injury. Support for cognitive–affective regulation and opponent processes from a novel psychophysiological Paradigm. *Journal of Abnormal Psychology, 119*, 850–862.

Franklin, J. C., Lee, K. M., Hanna, E. K., & Prinstein, M. J. (2013). Feeling work to feel better. Pain-offset relief simultaneously stimulates positive affect and reduces negative affect. *Psychological Science, 24*, 521–529.

Franklin, J. C., Puzia, M. E., Lee, K. M., Lee, G. E., Hanna, E. K., & Spring, V. L. (2013). The nature of pain offset relief in nonsuicidal self-injury. A laboratory study. *Clinical Psychological Science, 1*, 110–119.

Garey, J., Goodwillie, A., Frohlich, J., Morgan, M., Gustafsson, J.-A., Smithies, O., et al. (2003). Genetic contributions to generalized arousal of brain and behavior. *Proceedings of the National Academy of Sciences USA, 100*, 11019–11022.

Gear, R. W., Aley, K. O., & Levine, J. D. (1999). Pain-induced analgesia mediated by mesolimbic reward circuits. *The Journal of Neuroscience, 19*, 7175–7181.

Glucklich, A. (2001). *Sacred pain. Hurting the body for the sake of the soul*. New York, NY: Oxford University Press.

Guidi, M. E. L. (1994, August). Pain and human action. Locke to Bentham. In *Fourth conference of the international society for utilitarian, studies*. Tokyo.

Klonsky, D. E. (2009). The functions of self-injury in young adults who cut themselves. Clarifying the evidence for affect regulation. *Psychiatry Research, 166*, 260–268.

Kristeller, J. L., Baer, R. A., & Wolever, R. Q. (2006). Mindfulness-based approaches to eating disorders. In R. Baer (Ed.), *Mindfulness and acceptance-based interventions. Conceptualization, application and empirical support*. San Diego: Elsevier.

Le Breton, D. (2000). Playing symbolically with death in extreme sports. *Body & Society, 6*, 1–11.

Legrain, V., Van Damme, S., Eccleston, C., Davis, K. D., Seminowicz, D. A., & Crombez, G. (2009). A neurocognitive model of attention to pain. Behavioral and neuroimaging evidence. *Pain, 144*, 230–232.

Leknes, S., Brooks, J. C. W., Wiech, K., & Tracey, I. (2008). Pain relief as an opponent process. A psychophysical investigation. *European Medical Journal, 28*, 794–801.

Leknes, S., & Tracey, I. (2008). A common neurobiology for pain and pleasure. *Nature Reviews Neuroscience, 9*, 314–320.

Lindquist, K. A., Wager, T. D., Kober, H., Bliss-Moreau, E., & Barrett, L. F. (2012). The brain basis of emotion. A meta-analytic review. *Behavioral and Brain Sciences, 35*, 121–143.

Mather, M., & Sutherland, M. R. (2011). Arousal-biased competition in perception and memory. *Perspectives on Psychological Science, 6*, 114–133.

Morris, D. B. (1991). *The culture of pain*. Berkeley, CA: University of California Press.

Murphy, M. R., Checkley, S. A., Seckl, J. R., & Lightman, S. L. (1990). Naloxone inhibits oxytocin release at organism in man. *Journal of Clinical Endocrinology and Metabolism, 71*, 1056–1058.

Nock, M. K. (2010a). Why do people hurt themselves? New Insights into the nature and function of self-injury. *Current Directions in Psychological Science, 18*, 78–83.

Nock, M. K. (2010b). Self-injury. *Annual Review of Clinical Psychology, 6*, 339–363.

O'Connor, P. J., & Cook, D. B. (1999). Exercise and pain. The neurobiology, measurement, and laboratory study of pain in relation to exercise in humans. *Exercise and Sport Sciences Reviews, 27*, 119–166.

Parker, L. A., Maier, S., Rennie, M., & Crebolder, J. (1992). Morphine- and naltrexone-induced modification of palatability. Analysis by the taste reactivity test. *Behavioral Neuroscience, 106*, 999–1010.

Pecina, S., & Berridge, K. C. (1995). Central enhancement of taste pleasure by intraventricular morphine. *Neurobiology, 3*(3–4), 269–280.

Pecina, S., & Berridge, K. C. (2000). Opioid eating site in accumbens shell mediates food intake and hedonic 'liking'. Map based on microinjections Fos plumes. *Brain Research, 863*, 71–86.

Pfaff, D. W. (2006). *Brain arousal and information theory. Neural and genetic mechanisms*. Cambridge, MA: Harvard University Press.

Price, D. D. (2000). Psychological and neural mechanisms of the affective dimension of pain. *Science, 288*, 1769–1772.

Rideout, H. J., & Parker, L. A. (1996). Morphine enhancement of sucrose palatability. Analysis by the taste reactivity test. *Pharmacology Biochemistry and Behavior, 53*, 731–734.

Rozin, P., Guillot, L., Fincher, K., Rozin, A., & Tsukayama, E. (2013). Glad to be sad and other examples of benign masochism. *Judgment and Decision Making, 8*, 439–447.

Rozin, P. (1990). Getting to like the burn of chili pepper. Biological, psychological and cultural perspectives. In B. G. Green, J. R. Mason, & M. R. Kare (Eds.), *Chemical senses. Irritation* (Vol. 2, pp. 231–269). New York, NY: Marcel Dekker.
Rozin, P. (1999). Preadaptation and the puzzles and properties of pleasure. In D. Kahneman, E. Diener, & N. Schwarz (Eds.), *Well being. The foundations of hedonic psychology* (pp. 109–133). New York, NY: Russell Sage.
Rozin, P., & Schiller, D. (1980). The nature and acquisition of a preference for chili pepper by humans. *Motivation and Emotion, 4*, 77–101.
Shackman, A. J., Salomons, T. V., Slagter, H. A., Fox, A. S., Winter, J. J., & Davidson, R. J. (2011). The integration of negative affect, pain and cognitive control in the cingulate cortex. *Nature Reviews Neuroscience, 12*, 154–167.
Small, D. M., & Apkarian, A. V. (2006). Increased taste intensity perception exhibited by patients with chronic back pain. *Pain, 120*, 124–130.
Smith, M. P., & Buchanan, G. (1954). Acquisition of secondary reward by cues associated with shock reduction. *Journal of Experimental Psychology, 48*, 123–126.
Sprenger, T., Valet, M., Boecker, H., Henrikson, G., Spilker, M., Willoch, F., et al. (2006). Opioidergic activation in the medial pain system after heat pain. *Pain, 122*, 63–67.
Tanimoto, H., Heisenberg, M., & Gerber, B. (2004). Experimental psychology. Event timing turns punishment to reward. *Nature, 430*, 983.
Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measure of positive and negative affect. The PANAS scales. *Journal of Personality and Social Psychology, 45*, 1063–1070.
Weil, Z. M., Zhang, Q., Hornung, A., Blizard, D., & Pfaff, D. W. (2010). Impact of generalized brain arousal on sexual behavior. *Proceedings of the National Academy of Sciences USA, 107*, 2265–2270.
Wong, D., & Baker, C. (1988). Pain in children. Comparison of assessment scales. *Pediatric Nursing, 14*, 9–17.
Zanna, M. P., Kiesler, C. A., & Pilkonis, P. A. (1970). Positive and negative attitudinal affect established by classical conditioning. *Journal of Personality and Social Psychology, 14*, 321–328.
Zenner, R. J., De Decker, D. E., & Clement, D. L. (1980). Blood-pressure response to swimming in ice-cold water. *Lancet, 8160*, 120–121.
Zubieta, J.-K., Smith, Y. R., Bueller, J. A., Xu, Y., Kilbourn, M. R., Jewett, D. M., et al. (2001). Regional muopioid receptor regulation of sensory and affective dimensions of pain. *Science, 293*, 311–315.