Beyond Conformity: Social Feedback Shapes Conditioned Pain Modulation

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Introduction

> *I said that the cure itself is a certain leaf, but in addition to the drug there is a certain charm, which if someone chants when he makes use of it, the medicine altogether restores him to health, but without the charm there is no profit from the leaf.*
>
> –Plato (Charmides, 155-6)

Even in ancient Greece, philosophers recognized the powerful role that expectations and beliefs play in shaping our experiences. As time has passed, we have come to understand that both internal and external factors motivate treatment outcomes and influence the beneficial qualities of some medical procedures. No doubt, social communication of positive treatment effects has aided in facilitating the efficacy of unhelpful or sometimes detrimental practices such as bloodletting, electroshock therapy, and now perhaps anti-depressants.

Within the past few decades research investigating the placebo effect has shown that indeed, positive expectations or beliefs do account for a significant percent of symptom relief in many diseases, illnesses, and afflictions; including depression (Thompson, Hermann, Rapoport, & Lanctôt, 2007; Kirsch, 2010), Parkinson's disease (de la Fuente-Fernández, 2001), addiction (Volkow et al., 2003), anxiety, high blood pressure (Moerman, 2000), and pain (Amazio & Benedetti, 1999; Montgomery & Kirsch 1997; Atlas, Bolger, Lindquist, & Wager, 2010). Being that the placebo effect has such a prevalent role in all realms of medical treatment, it is important to understand what socio-environmental factors do contribute to its effect. How do we learn about pain and relief, and how do we learn from each other about how to react to it?

Consider this situation: you have recently been suffering from spring allergies and you find a new drug to treat your symptoms at the pharmacy. After a week, the drug doesn't seem to be helping though, and so you put it aside. One night, you tell your friends about this ineffective drug and how you stopped using it, and maybe how it was a waste of money. They all seem surprised and tell you that they too have been using this drug recently, but contrary to your report, unanimously endorse the drug. How do you evaluate this medication now? Will you maybe try it again? What would the situation have been like if the group's feedback was consistent with your evaluation?

It is the aim of this thesis to investigate how social information facilitates the learning of pain and relief, and to explain how it is that information from others is utilized in shaping our own realities of pain, painful experiences, and relief.

Cognitive Factors and the Placebo Effect

Initially, placebo research sought to understand how drug responses could be learned via classical conditioning. It was thought that through repeated exposure to conditioned stimuli (CS), such as pill characteristics, environment, procedures or verbal cues (Wickramasekera, 1980), participants could be 'taught' to expect drug effects. Just as in Pavlov's classic experiments (Pavlov, 1927), human studies that included the administration of conditioned treatments also yielded conditioned analgesia responses (CR) in the absence of any previously conditioned active ingredients (UCS) (Ross & Schnitzer, 1963; Amanzio & Benedetti, 1999; Voudourls, Peck, & Coleman, 1990). While research has shown that some placebo responses are learned solely on the basis of conditioning (Vourdouis, et al. 1990; Amanzio, & Benedetti, 1999), it is more likely the case that learned pain is not strictly a direct CS-CR pairing, and is instead mediated by expectancies (Montgomery & Kirsch, 1997; Atlas et al., 2010).

Expectations may be brought about through many socio-environmental factors, including positive patient-practitioner engagement, setting or procedural action, and other psychosocial information sources (Kaptchuk, 2002; Di Blasi & Kleijen, 2003; Miller & Kaptchuk, 2008). Bruce Moseley et al. (2002) conducted research on placebo treatment without conditioning so to understand these factors. The effects were striking. In this double-blind experiment patients with osteoarthritis were placed in one of three arthroscopic surgery conditions, one of which was a sham surgery (i.e. participants simply received an incision at the knee but no lavage or debridement). Post-surgery and two-year follow up evaluations showed that expectations, the subjective benefits of the surgery, and knee function did not differ between any of the surgical conditions (Moseley et al., 2002); those who did not receive the real surgery reported similar benefits to those who underwent a complete lavage and debridement. These results indicate that the expectation of a treatment alone can elicit a placebo effect, even without past exposure and conditioning to this specific medical procedure (i.e. osteoarthritic knee surgery).

Needless to say, conditioning remains a highly effective means for learning to form pain and analgesic predictions, because it relies upon past experiences, which reinforce expectations (Benedetti, Pollo, Lopiano, Lanotte, Vighetti, & Rainero, 2003;

Mongomery & Kirsch, 1997). The expectancy theory, originally introduced by Robert Rescorla in 1967, holds that conditioning is mediated by the contingency between CS and CR rather than a simple process of direct reinforcement through repeated exposure (Rescorla, 1968). The expectancy theory explains conditioned behaviors in terms of predictions: if the prediction of an UCS occurring in the presence of a CS is greater than without the CS, the association between CS and CR is strengthened. With repeated exposure, conditioning leads to a reduction in prediction and behavioral errors through reinforcement learning. Simply put, accurate expectations are formed through the reinforcement of the value assigned to a CS (Cohen & Ranganath, 2007; Bayer & Glimcher, 2006; Schultz et al., 1997; Sutton & Barto, 1981).

Studies directly investigating how expectancies act in eliciting analgesia have provided evidence that the placebo effect is strongly mediated by them (Montgomery & Kirsch, 1997). While conditioning is a powerful mechanism for learning placebo analgesia, it is not the ultimate means to the positive end. Rather, conditioning is a strong force in modifying and updating expectancies and stimulus value – more so than verbal manipulations or other environmental CS factors – which ultimately lead to placebo effects (Voudouris, Peck, & Coleman, 1989; Voudouris, Peck & Coleman, 1990; Wickless & Kirsch, 1989).

Mechanisms of Social Conformity

From the time that we are born, we inherit behaviors simply through our observations of other individuals. This process, it seems, may be hardwired– neonates have been reported to mimic the faces of their caretakers simply through interacting with them (Field, Woodson, & Cohen, 1982). Such learning processes are continued throughout the entirety of life in more complex behaviors. The social learning theory explains that not only can learning and reinforcement of behaviors occur through direct experience, but also can occur through the vicarious observation of others or through information provided by groups or trusted individuals (Bandura, 1971). Two distinct forms of conformity are thought to arise through such processes: normative and informational. These conforming behaviors have more widely been termed *public compliance* and *private acceptance*, as these names more accurately reflect the acquiescent or internalization that results from each. Parsing the difference between the two conforming behaviors has been a continuous struggle within social psychological research though, as it is thought that normative motivations persist even in the private behaviors of individuals. Even in Solomon Asch's classic investigations on social conformity, participants conformed to the erroneous reports of several other individuals even though their reports were private and anonymous (Asch, 1956). While there is an important difference to be noted, it is assumed that both private and public conformity are different means to the same end.

In the last decade a large body of work investigating the social transfer of beliefs, attitudes, and conditioned responses have supported that a great deal can be learned through social information (Klucharev et al., 2009; Colloca & Benedetti, 2009; Hunter, Sless, & Colloca, 2013; Jeon et al., 2010; Yoshida, Seymour, Koltzenburg, & Dolan, 2013; Olsson & Phelps, 2007; Valentini, Martini, Lee, Aglioti, & Iannetti, in press; Zaki, Schirmer, & Mitchell, 2011). Whether these behaviors are learned through private or public acceptance, their effects are robust and have great implications for how social factors can motivate evaluative and perceptual processes.

Group normative information has been shown to effect evaluative behaviors (Klucharev et al. 2009; Zaki et al., 2011). The subjective evaluation of attractiveness has been shown to be readily modified by group feedback, and brain areas associated with reward value (Nucleus Accumbens), and prediction error (Rostral Cingulate zone) react differently in relation to participants' deviation from group norms: the Nucleus Accumbans is less active with greater deviation from norms, and the opposite activation is seen in the Rostral Cingulate zone. This pattern of activation shows that reinforcement learning motivates conforming behaviors, as these dopaminergic brain regions drive error correction and learning by coding deviant behavior as less rewarding. These same areas also are active during personally experienced reinforcement learning (Cohen & Ranganath, 2007; Bayer & Glimcher, 2005). Along with these findings are those by Yoshida et al. (2013), who found that when group pain ratings are presented before pain stimulations experienced pain can be modified, indicating that social learning and reinforcement learning mechanisms, such as group feedback, can modify pain perception.

Most important to the current research are reports that cue value and subsequent conditioned responses can be transferred through social information. Vicarious observation of conditioning can yield conditioned responses. In a study by Colloca and Benedetti (2009) it was found that the observation of another individual being conditioned can lead to conditioned responses in the observer that are almost as strong as those learned through direct experience. In their task, a group of participants watched confederates report pain using a visual analogue scale (VAS) after the presentation of a high or low cue and a subsequent shock. Confederates were instructed to always rate high cues as highly painful, and low cues as less painful, so to fully communicate cue value to participants. When participants were tested, it was seen that cues were learned just as well in the observational learning group than in the direct conditioning group, and placebo analgesia effects were also nearly the same in both conditions. These results along with those reported in Olsson and Phelps' (2008) vicarious fear learning research, show that stimulus value, and further, placebo effects can be conditioned through social learning.

While these studies indicate that social feedback is a powerful source of evaluative information, it is still not fully understood how it acts in reinforcing the value of pain predictive cues that have already been learned through direct experience.

Aims & Hypothesis

In this study, a conditioning task adapted from Atlas et al. (2010) was used to investigate how personal experience with pain predictive cues and social feedback are utilized in evaluating cue meaning, and predicting and perceiving painful stimuli. The current research included social feedback ratings at the end of each trial – several lines on a VAS indicating group pain ratings, where each line represented one other person's pain rating for the current stimulus. Social feedback ratings varied within either the high or low end of the VAS to make either 'group-high' or 'group-low' ratings. Social feedback ratings always followed either a Cue_{high} or Cue_{low} pain predictive cue; for two of the cues social feedback ratings were consistent with the cue value and for two others the social feedback was inconsistent with the cue value (see figure 2). The cues in this experiment were four different isoluminant color patches (blue, green, pink, and orange), the associated conditioned stimulus-unconditioned stimulus (CS-UCS) associations were learned implicitly through experience with the cues, and an expectation of pain variable was measured.

The current hypotheses are as follows:

(H1) Learned cue value modulates pain ratings and physiological responses to medium heat pain stimulation, i.e. Cue_{high} leads to greater pain than Cue_{low}.

(H2) Predictive cues that are followed by consistent social feedback are better learned over time than those followed by inconsistent social feedback.

(H3) Conditioned cue effects on pain are greater in the social consistent condition than in the social inconsistent condition.

All three of these specific hypotheses support the overall hypothesis, that social information functions in such a way that it reinforces the learning of predictive cues that have been conditioned through direct experience, for a pain-learning task.

In addition to the main experiment a generalization task was included at the end of the study, so to investigate whether placebo effects generalize to stimuli perceptually similar to the CS. A long history of research investigating CS generalization has indicated that responses to conditioned stimuli do generalize to perceptually similar cues (Watson, 1920; Schechtman, Laufer & Paz, 2010; Resnik & Paz, 2011). Perhaps this effect is brought about by an evolutionarily beneficial behavior that has developed through species, which seeks to err on the side of safety with aversive stimuli (e.g. “a red berry in the past made me sick, I should stay away from berries of a similar color!”) Understanding this effect in placebo analgesia might be beneficial to practitioners and researchers, as it will inform what sorts of similar treatments or conditions can be used in future tests that recruit people who have already been conditioned in the past studies. It is the primary aim of this test to investigate whether the effect of social feedback on cue learning is also reflected in subsequent generalization slopes. In considering this test the following hypothesis are formed:

(H4) Conditioned cue effects on heat pain experience will generalize to previously not experienced but perceptually similar color stimuli, i.e. colors that are more similar to the Cue_{high} will lead to greater pain than colors more similar to Cue_{low}

(H5) Cues previously paired with consistent social feedback will show larger generalization effects than cues previously paired with socially inconsistent feedback.

Method

Participants

29 healthy, adult volunteers between the ages of 18-55 (M age =22.4 years, STD= 4.8, 15 men, 14 women) completed the behavioral session and provided informed consent. Four additional participants did not complete the experiment because of their decision to quit after the calibration, due to high pain sensitivity. Eligibility was assessed using an online general health questionnaire and pain safety screening form. Screening forms also included general information about procedures, risks and

discomforts, and participant compensation. All participants were paid for their time ($12/hour).

Materials and procedures

Thermal Stimulus and Pain Ratings

Thermal stimulation was administered using a Contact Heat Evoked Potential stimulator (CHEPS), a two-layered heating thermofoil thermode (27 mm diameter) controlled by a MEDOC Pathway system (Medoc). Thermal stimulation was administered to six locations along the volar surface of the non-dominant forearm. Each heat stimulation lasted ~1.85s, with a .45s ramp-up, 1s period at target temperature, and immediate return to baseline after peak temperature was reached. Target temperatures ranged from 46° C to 50° C; participants were told that the top temperature would compare to holding a very hot cup of coffee. Heat intensity and expectations were rated using a continuous visual analogue scale (VAS) ranging from 0 to 100 – 0 being no sensation, 100 being the worst pain imaginable. Participants were explained that 'worst pain imaginable' was limited to the worst pain that they could imagine feeling within the context of the experiment. Participants were given an opportunity before the start of each phase of the experiment to practice with the VAS and become acquainted with the task and interface.

Physiological Measures

Heart rate and skin conductance responses were recorded using a Biopac MP150 system, which included an ECG100c amplifier unit and a GSR100c transducer module

(Biopac Systems Inc.). Physiological data was acquired and preprocessed using the AcqKnowledge software (version 4.2.0, Biopac Systems Inc. 2011) and analyzed using MATLAB software. Changes in heart rate and skin conductance are reliable correlates of pain and threat anticipation in various pain modalities, including thermal, mechanical and cold pain (Lavigne et al, 2001; Breimhorst et al., 2011; Möltner, Hölzl & Strian, 1990; Loggia, Juneau & Bushnell, 2011).

Pain Calibration Procedure

Participants first completed a brief calibration procedure, where each of the six skin sites was stimulated in a randomized order. Each site was stimulated three times. Stimulation intensities were randomly ordered between three different intensity groups: high, medium and low. Each group had two temperature levels, resulting in a total of six different temperatures (Low, 45° & 46°; Medium, 47° & 48°; high, 49° & 50°). A total of 18 stimulations were administered in the calibration task. Participants were instructed to rate the intensity of the stimulations using a VAS. Before the actual task, participants were given one trial to practice with the scale. When participants finished this practice trial, the experiment began. The experimenter sat beside the participant moving the thermode to each site when prompted by the computer monitor. After each stimulation the thermode was moved to a new site. The calibration task was used in this experiment to familiarize the participants with the heat pain stimulation, and to assess the relationship between participants’ pain intensity ratings and temperature.

Main Task

Before the main task began, GSR electrodes were attached to participants' left index and middle fingers. ECG electrodes were also placed on the participants' lowest left rib and right collarbone. Initial physiological measures were taken — to ensure signal quality — by asking participants to sit still and take in three deep breaths. Once the initial reading was acquired, the experimenter explained the procedure of the main task.

To ensure that all participants would focus on the cues, the experimenter informed participants that they were going to see several different abstract symbols, which would contain important information about upcoming thermal pain that they would be experiencing, and that it was very important that they pay attention to the meaning of these cues. Participants were also told that at the end of each trial they would see the ratings of several other individuals who had experiences the same level of heat pain just administered. All social information was in fact sham, and this verbal instruction helped to ensure the believability of the information.

After verbal instruction, participants reviewed the procedures again during a short practice phase. During this time instructions were presented at the top of the screen while participants stepped through the task. Participants were given the opportunity to practice with the rating scales and were shown examples of color cues and social information. The social stimuli were carefully explained in this practice phase to ensure that participants understood the meaning of the information. Once the practice phase was completed, participants were informed that the testing would begin.

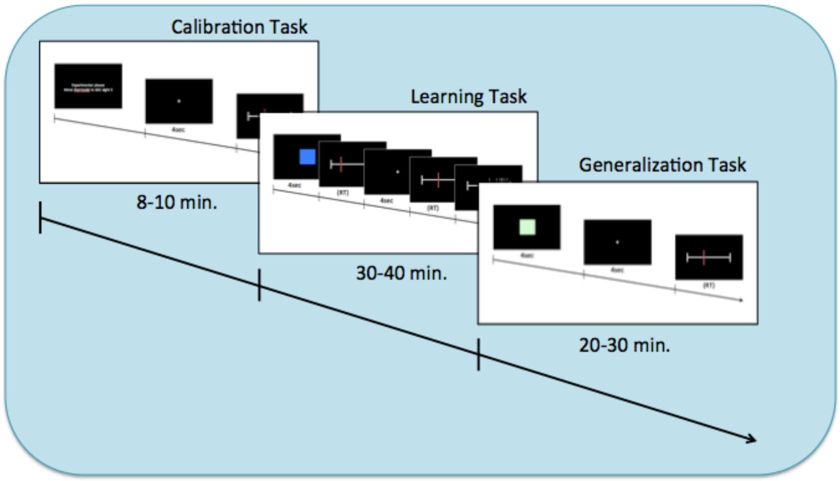

Figure 1. Participants first completed a calibration task that lasted approximately 10 minutes; during this task participants were asked to rate the intensity of thermal stimulations. After the calibration task participants then completed the main learning task (30-40 minutes). Last, participants completed a generalization task, which assessed whether placebo/nocebo effects would generalize to cues similar to those with predictive value; this task lasted approximately 30 minutes.

The main task was divided into six blocks, with thermal stimulation being applied to the six different skin site locations. The thermode was held in place using a large elastic Velcro band, and was moved to different skin sites by the experimenter between blocks. At the beginning of each block, participants received a single brief heat stimulation (49° C) to prevent significant changes in pain sensitivity (habituation) during the actual testing (Jepma, Jones, & Wager, in press).

For the learning task, four isoluminant color patches (green, blue, orange, and pink) were used as cues, each of which was associated with one of four conditions: high-heat social consistent (cCHSH), where the color-cue was paired with high heat stimulations and high social ratings; low-heat social consistent (cCLSL), where the color-cue was paired with low heat stimulations and low social ratings; high-heat social inconsistent (iCHSL, iCHSH), where the color-cue was paired with high heat stimulations and either low or high social ratings; or low-heat social inconsistent (iCLSL, iCLSH.), where the color-cue was paired with low heat and either low or high social ratings (see figure 2). Color assignment was counterbalanced so to control for any color temperature associations that participants may have already had (Morgon, Goodson & Jones, 1975).

Cues appeared for 4s at the beginning of each trial in random order. For each skin site every color was presented four times, resulting in 16 cue presentations for every site, and 96 trials total. After cue presentation a VAS was presented for participants to rate the amount of pain that they expected to receive (expectancy rating). Thermal stimulations were then administered according to cue value. Three temperatures were administered (47°C, 48°C, 49°C) and were categorized into two groups: high and low heat. Both groups included 48°C as a crucial medium temperature, which participants could perceive differently given the conditional context. 47°C and 49°C were each administered four times and 48°C was administered eight times over the course of each skin site block; cue paired temperatures were randomly administered within each cue presentation. After stimulations participants saw the word "wait." Participants then rated the intensity of the pain that they just experienced using a VAS.

After a short delay, participants were shown the pain ratings of ten other individuals, which were presented on a VAS that looked just the same as the one that the participants rated their own pain on — this was done to further convince participants that the ratings were those of real people. Samples were presented for 3s before the next trial began. For each experimental condition, four social rating samples were randomly selected from a catalogue of 96 different images (48 low rating samples and 48 high rating samples). Sample ratings each varied in their group deviations from mean scores, which always were clearly high or low on the VAS. In the social consistent condition (cCLSL, cCHSH), the vicarious ratings were always consistent with the cue value (i.e. low color cues were always followed by low social ratings, and high color cues by high social ratings). Social inconsistent conditions were followed by high or low social pain ratings (iCLSH, iCLSL, iCHSH, iCHSL), which were therefore not systematically correlated with respective cue values. After the presentation of the social rating samples and a short delay, the next color patch was presented. Thus beginning the next trial. At the end of the main task, participants were informed that the task was over.

Generalization Task

Participants viewed 16 different gradients of color between consistent high and consistent low colors, and inconsistent high and inconsistent low colors (e.g. pink to blue). The generalization task consisted of four skin site blocks, each containing 16 heat stimulations at 48°C. It was the aim of this task to assess whether colors that had been conditioned with high heat would generalize to different but similar colors, and whether this generalization would lead to differences in pain reports. All procedures for this task were the same as in the main task, except for the exclusion of the expectation ratings and the social rating samples.

Once the participants completed the generalization task, they were informed that the experiment was over. Participants were given a short debriefing form, which asked them to express what they thought the aims of the study were, and their general impressions. The debriefing questionnaire also asked participants to indicate how useful they found the colors to be for predicting pain, how much pain they believed each color cue to predict, and how useful they found the social information for predicting heat pain on visual analogue scales. After participants completed this form, they were thoroughly debriefed by the experimenter. The experimenter explained the aims of the current research and explained the nature of the stimuli that they had just viewed, mainly informing participants that the social information was sham. The experimenter then thanked and compensated participants for their time and provided them with contact information, in the case that the participant has questions or concerns following their session.

Behavioral Data Analysis.

The effects of the color cues and social information on expectation and pain ratings were assessed using a repeated measures general linear model, with the following within subject factors: cue condition (high and low) and social feedback condition, (consistent and inconsistent) For the generalization task, color effects were tested also using a repeated measures general linear model with color (eight levels of varying color similarity to predictive cues) and social feedback conditions (consistent, inconsistent) as within subject factors. Significance was set at an alpha of

p = .05. SPSS statistical software and custom scripts developed in MATLAB were used to conduct the analysis techniques.

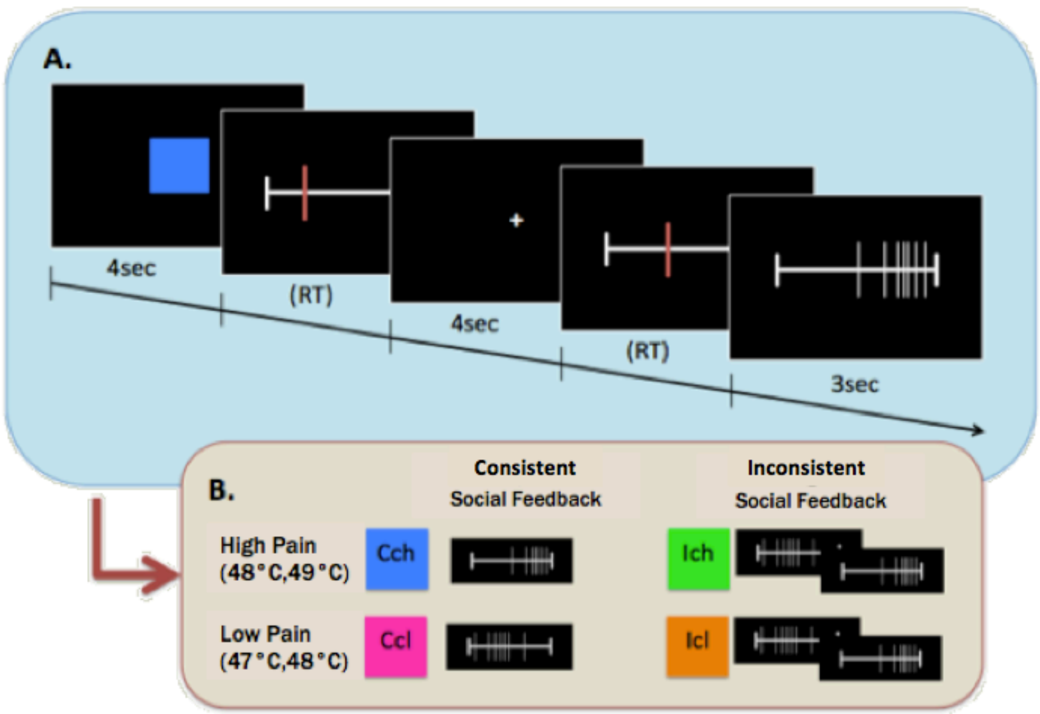

Figure 2. Learning Main Task Design ***A,*** The sequence of events was as follows. First, Participants viewed one of four isoluminant color cue, which was always related to either high or low heat; these color cues remained on the computer monitor for 4 second. Next, participants were asked to rate how much pain they expected to receive using a visual analogue scale (VAS). Once participants reported their expectation, a 2 second heat stimulus was presented with a fixation cross for 4 seconds. Participants then were asked to rate how much pain they had experienced, using another VAS. Once participants rated their experienced pain, they were presented with a social rating sample, which they were told represented the ratings of several other individuals who had experienced the same level of heat participants just received; this sample stayed on the monitor for 3 seconds. After 16 trials the thermode was moved to the next skin site and procedures began anew. ***B,*** There were four different cues presented to participants within the main learning task. One that predicted medium-to-high pain and was paired with consistent social feedback (Cch), one that predicted low-to-medium pain and was followed by consistent social feedback (Ccl), another that predicted medium-to-high pain but was paired with social feedback (Ich), and one that predicted low-to-medium pain but received inconsistent social feedback(Icl). Each cue was presented four times for each skin site block.

Results

Main Learning Task

First, it was found that pain ratings increased with temperature $F(1,29)=118.91$, $p<.05$, confirming that the different temperatures were discriminable by the participants.

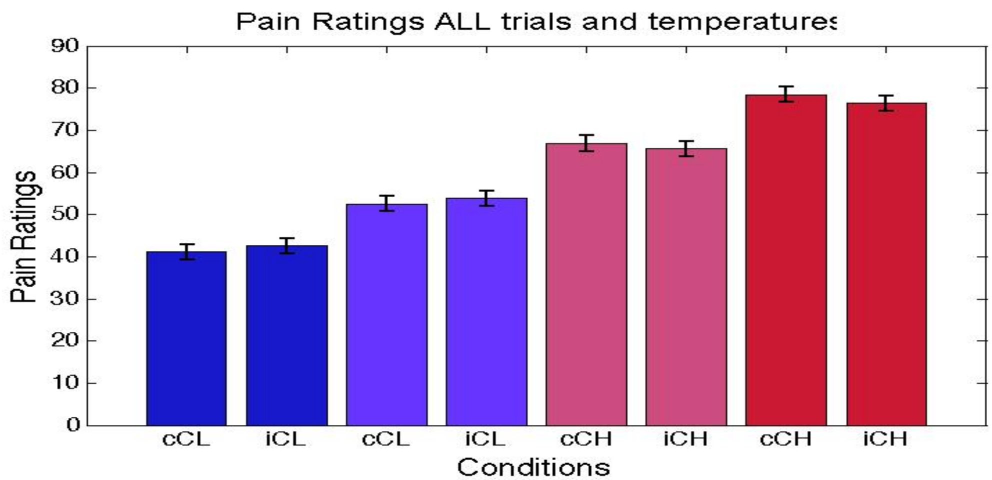

Figure 3. Pain ratings for all conditions and temperatures. (dark blue) T47-cue low (light blue) T48-cue low, (pink) T48-cue high, (red) T49-cue high. c = consistent, i = inconsistent.

Next, we examined how the different predictive cues modulated expectation and pain ratings. A repeated measure ANOVA revealed a significant main effect of cue value (low vs. high) for expectation ratings $F(1,28)= 43.93$, $p<.05$, but no significant main effect of social feedback (consistent vs. inconsistent) $F(1,28) =.001$, $p=.978$, nor an interaction effect between cue value and social feedback $F(1,28)=.659$, $p=.429$ (see figure 4). No interaction was expected in this case; as social information was presented only after pain stimulations were delivered.

In analyzing the pain ratings, we controlled for temperature effects by examining only pain ratings following medium heat pain stimulation (see figure 4). Similar results were produced: a significant cue main effect $F(1,28)=.44.50$, $p<.05$, no social feedback main effect $F(1,28)=.000$, $p=.994$, nor an interaction between cue value and social feedback $F(1,28)=339$, $p=.565$.

Individuals' pain ratings were significantly higher when the Cue_{high} stimulus was presented than when the Cue_{low} stimulus was presented before heat stimulations were delivered $t(28)=22.8$, $p<.05$. The relationship between expectations and pain ratings also correlated strongly across all participants, $r(28)=.66$, $p<.05$.

To test whether cue effects changed over time due to learning, a repeated measure ANOVA was conducted with cue condition (high, low), social (consistent, inconsistent), and time (four time bins with averaged across 6 trials) as within-subject factors for expectation ratings. Results showed a marginally significant interaction effect between cue, social feedback and time for cue expectation ratings in the predicted direction (see figure 5) $F(1,28)=2.169$, $p=.098$. These results indicate that over time consistent social feedback may facilitate the learning of cue value.

A similar ANOVA was conducted with pain ratings and yielded no signifcant interaction between cue, social condition and time $F(1,28)1.512$, $p=.217$). However, in looking at the timecourse graphs (see figure 5) a numeric

trend was recognized in the pain ratings over time. This trend agreed with the notion that the learned effect of the cues could not have altered pain reports in the initial time points; we can only be sure that the effects of the learned cue value could have effected pain in the later part of the learning task.

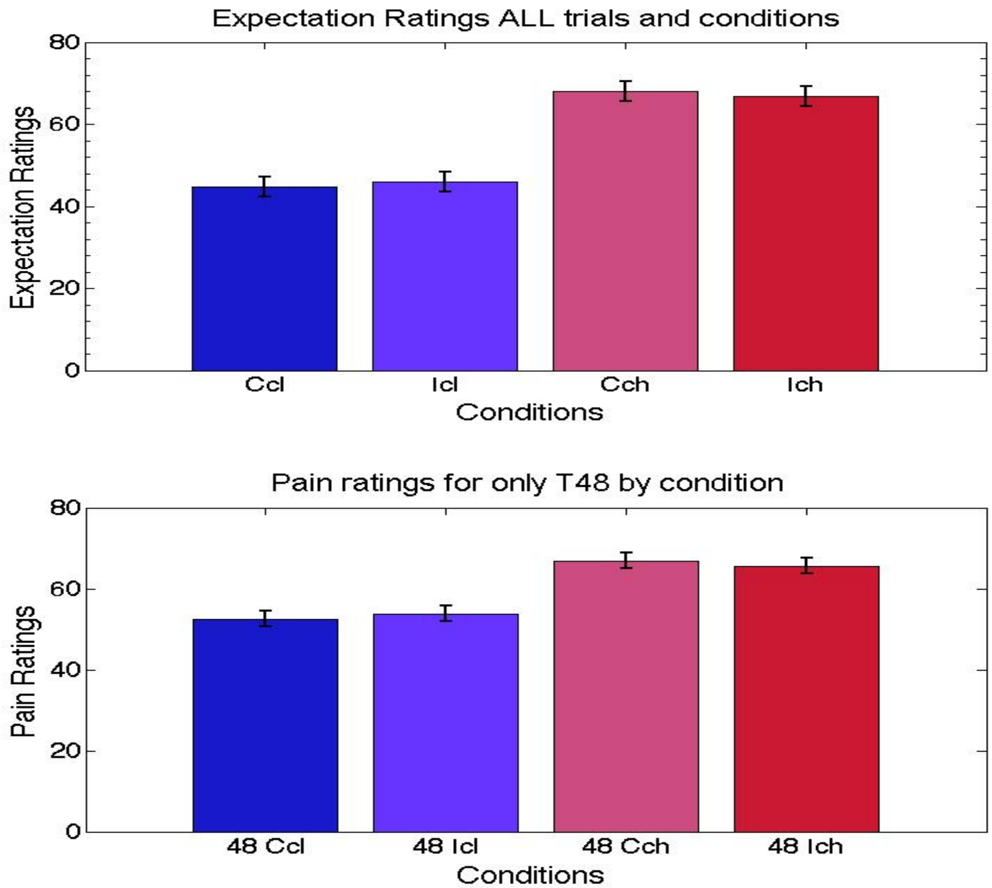

Figure 4. Expectation and pain ratings for all 48°C conditions

To test this hypothesis, only the trials in the final time bin were included in the next GLM analysis. This was done to ensure that the only trials included in the test were those where we could be confident that learning had occured. This test yeilded a significant cue by social interaction, $F(1,28)=5.125$, $p=.032$.

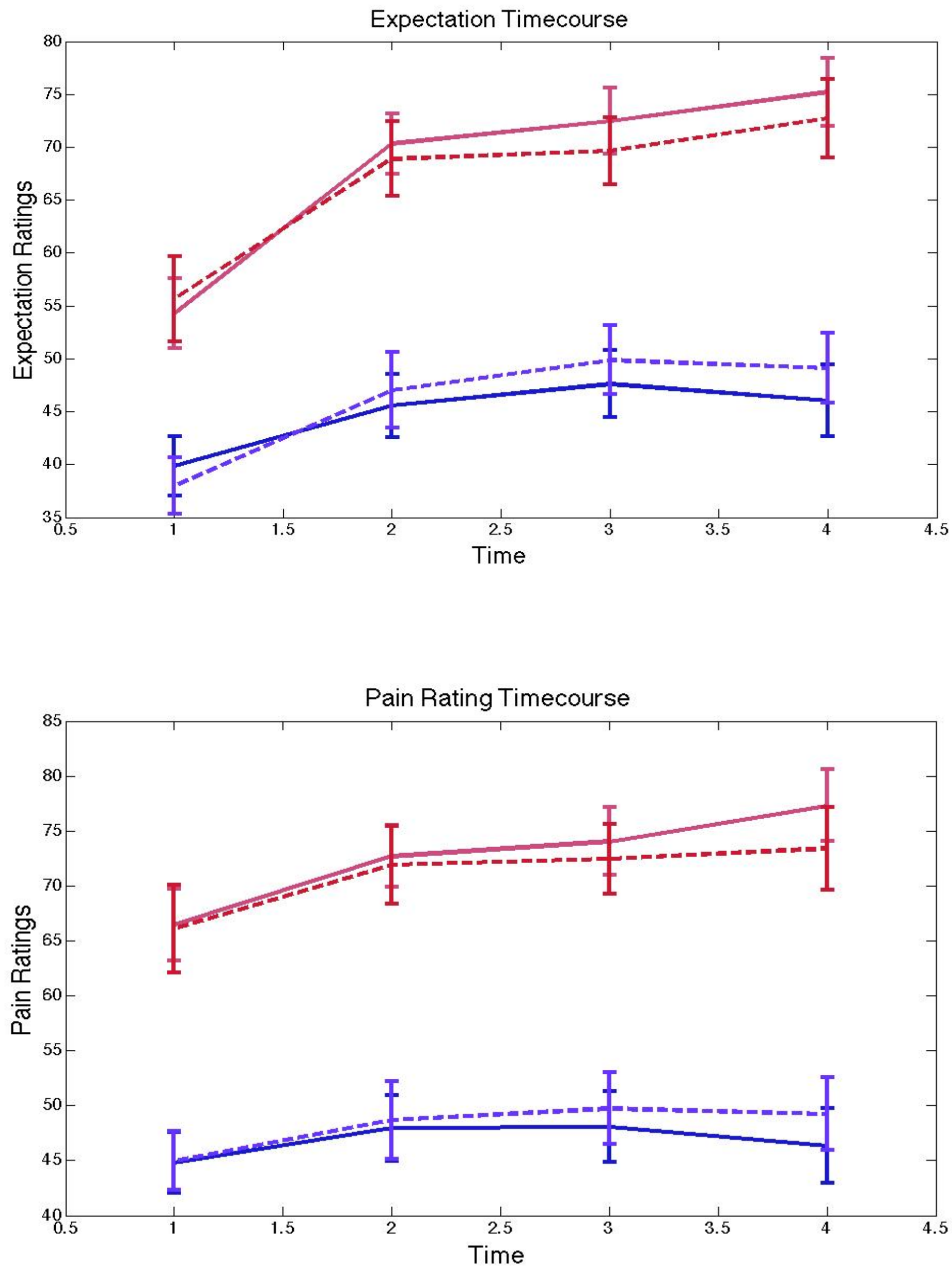

Figure 5. Expectation and pain rating timecourses for all 48°C conditions

Generalization Task

A repeated measure ANOVA was used to asses the effect of color (8 different color morph levels ranging from the Cue_{high} to the Cue_{low}) and social condition (consistent, inconsistent) on pain reports, which yielded a significant main effect for color $F(1,28)=9.234$, $p<.05$. Planned comparisons revealed a strong linear trend for color, indicating that colors more similar to the previously conditions Cue_{high} lead to higher pain ratings than colors more similar to the Cue_{low}. No main effect for social condition was found ($p=.321$), and no significant interaction between the color and social condition was found either ($p=.285$). These results indicate that the meaning of the cues that were previously conditioned in the main learning task generalized to cues that were perceptually similar. These results though also show that there was no significant difference between the level of generalization between the consistent and inconsistent social feedback conditions; this is consistent with the effects of social information on pain ratings in the main learning task.

For further analysis, a value deemed the 'Social Learning Bias" (SLB) was calculated from participants' final time bin expectation ratings from the main learning task, in order to determine which participants attended to and learned from the social information.

$$SLB= (Cch-Ccl)-(Ich-Icl)$$

SLB scores ranged from negative to positive values (min= -44.35, max= 56.79). A median-split (median = 5.55) was used to separate participants into SLB_{high} and SLB_{low} groups ($n_{SLBh}=15$, $n_{SLBl}=14$). SLB_{high} and SLB_{low} generalization task pain ratings were analyzed for both groups, in order to assess whether the lack of a main effect for social condition and interaction was due to participants' possible lack of a significant SLB. No main effect for social condition was found in both groups, and a significant between-group interaction, $F(1,13)=373.21$, $p<.05$ indicated that although groups were different in their overall pain ratings, neither SLB_{high} nor SLB_{low} groups generalized more readily to the colors based on social condition.

Role of Individual differences and debriefing responses

Social learning bias scores correlated –with marginal signifcance – with a social desireability bias measure, which was acquired during the initial questionnaires that participants completed before the calibration task, $r(28)=.33$, $p=.083$. The social desireabilty bias measure is used to assess how likely individuals are to admit to socially desireable actions or thoughts (Chung & Monroe, 2003). No other personality triats, including empathic concern, personal distress, and perspective taking correlated with SLB.

Participants reported how useful the cues were for predicting pain, how much pain they experienced from each cue, and how useful social feedback was for predicting pain on a debriefing questionnaire at the end of the experiment. Cue reports did not reflect any useful information about cues, but the social feedback use measure was helpful for understanding participants' explicit evaluation of social information. Participants' evaluation of the social information's usefulness was not significantly correlated with SLB ($p=.496$).

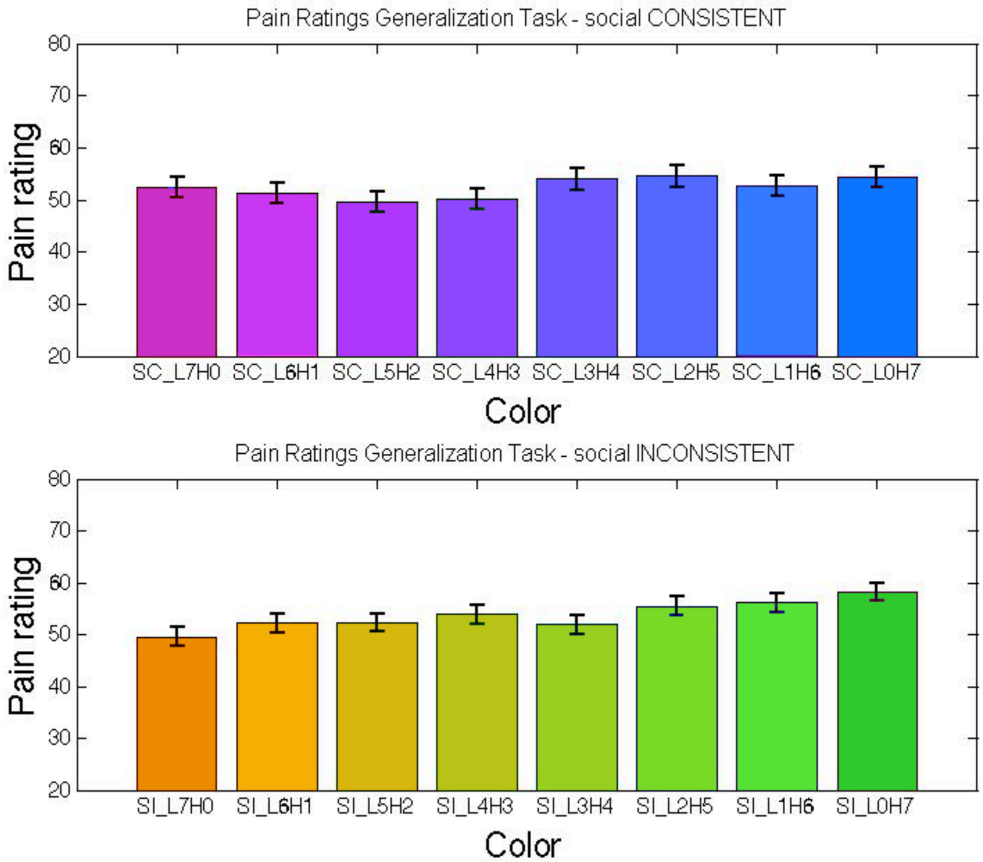

Figure 7. Generalization Task: Pain ratings for all colors for both consistent and inconsistent social feedback conditions, according to color similarity to previously conditioned cues. Colors differed on a gradient of 0 to 7 from previously conditioned predictive cues, where L1H6 represents the most similar color to cue high, and L6H1 represents the most perceptually similar color to cue low.

Discussion

Throughout life we are tasked with evaluating and responding to our surroundings, and predicting future events given our past experiences, but we also constantly look to each other for information that can help us to confirm or correct our predictions and experiences. Here it is shown that social information may have a role in reinforcing the value and expectations associated with stimuli that have been conditioned through direct experience., and further that these conditioned expectations can lead to changes in perceived pain. Solomon Asch's classic experiments on social conformity show exactly how far we go in seeking input from our peers to evaluate information, and highlights how susceptible we are to the power of normative influence (Asch, 1956). it is not known whether the findings here are due to normative or informational conformity, but it is apparent that the social information did marginally alter participants' expectations over time, and further, the experiences that were associated with the conditioned stimuli.

Participants appeared to learn quite clearly the meaning of the predictive cues (high vs. low), and it seems that the value that was associated with each cue respectively modulated participants' reported pain experiences. By looking closer at the medium temperature condtiions, it was seen that the high and low cues had a significant effect on the level of pain that participants experienced. This finding confirms Hypothesis (1) and is congruent with past research that has found that when participants are conditioned on high and low heat predictive cues, these cues modify the way in which participants perceive the same level of heat pain (Atlas, Lindquist, Bolger, & Wager, 2010; Colloca & Bendetti, 2009). If expectations are considered to be the driving force behind the effect of conditioned stimuli, it would also be expected that a signficant relationship between expectations and pain exists. Indeed, such a relationship was found in this study, and is further evidence that the expectancy theory, introduced by Robert Rescorla and advocated by modern scientists today, is a powerful theory for explaining how CS and CR pairing functions (Rescorla, 1967; Montgomery & Kirsch, 1997).

Participants' expectation ratings were used as a means by which to measure the amount of learning that occurred throughout the main learning task, and expectation ratings changed over the course of the learning task in such a way that cues which were paired with consistent social feedback appeared to be learned somewhat more strongly than cues that were paired with inconsistent feedback. Although the results of this experiment only yielded a marginally significant interaction effect for social information, predictive cues and time, the direction of the trend lines indicate that with more time and perhaps more participants, a signficant interaction between social information, predictive cues and time could be found. The fact that social information even marginally influenced the degree to which participants learned the value of the cues, suggests that social information may act as a reinforcement mechanism, which confirms the value of stimuli that are assigned to cues through direct experience. This report also adds to a body of research advocating the influence that social information has on our expectations, perception, and behaviors (Colloca & Benedetti, 2009; Olsson & Phelps, 2009; Jeon et al., 2010; Klucharev, et al. 2009).

From looking at the overall pain ratings across conditions it appears that there was no significant main effect or interaction for social information. But because these results were attained by averaging across all trials, even those at the beginning of the learning phase, it is understandable that no main effect was found. Without a doubt, learning, and more, modulation of pain by expectations could not have been expected to occur within the first several trials of the main learning task. To account for this, only the last time bin of the learning task trials was analyzed, and a significnat interaction between cue and social information was found. So, perhaps it is the case that only after cues have been conditioned does social information facilitate and reinforce the expected pain formed for stimuli.

Apart from the findings provided by the main learning task, a strong generalization effect occurred for learned cues. This finding corroborates past research that aversive stimuli are readily generalized to perceptually similar stimuli within our world, and is, to the author's best knowledge, the first evidence of generalized cue effects on pain experience (Watson, 1920; Schechtman, Laufer, & Paz, 2010; Resnik & Paz, 2011). Because no significant main effect or interaction of the social feedback was found for this generalization task, it cannot be said whether previous social information facilitates generalization to perceptually similar stimuli.

One last finding that is of interest is that the social information provided was not considered to be useful by about half of the partiicipants (n=14) – this measure was attained from the debriefing questionaire at the end of the experiment, and subjects' ratings were considered 'not useful' if scores were lower than the median-split value. This result would be expected, considering that on half of the cue conditions, social feedback samples were designed to not be of any use. We can take this finding to mean that the social information was succesful in conveying sometimes useful but sometmes not useful information to the participants, as subject's also reported verbally to the experimentor during debriefing that on some trials the social information appeared to be geniuine, but on others appeared to be completely off.

Our direct experiences with the world help us to form correct predictions and behave appropriately, but humans are also social animals who learn from each other how to optimally perform in given situations. In the real world, it is not the case that we are only exposed to our direct experiences or only social information when reacting to important events or stimuli. We must learn to navigate the world, taking into account both our history and the history of others as well. Today, the internet provides an amazing amount of interconnective social feedback about any sort of task, thought or opinion. We have become especially good at evaluating our own behaviors and correcting them through what we see and hear on the web. Pain research is a powerful tool for understanding how subjective experiences can be modulated by social information, but perhaps because it is such a powerful lense for understanding perception, it can also help to understand how our thoughts, behaviors and attitudes may be changed even by those thousands of miles away.

Limitations

There were several limitations of this study. First, the number of participants that were recruited for ths study were not enough to lead to significant main effects for some measures. It is recognized here that with more participants, perhaps stronger statistical significance could have been found for some of the dependent measures. Second, the length of the experiment is one issue which makes itself seen in the expectation cue by social by time interaction plot. From looking at the trajectory of the expectation ratings over time, it appears that with more time social information's influence on the value of the cues might have become even stronger. This issue also can be seen in the pain ratings over time. It is difficult though to make this experiment longer, as the full procedure lasted approximately two hours, and some participants did report the experiment being long and exhausting.

Lastly, a considered issue with the design of this study is that the social information s might be seen as a second demanding cognitive task that took away energy and mental resources from the actual learning of the cue values. Attending to both cue values and also social information might be considred each to be demanding cognitive procedures alone. To investigate this possible issue, it would be useful to investigate other experimental designs, where soial information is presented at different times – temporally closer to the cue presentation or before the participants' pain rating– to make certain that it is evaluated as a reinforcing mechanism for cues, and not as a separate evaluative procedure.

Future Directions

It is expected that we will follow up this experiment within the laboratory of Dr. Tor Wager at the University of Colorado at Boulder, in the hopes of attaining at least another 20 participants. Having a larger sample might lead to greater statistical power and provide more conclusive results than this preliminary study.

Physiological data was acquired and processed for this study, but because of time limtations was not analyzed and included in the present paper. It is also expected that as this project continues into the future, the physiological data will be analyzed and included in the future report.

It is lastly also expected that further and more advanced statistical analysis will be conducted on the final data acquired. Amongst other tests, a mediation analysis and possible investigation into the effect of social feedback sample variance on expectation and pain ratings could reveal more fine-grained results. Along with these tests, an investigation into conformity effects on subsequent cue presentation would also help to understand the way in which participants are directly responding to social information. Comparing the difference over time of participants' expectation ratings before and after social feedback would be a possible technique for investigating conformity.

It would lastly be beneficial to investigate different order effects of the social information. Perhaps it is the case that social information presented at different times during the procedure of the main learning task will have varying effects on the expectation and pain ratings of participants. Yoshida, Seymour, Koltzenburg & Dolan (2013) presented social information to participants directly before pain stimulation to investigate how it would modify pain ratings. This design, and also maybe presenting social information before cues, could help to understand order effects when assessing both social information and directly experienced conditioning. It is not only the case that social information strictly follows direct experience in life, and so it would be interesting to have a more comprehensive understanding of both social information that precedes and follows direct experience.

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