Modified Biofeedback as A Potential Treatment in Reducing Chronic Pain Risk: A Controlled Trial

Natalie Hellman, M.A., Cassandra A. Sturycz, M.A., Tyler A. Toledo, M.A., Parker A. Kell, B.A., Burkhart J. Hahn, HGSD, & Jamie L. Rhudy, Ph.D.

Department of Psychology, The University of Tulsa, 800 South Tucker Drive, Tulsa, OK 74104

PLAN Psychophysiology Laboratory for Affective Neuroscience

THE UNIVERSITY of TULSA

Introduction

Chronic pain is associated with significant burden, health care utilization, and suffering. Unfortunately, pharmacological treatments (i.e., opioids) pose significant risks of addiction and serious side-effects, and non-pharmacological treatments (i.e., cognitive behavioral therapy) produce small short term effects. Thus, new or augmented approaches are needed.

One new version of cognitive behavioral therapy that shows promise in treating pain is conditioned biofeedback. **Conditioned biofeedback** provides visual feedback about ongoing sympathetic arousal (i.e., **skin conductance**) while delivering painful electric stimulations that are surreptitiously controlled by the participants' arousal level. This conditions/pairs pain relief with the experience of relaxation, and forms an expectancy that relaxation will promote pain reduction in the future.

Laboratory studies can utilize experimental pain paradigms to assess both pain and nociception (the neural signals that encode pain). This study assessed the **nociceptive flexion reflex (NFR; physiologic measure of spinal nociception)** and **temporal summation of pain (TS-Pain, the degree to which pain increases/summates in response to a train of painful stimuli)** before and after biofeedback training with healthy, pain-free participants. The purpose of this study was to see if conditioned biofeedback would alter pain and nociception (the neural signals that encode pain) by increasing descending inhibition and decreasing pain facilitation in healthy, pain-free participants to reduce their risk of future chronic pain onset.

Objective

This study examined whether a modified version of biofeedback is effective in reducing chronic pain risk via an anti-nociception pain modulation profile.

Procedure

Overview and Group Characteristics

- All participants completed a thorough informed consent process
- 3 separate sessions approximately one week apart
- Assigned to 1 of 3 groups stratified by sex
  - Biofeedback Only group controlled for general biofeedback/relaxation
  - Biofeedback+ Shock group controlled for the effects of practicing biofeedback during painful shocks
  - Conditioned Biofeedback group received painful electric stimulations during biofeedback that were surreptitiously controlled by their arousal level to pair pain relief with relaxation
- All groups received education in relaxation strategies and rationale for biofeedback
- 3 biofeedback trials were completed per session
- Trial length dependent on the length of time required for a 35% reduction in skin conductance
- NFR and TS-Pain ratings were tested at the beginning and end of each session

Procedural Characteristics of the 3 Groups:

	Biofeedback Only	Biofeedback + Shock	Conditioned Biofeedback
3 biofeedback trials each session	✓	✓	✓
Electric stimulations on first trial of first session	✗	✗	✗
Electric stimulations on all other trials	✗	✓	✓
Reduced arousal by 35% from baseline	✓	✓	✓
Stimulus intensity reduced by skin conductance	✗	✗	✓

Participants

Exclusion Criteria:

< 18 years of age, BMI > 35, current acute illness, psychotic symptoms, chronic pain condition, inability to speak/read English, hypertension, history of panic attacks, history of serious cardiovascular, neurological, neuroendocrine problems, recent use of analgesic, antidepressant, anxiolytic, antihypertensive medications, baseline NFR ≥ 50 mA.

	Biofeedback Only n=24		Biofeedback +Shock n=21		Conditioned Biofeedback n=28				
Nominal	***N***	***%***	***N***	***%***	***N***	***%***	***C²***	***df***	***p***
Female (Sex)	13	54%	10	48%	14	50%	0.20	2	0.91
Race (White)	22	92%	13	62%	20	71%	9.96	8	0.29
Marital Status (single)	16	67%	16	80%	18	64%	2.22	6	0.90
Employed (full)	21	88%	15	75%	18	64%	9.18	6	0.16
Continuous	***M***	***SD***	***M***	***SD***	***M***	***SD***	***F***	***p***	***Partial η²***
Age (yrs)	31.21	12.91	30.29	12.67	32.54	14.07	0.18	0.83	0.01
Education (yrs)	15.10	2.55	15.10	1.64	15.79	2.48	0.75	0.48	0.02
BMI (kg/m²)	23.95	3.73	23.85	3.43	25.40	3.61	1.30	0.28	0.04
NFR Threshold (mA)	23.74	11.62	19.92	11.29	21.33	9.00	0.76	0.48	0.02
TS-pain (ΔNRS rating)	9.25	5.72	7.02	5.18	10.08	7.42	1.45	0.24	0.04

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Methods: Biofeedback Training

Pain Education: Psychoeducation about pain transmission, the gate control theory, and the interaction between cognitions, emotions, behaviors, and arousal.

Arousal Reduction (Relaxation) Strategies:

- diaphragmatic breathing
- minimize movement
- pleasant mental imagery
- reduce negative thoughts
- remove distractions
- stay in the moment (mindfulness)

The Biofeedback + Shock and the Conditioned Biofeedback groups also received additional strategies of pain control statements and reinterpreting the pain.

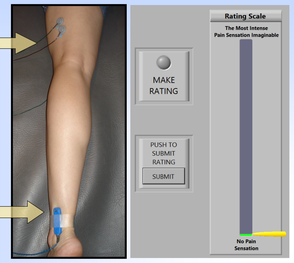
Training Sessions: 3 trials each session for a minimum of 6.5 minutes each.

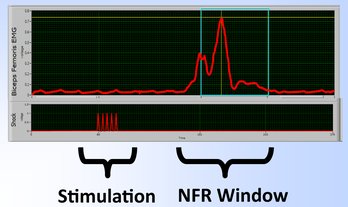
- 1st trial of session 1 was always without stimulations
- Goal was to reduce skin conductance by 35%.

In the Biofeedback + Shock and the Conditioned Biofeedback, electric stimulations were delivered at random 8-12 ISIs.

The Biofeedback + Shock group received stimulations based on a randomized set of intensities obtained from a participant that completed the Conditioned Biofeedback group.

Outcome: Descending Inhibition via NFR Testing





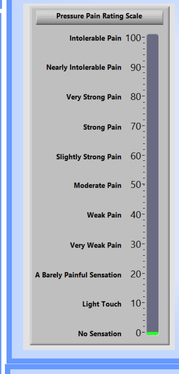
Nociceptive Flexion Reflex (NFR): A spinally-mediated protective withdrawal reflex elicited by Aδ fiber activation.

NFR Threshold: Biceps femoris EMG activity in the 90-150 ms post-stimulus window

- Stimulus intensity (in mA) required to reliably elicit NFR
- Used as a measure of spinal inhibition such that increased threshold signifies increased spinal inhibition

Stimulus Intensity During Biofeedback Training: Stimulus intensity was individually calibrated to each person to ensure the stimuli was painful (rating ≥ 30) at the start of the training trial but no greater than >20 mA for the starting intensity.

Outcome: Pain Facilitation via TS-Pain



Temporal Summation of Mechanical Pain (TS-Pain): degree to which pain increases/summates in response to a train of painful stimuli that reflects pain facilitation.

Summation procedure: A 6.45 (180 grams of force) monofilament was pressed against the skin 1 time and then 10 times at 1 Hz. This procedure was applied to 2 sites on the dorsum of the left hand.

Participants verbally provided their maximum pain ratings after the 1st single application and after the 10 stimulus series using the Numerical Rating Scale.

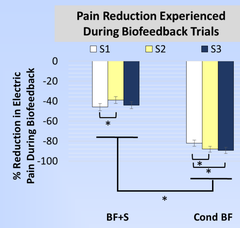
TS-Pain was determined as the 10 stimulus series rating minus the single stimulus rating (averaged across testing sites).

Data Analysis

Group outliers were detected according to Wilcox (MAD-median procedure) and replaced with nearest non-outlier neighbor value.

Multilevel ANOVA models were used to analyze pain and nociceptive outcomes. The repeated measures variance-covariance structure was modeled using an autocorrelation matrix (AR1) and participants served as level 2 units (i.e., repeated measurements were nested within participants). Significant interactions were followed-up with Fisher's mean comparisons. *A priori* planned mean comparisons were conducted to examine whether biofeedback training led to persistent changes in pre-session (baseline) NFR threshold and TS-pain across sessions.

Results

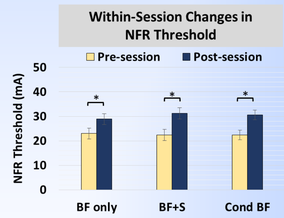


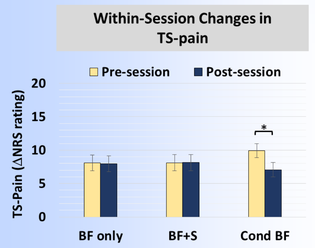
Pain Reduction During Biofeedback (Manipulation Check): The Conditioned Biofeedback group showed greater pain reduction during biofeedback than the Biofeedback + Shock group ($F[1,47] = 117.08$, $p<.001$).

This supports the notion that pain relief was paired with successful relaxation.

Within Session Descending Inhibition: All groups showed pre- to post-biofeedback increases in NFR threshold ($F[1,191.57] = 121.35$, $p<.001$) and did not vary across groups or sessions.

Effect sizes: $d_{Biofeedback\ only}=0.54$, $d_{Biofeedback\ +Shock}=0.83$, and $d_{Conditioned\ Biofeedback}=0.96$



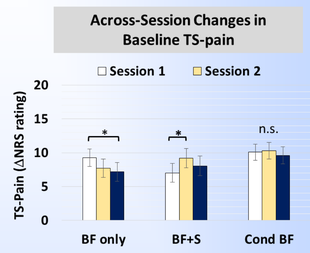


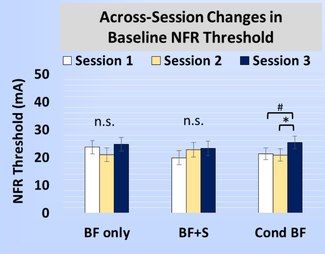
Within Session Pain Facilitation: Only the Conditioned Biofeedback group showed pre– to post-biofeedback reductions in TS-Pain following biofeedback training ($F[2,151.14] = 11.37$, $p<.001$).

Effect sizes: $d_{Biofeedback\ Only}= 0.03$, $d_{Conditioned\ Biofeedback}=0.004$, and $d_{Biofeedback\ +\ Shock}=0.42$

Across-Session Descending Inhibition: Conditioned Biofeedback resulted in a persistent (pre-biofeedback) increase in NFR threshold even when they had not completed a trial that day.

Effect sizes: Biofeedback Only ($d_{S1vS2}= 0.22$, $d_{S1vS3}= 0.08$, $d_{S2vS3}= 0.28$), Biofeedback + Shock ($d_{S1vS2}= 0.25$, $d_{S1vS3}= 0.24$, $d_{S2vS3}= 0.03$), and Conditioned Biofeedback ($d_{S1vS2}= 0.06$, $d_{S1vS3}= 0.38$, $d_{S2vS3}= 0.45$)





Across-Session Pain Facilitation: Biofeedback Only resulted in a persistent (pre-biofeedback) decrease in TS-pain, while the Biofeedback + Shock group's TS-pain *increased* from S1 to S2.

Effect sizes: Biofeedback Only ($d_{S1vS2}= 0.29$, $d_{S1vS3}= 0.41$, $d_{S2vS3}= 0.12$), Biofeedback + Shock ($d_{S1vS2}= 0.37$, $d_{S1vS3}= 0.18$, $d_{S2vS3}= 0.18$), and Conditioned Biofeedback ($d_{S1vS2}= 0.03$, $d_{S1vS3}= 0.06$, $d_{S2vS3}= 0.09$)

*= p<.05, #= p=.059

Conclusions

Results indicated that all groups experienced a within-session (pre- to post-biofeedback) increase in NFR threshold which suggests that biofeedback/relaxation, regardless of the type, led to increases in descending inhibition.

Conditioned Biofeedback may produce greater increases in descending inhibition, as this group demonstrated the largest increases in NFR threshold. Further, only the Conditioned Biofeedback group showed increases in baseline NFR threshold across sessions, suggesting that this group is superior to other groups in improving pain inhibition.

Conditioned Biofeedback appears to produce an immediate reduction in TS-pain following biofeedback, whereas Biofeedback Only may produce a reduction that is only observed across-sessions.

We found that **Conditioned Biofeedback can increase anti-nociceptive tendencies** by increasing descending inhibition of spinal nociception and reducing pain facilitation. These effects were present after only one session, and Conditioned Biofeedback produced a persistent increase in descending inhibition.

Conditioned Biofeedback may be superior to the other biofeedback modalities at reducing chronic pain risk.

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