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Alpha band prefrontal asymmetry does not underlie pain approach-avoidance: Results from two EEG studies

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Alpha band prefrontal asymmetry does not underlie pain approach-avoidance: Results from two EEG studies

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Abstract

Pain research is often focused on escape from pain or approach of relief, yet individuals with chronic pain make complex choices to face their pain to satiate other drives (approach-avoidance conflicts). An abundance of research has indicated that prefrontal alpha band asymmetry (PFA) underlies approach-avoidance in general, but there is limited information about whether PFA underlies pain approach-avoidance conflicts. Electroencephalogram activity was recorded while 70 participants with chronic pain (*n*=33) and without chronic pain (*n*=37) approached/avoided stimuli containing simultaneous pain (low-high) and monetary reward (low-high). Findings from both studies revealed that approach-avoidance for pain stimuli is not accompanied by prefrontal asymmetry, irrespective of the presence of chronic pain.

Keywords: pain, chronic pain, EEG, prefrontal asymmetry, pain avoidance, alpha band

Alpha Band Prefrontal Asymmetry Does Not Underlie Pain Approach-Avoidance: Results from Two EEG Studies

Chronic pain is the primary reason to seek care from a medical professional and affects between 11- 43% of U.S. adults (Dahlhamer et al., 2018; Pitcher et al., 2019; Zimmer et al., 2022). Chronic pain is a health concern in its own right and has been associated with a decrease in quality of life, dependence on medications (e.g., opioids), and comorbidities with anxiety and depression (Dahlhamer et al., 2018; Simsek et al., 2019). An abundance of literature has focused on neural activity during escape/avoidance of pain, or pain relief (Barrot, 2012; Goubert et al., 2009; Gregory et al., 2013; King et al., 2009; LaBuda & Fuchs, 2000; Roy, 2010; Saadé & Jabbur, 2008; van Middendorp et al., 2008), but pain is not a unidimensional physiological response that occurs in a homeostatic vacuum (Craig, 2003).

Pain Approach-Avoidance

In addition to sensory-discriminative components, pain has affective-motivational and cognitive-evaluative dimensions (Eccleston & Crombez, 1999; Salcido et al., 2018a; Salcido et al., 2018b) and one may be motivated to approach aversive stimuli (pain) in order to obtain a reward or reduce a competing homeostatic imbalance, known as “approach- avoidance” (Epstein, 1978; Harris, 2013; Salcido et al., 2018a). LaGraize and colleagues (2004) found that when there are competing drives, rats will choose to address the drive which presents the most intense imbalance. Rats suppress lever responses for an appetitive reward (Harris, 2013; Salcido et al., 2018b) and demonstrate pain intensity-dependent lever responding (LaGraize et al., 2004). Whereas humans avoid painful stimuli less when in the presence of competing goals such as money, demonstrating that the drive to approach or avoid painful stimuli is not simple, but is context specific and subject to evaluation from competing drives (Van Damme et al., 2012).

Neurophysiological Correlates of Pain Approach-Avoidance

There is a lack of research investigating neurophysiological behaviors that underlie pain approach-avoidance. Cerebral markers for general approach-avoidance have been well-established in the psychophysics literature (Schlund & Cataldo, 2010; Schlund et al., 2011). Approach has been related to left hemisphere alpha band activity while right hemisphere alpha activity is related to avoidance, which together are referred to as "prefrontal alpha asymmetry" or "prefrontal asymmetry" (PFA; Davidson, 1995; Davidson, 1990; Elliot & Covington, 2001; Jensen et al., 2015). Further, this PFA arises due to action motivation (approach or avoidance) (Berkman & Lieberman, 2009).

It remains unclear if approach-avoidance motivations involving pain are accompanied by PFA processing, as in other contexts. However, PFA is measured in the alpha band (8-13 Hz) and reduced alpha wave activity has been well-documented in experimental pain studies (Chang et al., 2002a; Chang et al., 2002b; Egsgaard et al., 2009; Jensen et al., 2013) and is a target for pain biofeedback (Kozlova et al., 2017; Turner & Chapman, 1982). Brain oscillations in the alpha frequency range originate in the thalamus (Egsgaard et al., 2009). These oscillations indicate disengagement of exteroceptive inputs (cues from outside the body), and a focus on interoceptive operations- the cues from inside the body (Buzsáki, 2006).

Albu and Meagher (2016) report that low power in the alpha band during pain is indicative of the affective response to pain. Talmi and colleagues (2009) found that attenuation of reward activity in the anterior cingulate and ventral striatum when pain was present with the competing goal of monetary reward. When confronted with these challenges of competing salience, disruption of functional processing in the anterior salience network (which includes

areas such as the anterior cingulate cortex, insula, and prefrontal cortex) can result in meaningful behavioral changes (Kozlova et al., 2017; Senkowski et al., 2014; Borsook et al., 2013).

The Current Study

Fisher and colleagues (2016) measured approach-avoidance conflicts during pain in adolescents using vignettes that aligned facing pain with goal obtainment and found that in general, participants were more likely to avoid the threat of high intensity pain. Further, they found that there was no different in approach-avoidance in adolescents with and without chronic pain. To our knowledge, there have been no approach-avoidance studies investigating the effects of chronic pain on cortical activity during approach-avoidance. Therefore, the purpose of the current studies was to examine PFA and alpha band activity during pain approach-avoidance in participants that report chronic pain using EEG.

Method

Approval was granted from Tarleton State University institutional review board, and the two studies were conducted in accordance with both the American Psychological Association and Declaration of Helsinki guidelines. Participants received instructions prior to arriving at the lab not to wear caps, hair clips, or hair products to avoid interference with EEG recording. Participants were informed that a small amount of conductive gel would be used on their head in addition to electrodes to record EEG brain activity. Informed consent was obtained and data were stored in a de-individualized format.

Participants were collected for the studies based on power analyses for ANOVA using G*Power (Faul et al., 2007) and standards consistent with the EEG pain literature (Silva Dos Santos Pinheiro et al., 2016). Demographic and survey data means and standard deviations were generated in Excel. Descriptive and inferential frequentist statistics were run using JASP (JASP

Team, 2018) and IBM SPSS Statistics v25.0. Data are presented as mean ± *SD* or *SEM*. Conservative post hoc analyses were run when $p < .05$ (Bonferroni). Bayesian inference was used to quantify support for the alternative (BF_{10}) that group differences exist.

Study One

Participants

Thirty-nine participants were recruited via flyers, emails, or word of mouth. Left-handed or ambidextrous individuals (Gaudalupe et al., 2014), pregnant individuals, and those with epilepsy or a cardiac pacemaker were excluded (Barha & Galea, 2017; Clark et al., 1989; Scharfman, 2007). Nine exclusions were made; four were due to handedness, and five were due to poor electrode impedance/noise during EEG recording. Participants were asked to self-report the presence (*n*=15) or lack of chronic pain (n=15). Conditions reported included inflammatory pain and back pain with unknown etiology. Participants identified as American Indian or Alaska Native (*n*=1), White (*n*=23), Black or African American (*n*=1), and Hispanic or Latino (*n*=5). Demographics are available in Table 1.

Materials

Psychometric Assessments

The Edinburgh Handedness Inventory was used to determine handedness (Oldfield, 1971; Veale, 2014), and should be considered when analyzing PFA due to differences in lateralization. Questions were preceded by the following instructions: “Please indicate your preferences in the use of hands in the following activities or objects (always right, usually right, both equally, usually left, always left): writing, throwing, toothbrush, spoon” (Oldfield, 1971). The questionnaire is scored for each item as [(always right = 100; usually right = 50; both equally =

0; usually left = -50; always left = -100)/4]. Participants with scores from -100 to -61 (left handed) and -60 to 60 (ambidextrous) were excluded from analysis.

The McGill Pain Questionnaire short-form was administered to determine the subjective qualities of the pain experience such as intensity, quantity, and quality of pain (Burckhardt & Jones, 2003; Melzack, 1987). The short form has been validated (Lovejoy et al., 2012; Melzack, 1987; Wright et al., 2001). Participants rated 11 sensory words (throbbing, shooting, stabbing, sharp, cramping, gnawing, hot-burning, aching, heavy, tender, and splitting) on a scale of none-1, mild-2, moderate-3, and severe-4 which were summed into a *sensory dimension score.* Participants rated four affective words (tiring-exhausting, sickening, fearful, and punishing-cruel) on the same scale which were summed into an *affective dimension score*. The *Present Pain Intensity index* (PPI) question requires participants to rate their current pain intensity as no pain-0, mild-1, discomforting-2, distressing-3, horrible-4, or excruciating-5.

Approach-Avoidance Stimuli

Approach-avoidance stimuli were comprised of paired meters that contained levels of money (left meter) and levels of pain (right meter). Each of the meters indicated low, moderate, and high levels (Figure 1) to create varying levels of threat. For example, low threat stimuli contained a meter with low pain and high money. Participants received instructions to indicate if they are willing to approach or avoid (using a computer mouse) the scenarios containing varying levels of pain to receive a monetary reward for a total of 27 stimuli presentations. Money is a powerful reward motivator that has been used in previous studies as a competing goal with pain (Talmi et al., 2009).

Equipment and Data Recording

Participants viewed surveys and completed the behavioral task using a computer (Optiplex 990 desktop with a 23" monitor) equipped with iMotions software, and a computer mouse (Dell). To prepare for EEG recording, electrode pads were connected to strips of electrodes that were placed on the participant's scalp and mastoid bones behind the ear. The strips plugged into the wireless module that was attached to an adjustable headband worn around the head. Conductive gel (Synapse Cream) was placed underneath each electrode until a proper impedance level (less than 40 Ω) was indicated on iMotions software. Continuous EEG was recorded using the B-Alert x10 wireless EEG device from nine mono-polar electrodes (Figure 2) at a sampling rate of 256 Hz (mastoid leads for ground and reference). The EEG headset and head band were cleaned between participants using alcohol swipes. Participants were provided with alcohol wipes and bathroom access after recording.

Procedure

After providing informed consent and responding to demographic questions, the EEG was placed on the participant. Participants were instructed to remain still and minimize blinking before completing a nine-minute iMotions benchmark test to ensure proper impedance followed by the McGill pain questionnaire and the Edinburgh Handedness Inventory. Continuous EEG was recorded during the presentation of the approach-avoidance stimuli. Data was exported from iMotions software into Microsoft Excel files for offline post-processing and analyses.

Data Analyses

McGill Pain Questionnaire data were sorted in Excel and sums were created for the sensory dimension and emotional dimension. An ANOVA was run with group (chronic pain/no pain) as the between subjects variable and MPQ dimension as the within subjects variable (sensory,

emotional, and PPI). Bonferroni post hocs were used to probe significant effects (where $p < .05$). Approach-avoidance task data were coded in iMotions software by decision to approach as a "1" and to avoid as a "2." Data were summed into an avoidance score for each participant. A one-way ANOVA was run to compare avoidance scores by group (chronic pain or no pain).

EEG data were exported from iMotions software into Microsoft Excel files for offline post-processing arrangement. Excel files were loaded into the EEGlab plug-in of MatLab to apply low (0.02 Hz) and high (50 Hz) bandpass filters, reject artifacts (blinks, electrode drift, etc.), and assign electrode locations. A transposed copy of the data was pasted into Notepad++ with number of channels, sampling rate, and total number of samples to allow import into Cartool software where fast fourier transforms were computed to separate a single data set into the following frequency files: Delta (0-3 Hz), Theta (4-7 Hz), Alpha (8-12 Hz), Beta (13-30 Hz), and Gamma (31-50 Hz). Averages were calculated using Microsoft Excel for the alpha band (8-13 Hz) activity for all electrodes, and prefrontal asymmetry (PFA) was calculated as the natural log of right side absolute alpha (F4) - natural log of left side absolute alpha (F3). To investigate the effects of pain on prefrontal asymmetry in the approach-avoidance task, an ANOVA was computed with group (pain/no pain) as the between subjects factor and PFA scores by threat level (low/high) as the within subjects factor. Higher scores reflect greater left frontal hemisphere activity.

To investigate group differences in the alpha band, ANOVA analyses were run to compare the alpha frequency band (alpha 8-13 Hz) by group (chronic pain/no pain) for both low-threat stimuli and high-threat stimuli. Where there was a significant overall effect ($p < .05$), single electrode analyses were computed with an alpha criterion correction.

Results

McGill Pain Questionnaire

Results from the mixed ANOVA indicated that there was a main effect of dimension, F (2, 56) = 413.45, $p < .001$, $\eta^2 = .88$, $BF_{10} = 32.47$. There was a main effect of group, F (1, 28) = 44.11, $p < .001$, $\eta^2 = .61$, $BF_{10} = 2.74$. There was a significant interaction effect between dimension and group, F (2, 56) = 30.72, $p < .001$, $\eta^2 = .07$, $BF_{10} = 57.91$. Bonferroni post hoc analyses revealed that the chronic pain group (M = 20.07, SEM = 1.26) had significantly higher sensory dimension scores than the group without pain (M = 11.60, SEM = .21), $p < .001$. The chronic pain group (M = 5.80, SEM = .58) had significantly higher emotional dimension scores than the group without pain (M = 4.27, SEM = .15), $p < .001$. The chronic pain group (M = 3.05, SEM = .24) had significantly higher present pain intensity scores than no pain (M = 1.26, SEM = .10), $p < .001$.

Approach-Avoidance Behavior

A one-way ANOVA revealed that there was no significant difference in avoidance of approach-avoidance stimuli between the chronic pain group (M = 14.67, SEM = .95) and the group without pain (M = 12.20, SEM = 1.02), F (1, 28) = 3.13, p = .09, $\eta^2 = .10$, $BF_{10} = 1.10$.

Prefrontal Alpha Asymmetry

Results from the mixed ANOVA revealed that there was no main effect of group, [F (1, 28) = .19, p = .67, $\eta^2 = .007$, $BF_{10} = .342$], no significant effect of threat level, [F (1, 28) = .04, p = .85, $\eta^2 = .001$, $BF_{10} = .26$], and the interaction was not significant, [F (1, 28) = .05, p = .83, η^2 = .002, $BF_{10} = .10$]. Means and standard errors during low threat trials were as follows: group without pain (M = - .01, SEM = .10) and chronic pain group (M = .01, SEM = .10). Means and

standard errors during high threat trials were as follows: no pain (*M* = - .02, *SEM* = .10) and chronic pain (*M* = .05, *SEM* = .11) (Figure 3).

Frequency Band Analyses

During the presentation of low-threat stimuli, there was no significant difference in overall alpha band power between the chronic pain group and the group without pain, F (1, 28) = .60, p = .45, η^2 = .02, BF_{10}= .432. During the presentation of high-threat stimuli, the chronic pain group had significantly lower overall alpha band power overall than the group without pain, F (1, 28) = 6.76, p = .02, η^2 = .19, BF_{10}= 3.81 (Figure 4).

Single electrode analyses were run to determine which electrode regions were driving the overall difference between groups during high threat stimuli. To control for the family-wise error rate (multiple comparisons), the *p* value criterion was calculated as .05 (*p* value) / 9 electrode comparisons = .005. Using this correction, there were no significant differences between the groups at any electrode site: Poz (p = .03), Fz (p = .01), Cz (p = .04), P4 (p = .03), C3 (p = .14), C4 (p = .11), F3 (p = .07), F4 (p = .05), P3 (p = .06). Overall activity is presented in a topographical map for alpha band by group and threat level (Figure 5).

Study Two

The purpose of the second study was to replicate the first study and extend with the following improvements: (1) the number of EEG electrodes was increased from nine to 20, permitting a more in-depth EEG analysis, (2) the number of stimuli were increased, and an additional level of threat stimuli was added (moderate threat), and (3) survey questions regarding opioid use and physical activity were included.

Participants

Fifty-five individuals participated, and a total of 15 exclusions were made (due to technology issues, noise, and handedness), leaving 40 participants for analyses. Participants were asked to self-report the presence (n=18) or lack of chronic pain (n=22). Conditions reported included inflammatory pain, and back pain. Participants identified as American Indian or Alaska native (n=1), Asian (n=2), white (n=23), native Hawaiian or other Pacific Islander (n=1), and Hispanic or Latino (n=13). Demographics available in Table 2.

Materials

Psychometric Assessments

The Edinburgh Handedness Inventory and the McGill Pain Questionnaire short-form were administered. Participants were asked to report any medication(s) used to treat their pain condition, if present. Participants were asked questions about daily activities including miles walked per day, exercise (times per week), and level of activity during the work day. For the approach-avoidance task, three different stimuli combinations (threat levels) including low (low pain/high money), moderate (moderate pain/moderate money), and high threat (high pain/low money) were presented 25 times each for a total of 75 approach-avoidance stimuli presentations.

Equipment and Data Recording

Continuous EEG was recorded using the B-Alert x24 wireless EEG Device with 20 mono-polar electrodes (Figure 6) at a sampling rate of 256 Hz (mastoid leads as ground and reference).

Data Analyses

Analyses for the MPQ, approach-avoidance stimuli, and alpha band activity were computed as described in study one. Independent t-tests analyses were run to assess differences in daily activity between the chronic pain and group without pain. Prefrontal asymmetry (PFA) was calculated as the natural log of right side absolute alpha (F4; F8) - natural log of left side

absolute alpha (F3; F7). Higher scores reflect greater left frontal hemisphere activity. Analyses were not conducted to compare participants on medication use, because the number reporting medication use was too low (n=3).

Results

McGill Pain Questionnaire

Results from the mixed ANOVA indicated that there was a main effect of dimension, F (2, 76) = 283.65, $p < .001$, $\eta^2 = .84$, BF_{10}= 56.33. There was a main effect of group, F (1, 38) =18.03, $p < .001$, $\eta^2 = .32$, BF_{10}= 1.73. There was a significant interaction effect between dimension and group, F (2, 76) = 15.32, $p < .001$, $\eta^2 = .05$, BF_{10}= 37.75. Bonferroni post hoc analyses revealed that the chronic pain group (M = 18.11, SEM = 1.72) had significantly higher sensory dimension scores than the group without pain (M = 11.55, SEM = .23), $p < .001$. The chronic pain group (M = 5.50, SEM = .45) had significantly higher emotional dimension scores than the group without pain (M = 4.41, SEM = .16), $p < .001$. The chronic pain group (M = 2.39, SEM = .20) had significantly higher present pain intensity scores than the group without pain (M = 1.27, SEM = .12), $p < .001$.

Approach-Avoidance Behavior

The one-way ANOVA revealed that there was no significant difference in avoidance of approach-avoidance stimuli between the pain group (M = 105.33, SEM = 2.24) and the group without pain (M = 104.23, SEM = 1.88), F (1, 38) = .15, p = .71, $\eta^2 = .004$, BF_{10}= .33.

Prefrontal Alpha Asymmetry

Results from the mixed ANOVA for F3/F4 PFA revealed that there was no main effect of group, [F (1, 38) = 4.00, p = .05, $\eta^2 = .10$, BF_{10}= 1.29], no significant effect of threat level, [F (2, 76) = .88, p = .42, $\eta^2 = .02$, BF_{10}= .145], and the interaction was not significant, [F (2, 76) =

1.61, p = .21, η^2 = .04, BF_{10}= .187]. Means and standard errors during low threat trials were as follows: group without pain (*M* = - .01, *SEM* = .05) and chronic pain group (*M* = .19, *SEM* = .06), during moderate threat trials were as follows: no pain (*M* = .05, *SEM* = .05) and chronic pain (*M* = .14, *SEM* = .05), and during high threat trials were as follows: no pain (*M* = .02, *SEM* = .06) and chronic pain (*M* = .06, *SEM* = .05).

Results from the mixed ANOVA for F7/F8 PFA revealed that there was no main effect of group, [F (1, 38) = .01, p = .93, η^2 = .01, BF_{10}= .453], no significant effect of threat level, [F (2, 76) = 1.63, p = .20, η^2 = .04, BF_{10}= .279], and the interaction was not significant, [F (2, 76) = .41, p = .67, η^2 = .01, BF_{10}= .132]. Means and standard errors during low threat trials were as follows: group without pain (*M* = - .05, *SEM* = .10) and chronic pain group (*M* = - .08, *SEM* = .07), during moderate threat trials were as follows: no pain (*M* = - .06, *SEM* = .08) and chronic pain (*M* = - .03, *SEM* = .07), and during high threat trials were as follows: no pain (*M* = - .09, *SEM* = .07) and chronic pain (*M* = - .13, *SEM* = .09) (Figure 7).

Frequency Band Analyses

During the presentation of low-threat stimuli, there was no significant difference in overall alpha band power between the chronic pain group and the group without pain, F (1, 38) = 1.17, p = .29, η^2 = .03, BF_{10}= .49. During the presentation of moderate-threat stimuli, there was no significant difference in overall alpha band power between the chronic pain group and the group without pain, F (1, 38) = 2.11, p = .02, η^2 = .05, BF_{10}= .71. During the presentation of high-threat stimuli, the chronic pain group had significantly lower overall alpha band power than the group without pain, F (1, 38) = 1.83, p = .18, η^2 = .05, BF_{10}= .64 (Figure 8). Overall activity is presented in a topographical map for alpha band by group and threat level (Figure 9).

Daily Activity Questions

Results of the independent samples t-tests revealed no significant differences between the groups on any of the three activity questions which included: “How many miles do you walk per day?” [t (38) = .32, p = .75, BF_{10}= .32], “How many times do you exercise each week?” [t (38) = .58, p = .58, BF_{10}= .35], and “What is your level of activity during the work day?” [t (38) = .99, p = .33, BF_{10}= .46].

General Discussion

Previous researchers have extensively demonstrated that organisms will escape/avoid pain and move towards pain relief, yet people with chronic pain many not always have the option to avoid pain and may approach it to obtain a reward or satiate another drive. Oftentimes, constructs such as pain are more complex than what is typically measured in a laboratory. The effects of chronic pain on brain activity during approach-avoidance has not been well documented in humans. It is well known that science is considered to be in a “replication crisis” (Clayson et al., 2019). Therefore, we present the findings from two EEG studies with the same aim. Furthermore, there has been a call for a renovation in the field concerning the limitations of frequentist statistics (Clayson et al., 2019), which led us to include Bayesian statistics in our reporting.

In the present studies, participants were asked to approach or avoid stimuli that contained simultaneous competing goals (money and pain) at various levels of pain and reward. Like Fisher and colleagues (2016), results from both of our studies revealed that participants that reported chronic pain did not avoid approach-avoidance stimuli at a different rate than those without chronic pain. This finding could be explained by the motivational decision model of pain, which states that there are circumstances when reward is a more important drive to satiate than pain avoidance (Fields, 2004; Fields, 2007; Nees & Becker, 2017).

While an abundance of literature has indicated that approach is related to left hemisphere activity and avoidance is related to right hemisphere activity (Davidson 1990:1995), it was unclear if the well-documented reduction in alpha wave activity due to pain (Chang et al., 2002a, 2002b; Egsgaard et al., 2009; Jensen et al., 2013) would result in a lack of PFA during approach-avoidance. In both of the current studies, we found no evidence that PFA for approach-avoidance was influenced by the presence of chronic pain. In a rodent model, Schwartz and colleagues (2017) recently found that approach-avoidance for pain is regulated by activity in the infralimbic cortex and nucleus accumbens, and specific populations of neurons within each structure are activated during low or high reward. Future research should investigate whether the cortico-accumbens network underlies pain approach-avoidance in humans as well.

In both studies, during the approach-avoidance task of variable salience, people with chronic pain did not demonstrate significant differences overall in alpha band activity compared to those that did not report chronic pain. It should be noted that while in the first study, there was a significant difference between groups during high-threat stimuli, single electrode analyses with an applied correction did not yield any significant electrode drivers of that effect when an alpha criterion was applied. Furthermore, Bayesian analyses indicated that group differences were only 3.81 times more likely than the null hypothesis, which is considered only anecdotal evidence (Jarosz & Wiley, 2014). Albu and Meagher (2016) suggested that low power in the alpha band during pain indicates the affective response to pain, and these changes are predicted by pain catastrophizing. It is possible that the high threat trials in the current study do not incite pain catastrophizing at a level that generates meaningful changes in alpha band activity.

Future Directions

Consideration of motivational context is paramount in analysis of approach-avoidance paradigms. Money is a powerful secondary reinforcer. Future research will be aimed at continuing to unravel the approach-avoidance neural mechanisms that are relevant to cognitive and behavioral changes in participants with chronic pain for a variety of reinforcers. The broader impact of this research lies in the development of a body of literature to continue exploring the psychophysiology of pain, as a multidimensional, complex disruption of homeostasis. Preclinical animal research has failed many times to translate into effective clinical outcomes (Berge, 2011; Mao, 2009). One explanation may be that little is known about approach-avoidance conflicts when organisms are not able to choose to escape their pain or alleviate it. Ultimately, chronic pain patients may not be able to avoid their pain, and must make challenging evaluative decisions (Borsook et al., 2013; Harris, 2013; LaGraize et al., 2004), yet oftentimes cerebral psychophysiology studies are focused on escape of pain, resting state activity, or approach of relief.

Conclusion

To our knowledge, the current two studies are the first to investigate the cortical activity of PFA and alpha band activities in participants with chronic pain using EEG during pain approach-avoidance. Our conclusions are that PFA does not underlie approach-avoidance for pain, and participants with chronic pain do not demonstrate differences in PFA and alpha band activities during approach avoidance when compared to participants that do not report chronic pain.

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Declarations of Interest Statement

None. The authors declare no conflicts of interest.

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Appendix A

Table 1

Participant Demographics by Group for Study One

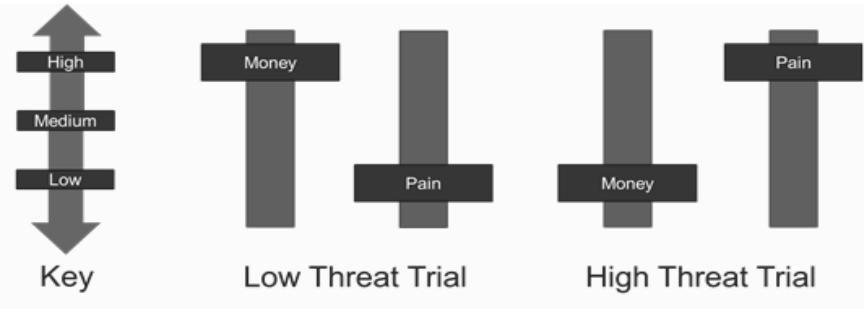
Group	n	Age	Gender
Chronic Pain	15	19-55 years (M = 25, SD = 8.87)	2 males 13 females
No Pain	15	20-55 years (M = 32, SD = 11.90)	2 males 13 females
Overall	30	19-55 years (M = 28, SD = 11.08)	4 males 26 females

Note. Demographics by group and overall including: frequency by group (chronic pain/no pain), range, standard deviation, and mean age of participants, and frequencies of gender. Chronic pain was classified as pain that lasted more than 12 weeks. Participants were asked to self-identify as having no history of a chronic pain condition (n= 15) or current chronic pain (n= 15). Conditions reported included inflammatory pain and back pain with unknown etiology. Participants identified as American Indian or Alaska Native (n= 1), White (n= 23), Black or African American (n= 1), and Hispanic or Latino (n= 5). The participants were recruited using flyers on campus or electronic flyers sent via email.

Appendix B

Figure 1

Sample High Threat and Low Threat Stimuli with Key

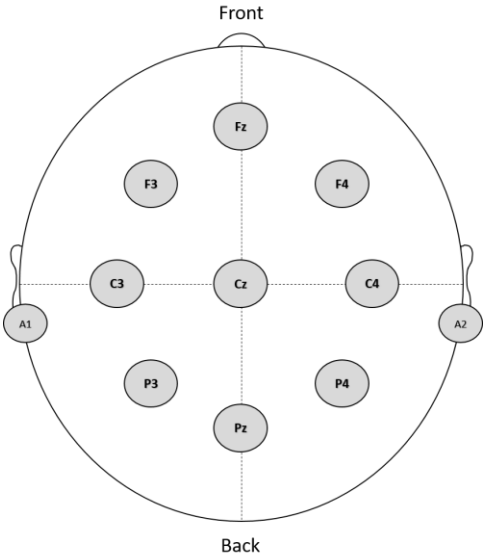


Note. Participants were presented with one stimulus at a time containing two meters and were instructed to choose to approach or avoid the scenario. One meter was assigned to pain (negative stimulus) and the other meter was assigned to money (positive stimulus). Meters varied in levels of pain and money (low or high) as depicted by the key on the left.

Appendix C

Figure 2

Location of Active Recording Electrodes for Study One

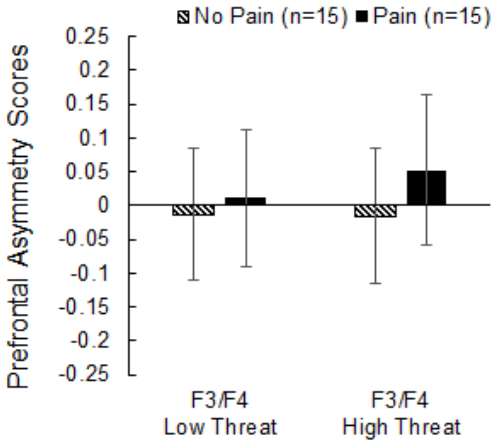


Note. Electrodes were located as Cz (center), C3 (left/lateral of center), C4 (right/lateral of center), Fz (front and center), F3 (left frontal), F4 (right frontal), POz (center temporal), P3 (left temporal), and P4 (right temporal). Ground and reference electrodes were placed on the mastoid bones behind the ears.

Appendix D

Figure 3

Prefrontal Alpha Band (8-13 Hz) Asymmetry Scores by Group for Study One

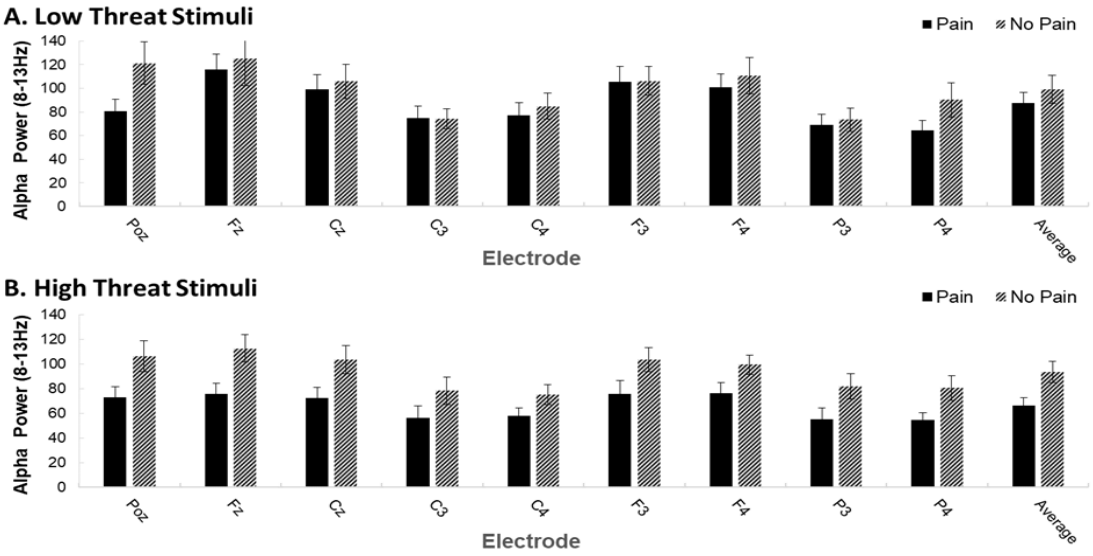


Note. Prefrontal Asymmetry was calculated as the natural log of right side absolute alpha (F4) - natural log of left side absolute alpha (F3). Higher scores reflect greater left frontal hemisphere activity. There were no group differences, $p > .05$.

Appendix E

Figure 4

EEG Alpha Frequency Band (8-13Hz) Power (μV2) by Threat Level and Group for Study One

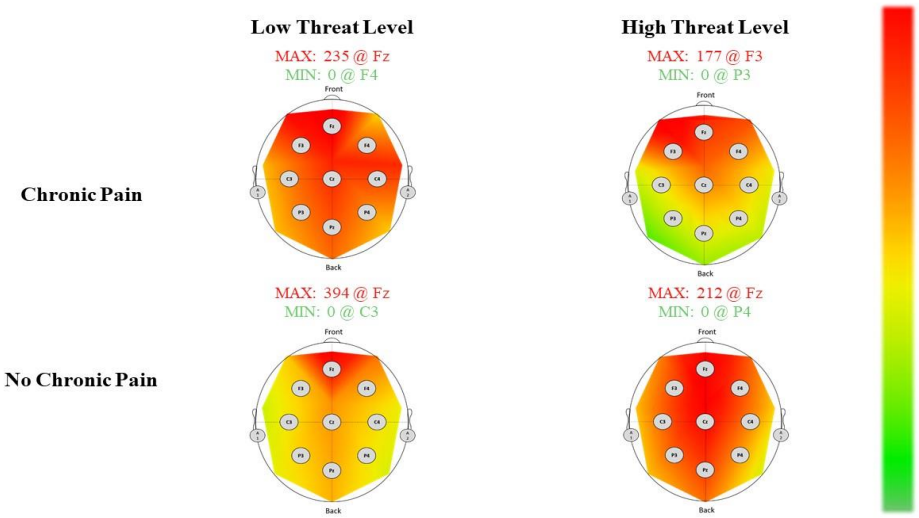


Note. Results of ANOVAs performed on fast fourier transform data by group (chronic pain/no pain) for the alpha frequency band power (μV^2). For low threat stimuli (A), there were no significant differences between groups. For high threat stimuli (B), the chronic pain group demonstrated significantly less alpha band activity overall, with anecdotal level Bayes support for the alternative hypothesis. Single electrode analysis did not reveal significant differences between groups when a *p* value correction for familywise error was applied (.005).

Appendix F

Figure 5

Alpha Band Topographical Map by Group and Threat Level



Note. Maximum and minimum activity are reported for each topography with the corresponding electrode location for study one.

Appendix G

Table 2

Demographics by Group for Study Two

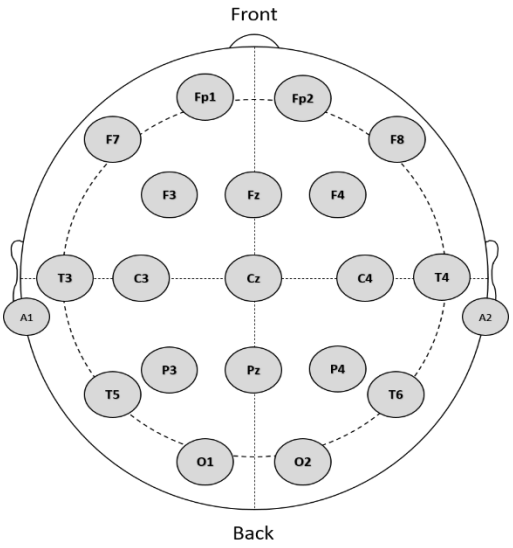
Group	*n*	Age	Gender
Chronic Pain	18	18-30 years (*M* = 22.2, *SD* = 4.04)	6 males 12 females
No Pain	22	18-29 years (*M* = 20.5, *SD* = 2.65)	3 males 19 females
Overall	40	18-30 years *(M* = 21.3, *SD* = 3.42)	9 males 31 females

Note. Chronic pain was classified as pain lasting more than 12 weeks. Participants were asked to self-identify as having no history of a chronic pain condition (*n*=18) or current chronic pain (*n*=22). Conditions reported included inflammatory pain and back pain with unknown etiology.

Appendix H

Figure 6

Location of Active Recording Electrodes for Study Two

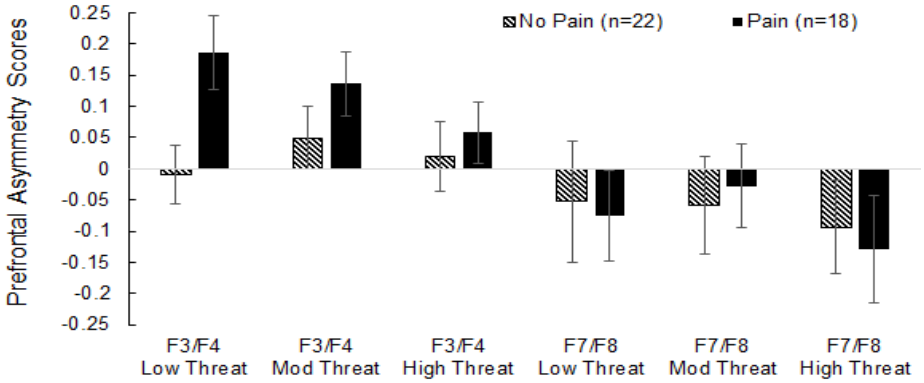


Note. Electrode locations are based on the international 10-20 system. Ground and reference electrodes were placed on the mastoid bones behind the ears.

Appendix I

Figure 7

Prefrontal Alpha Band (8-13 Hz) Asymmetry Scores by Group for Study Two

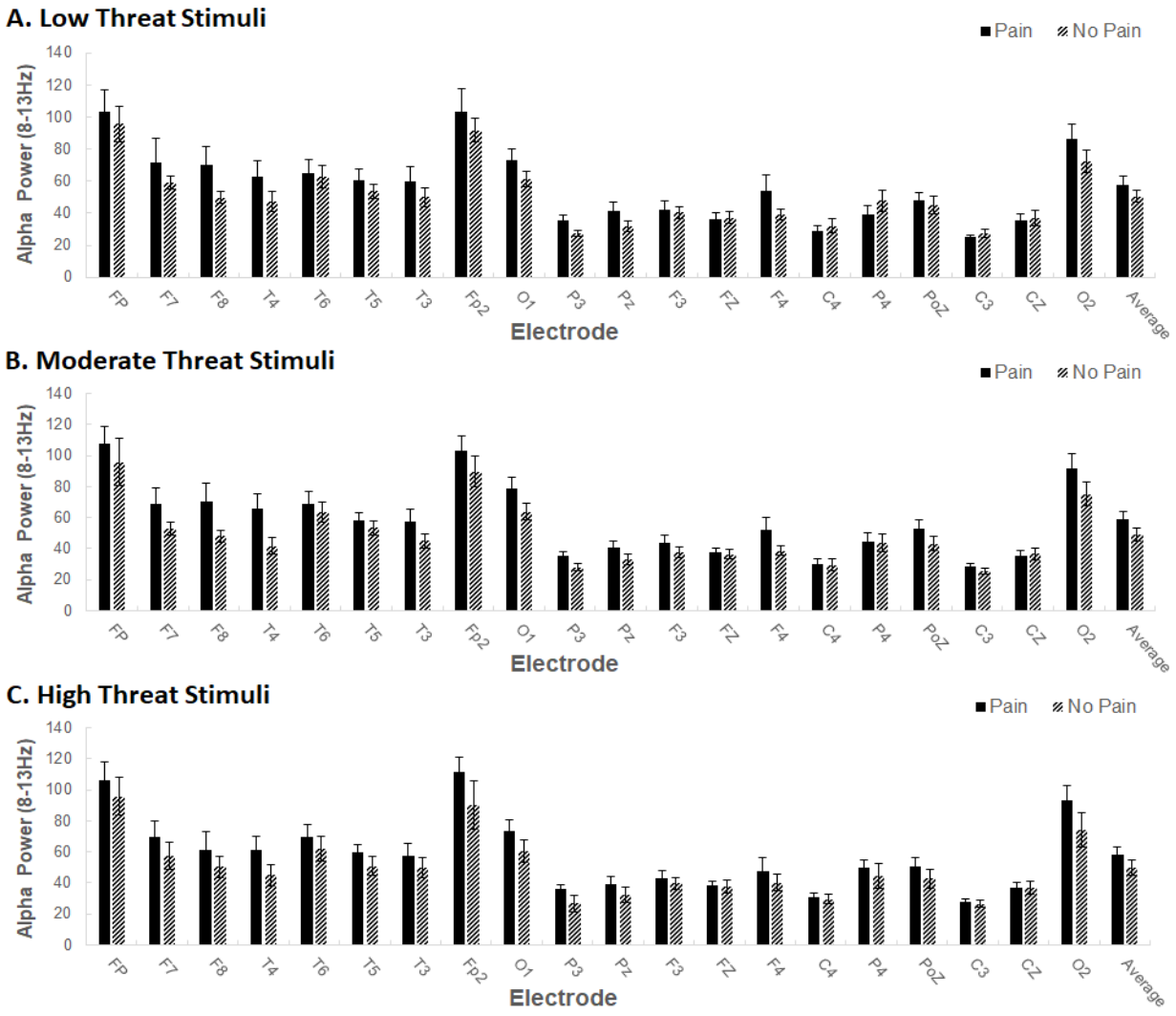


Note. Prefrontal asymmetry (PFA) was calculated as the natural log of right side absolute alpha (F4; F8) - natural log of left side absolute alpha (F3; F7). Higher scores reflect greater left frontal hemisphere activity. There were no group differences, $p > .05$.

Appendix J

Figure 8

EEG Alpha Frequency Band (8-13Hz) Power (μV2) by Threat Level and Group for Study Two

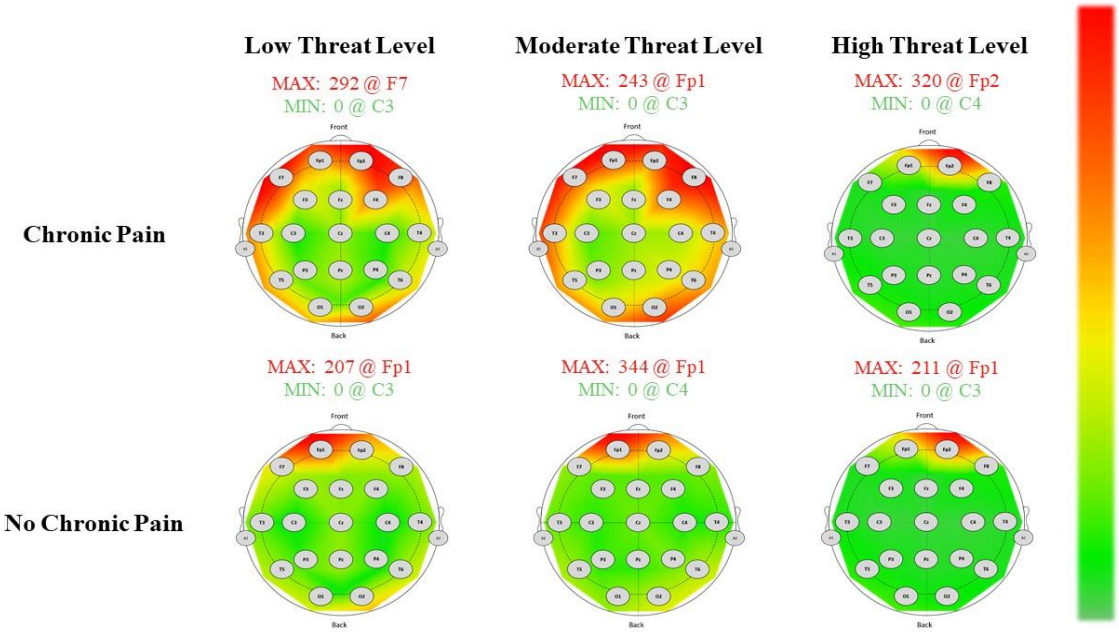


Note. Results of ANOVAs performed on fast fourier transform data by group (chronic pain/no pain) for the alpha frequency band power (μV^2) for low threat stimuli (A), moderate threat stimuli (B), and high threat stimuli (C). There were no significant differences between groups, $p > .05$.

Appendix K

Figure 9

Alpha Band Topographical Map by Group and Threat Level



Note. Maximum and minimum activity are reported for each topography with the corresponding electrode location for study two.