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Comparing Gamified Biofeedback and Visual Distraction for Acute Pain: Subjective and Psychophysiological Outcomes

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Abstract

Attentional distraction is an established strategy for reducing acute pain, yet relatively few studies have examined the psychophysiological correlates of gamified biofeedback interventions. This pilot study investigated whether gamified biofeedback tasks can modulate subjective and physiological responses to acute pain.

Twenty healthy adults participated in a within-subject experiment consisting of three successive pain conditions, induced by the Cold Pressor Test. The first trial used no intervention, followed by two gamified intervention conditions, presented in a counterbalanced order across participants. One used electrodermal activity (EDA) biofeedback with the Calm The Waves (CTW) system; the other used a visual search task designed to induce cognitive load. Seven participants had prior training in the CTW task (experts). Subjective pain intensity was assessed using a Numeric Rating Scale (NRS), and EDA was continuously recorded throughout each two-minute trial. Mixed-design repeated-measures analyses of variance (ANOVAs) were conducted to examine the effects of condition and prior CTW training.

Subjective pain ratings differed significantly across pain conditions, F (2, 36) = 11.41, $p < .001$, $\eta p^2 = .388$. Pain baseline M = 6.80 (1.10), pain with CTW M = 6.30 (1.90) and pain with Visual Task M = 5.40 (1.70). In contrast, mean EDA did not differ significantly across conditions, nor across participants' expertise status. These findings suggest that gamified interventions are associated with reduced subjective pain during acute pain exposure, while corresponding changes in average electrodermal activity were not evident. Both real-time physiological biofeedback and sustained cognitive engagement may contribute to acute pain modulation, although further research is needed to determine whether these effects translate into broader self-regulation skills. Future studies with larger samples and clinical populations should investigate whether dynamic EDA measures are more sensitive indicators of physiological changes associated with acute pain. These findings may contribute to the refinement of biofeedback training approaches for acute pain modulation.

Introduction

This article aims to explain the game elements in a novel Electrodermal Activity (EDA) Biofeedback tool, called Calm The Waves (CTW) and its effects on acute pain management. We combined gamification and EDA biofeedback in a pilot study of objective and subjective pain experiences with healthy adults.

Pain is one of the most common reasons why patients seek medical care, chronic pain prevalence rates fluctuate between 11% and 40% (Cohen et al., 2021). The Global Burden of Disease Study from 2010 states that musculoskeletal diseases such as low back pain are the highest disabling conditions. Therefore, developing effective pain management techniques is important (Blyth et al., 2019).

One of the first steps to successful pain treatment is effective pain assessment. Self-reported scales are commonly used, since the pain experience is subjective (Committee on Psychosocial Aspects of Child and Family Health & Task Force on Pain in Infants, 2001). Pain assessment is a broader concept than

pain measurement, since the latter relates to its intensity, whereas pain assessment takes into consideration the emotional and cultural components of the pain experience(Stinson et al., 2008). Nowadays, there is a growing interest in using more accurate measurements of pain levels, specifically for research purposes. Currently, the gold standard pain assessment tools are the self-report rate scales - Numeric Rate Scale and (NRS) and Visual Rate Scale (VRS) (Small & Laycock, 2020).

Pain experience is not necessarily associated with an injury, as postulated first by Beecher (1956). The current bio-psycho-social model on pain experience explains the phenomenon from the individual's perspective, highlighting several factors that may modulate the experience: e.g. culture, personality, level of cognitive development, and so forth (Twycross et al., 2008). Attention is involved in the cognitive aspects of pain, therefore, distraction from pain experience is one of the most endorsed techniques for acute pain management (M. H. Johnson, 2005). When directing the patient's attention to a concurrent stimulus, we can create distraction analgesia and ease the pain experience (Schreiber et al., 2014). The modulation of pain by distraction has its roots in the Pain Gate Theory, postulated by Melzack and Wall, in 1965.

Gamification originates from the digital media industry in 2008. It is defined as the use of game design elements in non-game contexts(Deterding et al., 2011). Regarding the non-game contexts, it can be understood as situations in which the game-based elements will be used for purposes other than enjoyment, such as learning, achieving health behaviors and so on. The literature points to three main outcomes from gamification: affective or motivational, cognitive and behavioral outcomes (Krath et al., 2021).

Gamification has been used as health care interventions in recent research, mostly in pediatric surgery contexts. This method has been described in the work of Rantala et al. (2020), and Rantala et al. (2022). The authors used gamification as a distraction from fear, anxiety, and pain management intervention during certain procedures. Despite their efforts to use a gamified experience to improve the hospitalization experience of children by reducing fear of hospitalization and pain, there are few limitations and a lack in the literature about the application of gamification in health settings as an intervention. In addition, there are criticisms of previous studies in gamification addressing behavior change, as they are often rooted in extrinsic motivation elements, and don't address intrinsic motivation elements (Johnson et al., 2016).

Biofeedback is a technique that enables a person to self-regulate, increase awareness and gain control over body and mind through a process in which their physiological responses, such as electrodermal activity (EDA), heart rate variability, blood pressure, skin temperature, brain electrical activity among others are provided to them as an external feedback (Yucha& Montgomery, 2008). Therefore, combining Biofeedback with gamification is a strategy to tackle the intrinsic motivation elements often lacking in previous serious games. In our study, we applied Calm the Waves (CTW) EDA Biofeedback for emotion regulation and a visual search game. CTW has been used previously as a validated strategy to increase effortful control and self-awareness in adults and children (Szekely & Veres, 2023).

Considering the theoretical background, the main hypothesis of the present study is that effortful control through biofeedback and distraction induced by cognitive load reduce subjective pain. We hypothesize that even if EDA levels increase, subjective pain ratings will not necessarily show a corresponding increase, since the subjective experience of pain may be modulated independently of changes in physiological arousal. Furthermore, we hypothesize that gamification may increase pain tolerance. To test these preregistered hypotheses (https://doi.org/10.17605/OSF.IO/BGMY7), we applied two tasks—a biofeedback task requiring effortful control and a visual search task requiring sustained cognitive engagement—while participants were exposed to a painful stimulus. We included both participants trained in the CTW biofeedback task (experts) and those without prior CTW training (beginners) and hypothesized that prior CTW training would enhance pain modulation. The four-week training program included weekly group sessions for practice and discussion, as well as individual biofeedback exercises at home, with a suggested frequency of at least three sessions per week, each lasting 10–15 minutes.

Method

Ethics declaration

The research was approved by the Research Ethics Committee of the Faculty of Education and Psychology at ELTE under license number 2022/621. Informed consent was taken from all the participants, and the data was processed according to the GDPR as well as the research was conducted in accordance with the Helsinki Declaration. The study was registered on Open Society Foundation - OSF under the registration DOI: https://doi.org/10.17605/OSF.IO/BGMY7.

Participants

Participants were reached through advertisements spread online among English-speaking communities and through courses at Eötvös Loránd University (ELTE), Budapest. To be eligible to participate in the study, the participants had to be at least 18 years old; not being diagnosed with chronic pain diseases and without acute pain complaints; not under usage of any kind of analgesic; and not scoring with moderate or severe anxiety in the GAD − 7. Two of the 22 participants were excluded, since one didn't meet the inclusion criteria by the time of the experiment and another due to invalid EDA measurement. From the 20 participants with valid data, 68% were female, 63% of the participants were between 18 and 24 years of age and 37% were older. Regarding prior CTW training participants, 63% of them were beginners (with no previous biofeedback training or some biofeedback training), and 37% of them were experts (had completed at least three weeks of CTW training before participation).

Design and Procedure

The study employed a within-subject design, with each participant completing an individual session lasting approximately 45–60 minutes. After providing informed consent, participants completed the

questionnaires, and the Obimon EDA measurement system was set up. Participants then rested with their eyes closed and were familiarized with the Calm The Waves (CTW) biofeedback task, as some participants had no prior experience with the procedure.

Participants subsequently completed three Cold Pressor Test (CPT) trials: a control trial without an additional task, a biofeedback trial, and a visual search trial. The control trial was always administered first, while the order of the biofeedback and visual search trials was counterbalanced across participants. After each CPT trial, participants dried their hands, and the next trial began only after they reported that any residual discomfort had subsided.

Trial 1: Cold Pressor Test control condition

Participants were instructed to immerse their hand in the cold-water tank for up to 2 minutes without performing any additional task or receiving feedback. Following the trial, they rated their pain intensity on a Numeric Rating Scale (NRS) ranging from 0 to 10.

Trials 2 and 3: Gamified intervention conditions

The biofeedback and visual search conditions were administered in a counterbalanced order across participants.

Biofeedback task: Calm The Waves biofeedback using Obimon EDA

Participants first performed the CTW biofeedback task without the cold pressor stimulus. EDA was measured using the Obimon system and provided as input to the CTW biofeedback software. The task required participants to reduce their physiological arousal, with successful regulation represented visually by the growth of a virtual tree. Participants then performed the same task while undergoing the CPT for up to 2 minutes. Following the trial, pain intensity was assessed using the 0–10 NRS.

Visual search task: searching for hidden objects

Participants first performed a visual search task in which they searched for hidden objects within complex images presented on a screen. After an object was found, a new image was presented, and the number of successfully identified objects was recorded. Participants then performed the task again using a different set of images while undergoing the CPT for up to 2 minutes. Following the trial, pain intensity was assessed using the 0–10 NRS.

Materials

For EDA data collection, we used the Obimon device (Kasos et al., 2019, 2020) and the Calm The Waves (CTW) software (Szekely & Veres, 2023). This technology is designed to collect real-time responses from the user, while performing an effortful emotional regulation task, and provide real-time feedback on emotion regulation. The electrodes were placed in the participant's index and middle fingers, and the device was connected to a laptop via Bluetooth.

In the Cold Pressor Test (Lovallo, 1975), a tank was filled with iced cold water, pumps were placed in the interior of the tank to keep the water moving, and the temperature was measured by an electronic thermometer to ensure its constancy between 0°C-2°C.

To collect demographic information such as gender, age, height, a questionnaire was used. In addition, the General Anxiety Questionnaire – 7 (GAD-7) was used to rate anxiety symptoms, and participants that reached moderate or severe anxiety symptoms were excluded. To assess fear of pain, the FPQ - Fear of pain questionnaire was used.

Statistical analysis

The raw EDA data collected from the different trials was treated with threshold rules to clear artifacts. Therefore, variations of more than 300 NanoSiemens were excluded as well as evident artifacts from sudden drops of missing data.

For statistical analysis, raw EDA data was averaged and analyzed in a mixed ANOVA (3x2) in which the repeated condition was the pain stimulus as a baseline, and while performing the CTW or Visual Task, and the between groups were experts and beginners (untrained participants in CTW).

The EDA outcome from the pain stimulation is called objective measurement, while the NRS value reported after every trial is considered the subjective outcome. Both combined with the description of their experience during the experiment are called pain experiences. To test the hypothesis that the intervention would reduce pain, we ran a mixed ANOVA (3x2) in which the repeated measurement was the reported pain during the pain baseline, and while the CTW and Visual Task under pain conditions. The valid data was analyzed using SPSS, version 29.

Pain reduction was operationalized as the within-subject difference between the subjective pain rating obtained during the baseline pain condition and the corresponding rating obtained during each intervention. Specifically, pain reduction scores were computed as Baseline Pain – CTW Pain and Baseline Pain – Visual Search Pain. Positive values reflected greater reductions in perceived pain relative to the pain-only condition, whereas values close to zero indicated lower variations on pain perception. These difference scores were subsequently entered into exploratory Pearson correlation analyses with psychological questionnaire measures.

Results

Pain responses were assessed using subjective pain ratings (NRS) and electrodermal activity (EDA).

Subjective Pain Ratings

Subjective pain intensity was measured immediately after each condition using a Numeric Rating Scale (NRS), where 0 indicated no pain and 10 indicated unbearable pain. We hypothesized that both gamified conditions, the Calm the Waves (CTW) biofeedback task and the Visual Search Task (VT), would decrease subjective pain intensity relative to the pain-only condition. As shown in Table 1, participants reported the highest pain intensity during the pain-only condition (M = 6.80, SD = 1.10). Pain ratings were lower during the CTW condition (M = 6.30, SD = 1.90) and lowest during the Visual Search Task (M = 5.40, SD = 1.70), suggesting that both gamified interventions reduced the subjective experience of pain, with the distraction task producing the greatest reduction.

Subjective pain ratings were positively correlated across conditions, including baseline and CTW (r = .83, p < .001), baseline and the Visual Search Task (r = .62, p = .004), and CTW and the Visual Search Task (r = .65, p = .002), suggesting consistent individual differences in pain sensitivity.

Subjective pain ratings differed significantly across the three experimental conditions. A mixed repeated-measures ANOVA revealed a significant main effect of condition, $F(2, 36) = 11.41$, $p < .001$, $\eta p^2 = .388$, indicating that pain intensity varied as a function of the intervention. Neither the main effect of group, $F(1, 18) = 0.74$, $p = .402$, $\eta p^2 = .039$, nor the interaction between condition and group, $F(2, 36) = 0.69$, $p = .506$, $\eta p^2 = .037$, was statistically significant.

Table 1
Descriptive statistics (mean ± SD) for electrodermal activity (EDA) and subjective pain ratings across the three experimental conditions (N = 20).

Condition	Mean EDA (SD)	Rated Pain (SD)
Baseline Pain	10,113 (8,767)	6.80 (1.10)
CTW + Pain	9,055 (6,442)	6.30 (1.90)
VisTask + Pain	8,846 (7,931)	5.40 (1.70)

Figure 1 presents the electrodermal activity (EDA) trajectories of individual participants across the three experimental tasks. Because participants differed substantially in their baseline skin conductance levels, the figure emphasizes within-subject changes rather than between-subject comparisons. Across participants, the initial baseline task generally showed the lowest EDA levels. The introduction of the cold pressor test was associated with an increase in electrodermal activity for most participants, reflecting heightened sympathetic activation during pain. During both pain modulation conditions, EDA typically declined over the course of the 2-minute task, although values generally remained above baseline levels. This pattern was observed for both the Calm the Waves (CTW) biofeedback task and the Visual Search Task (VT). As the order of the CTW and VT conditions was counterbalanced across participants, the

similar trajectories observed in these two conditions are unlikely to reflect a systematic order effect. Mauchly's test indicated that the assumption of sphericity was violated, $\chi^2(2) = 23.20$, $p < .001$. Therefore, Greenhouse-Geisser corrections ($\varepsilon = .573$) were applied. A mixed repeated-measures ANOVA revealed no significant main effect of condition on mean EDA, $F(1.15, 20.64) = 0.09$, $p = .798$, $\eta p^2 = .005$. Likewise, neither the interaction between condition and group, $F(1.15, 20.64) = 1.81$, $p = .194$, $\eta p^2 = .091$, nor the main effect of group, $F(1, 18) = 0.03$, $p = .872$, $\eta p^2 = .001$, reached statistical significance.

Fear of Pain Questionnaire – FPQ and GAD – 7

The sample had a mean total Fear of Pain Questionnaire (FPQ) score of *M* = 73.30 (*SD* = 13.06). Mean scores for the FPQ subscales were *M* = 31.80 (*SD* = 8.90) for Severe Pain, *M* = 18.75 (*SD* = 3.22) for Minor Pain, and *M* = 24.75 (*SD* = 6.61) for Medical Pain.

Participants with prior CTW training obtained a mean FPQ score of *M* = 76.83 (*SD* = 9.62), whereas participants without prior CTW training scored *M* = 74.64 (*SD* = 14.56). An independent-samples t-test indicated no significant difference between the groups, $t(18) = 0.34$, $p = .741$.

For the Generalized Anxiety Disorder-7 (GAD-7) questionnaire, participants had a mean score of *M* = 4.20 (*SD* = 2.06), indicating generally low levels of anxiety. Participants with prior CTW training obtained a mean score of *M* = 4.60 (*SD* = 1.96), compared with *M* = 4.00 (*SD* = 2.14) among participants without prior CTW training. This difference was not statistically significant, $t(18) = 0.65$, $p = .523$.

Pearson correlation analyses were conducted to examine the association between anxiety symptoms (GAD-7) and subjective pain ratings across the three experimental conditions. No significant correlations were observed between GAD-7 scores and pain ratings during the baseline condition ($r = -.03$, $p = .903$), the CTW condition ($r = -.10$, $p = .689$), or the Visual Search Task ($r = -.22$, $p = .362$), indicating that anxiety symptoms were not associated with perceived pain intensity in this sample.

Pain reduction

Exploratory Pearson correlation analyses were conducted to examine whether dispositional fear of pain was associated with the magnitude of pain reduction during the CTW and Visual Search conditions. No significant associations were found between FPQ total scores and pain reduction during the CTW condition ($r = -.03$, $p = .890$) or the Visual Search Task ($r = .04$, $p = .863$). Furthermore, the magnitude of pain reduction achieved in the CTW and Visual Search conditions was not significantly correlated ($r = .25$, $p = .292$).

Discussion

This pilot study examined whether two gamified interventions, CTW biofeedback and a Visual Search Task, modulated subjective and physiological responses to acute pain. Three principal findings emerged. First, subjective pain ratings differed significantly across conditions, with the Visual Search Task

producing the lowest pain ratings. Second, while large individual variability of EDA levels and trajectories were present, mean EDA did not differ significantly between conditions.

Despite relying on different mechanisms, both interventions shared several gamification elements, including sustained engagement, goal-directed behavior, and continuous interaction. These shared features may reduce attentional resources available for nociceptive processing, consistent with attentional models of pain modulation. These features are considered core components of gamification and are known to increase cognitive engagement (Krath et al., 2021). Consequently, both interventions may have reduced the attentional resources available for processing nociceptive input, thereby decreasing the subjective experience of pain.

According to the Pain Gate Theory, the modulation of pain occurs in the dorsal horn in the spinal cord (Melzack& Wall, 1965). Our assumption was that even if there's an observed increased arousal, the pain experience can be less severe with the effect of distraction. We based this assumption on the fact that it is not the stimulus itself that is modulated or decreased, but the process of transferring the signals to the sensorial regions in the cortex. In other words, the person while under the painful stimulus gets distracted, thus does not focus their attention on the unpleasant stimulus. Although both interventions may engage in attentional distraction, CTW differs fundamentally from the Visual Search Task because participants receive continuous information about their physiological state. Rather than merely diverting attention from pain, CTW encourages active regulation of autonomic arousal through biofeedback. Thus, the comparable outcomes observed in the present study suggest that, during an acute pain challenge, sustained engagement alone may be sufficient to reduce pain perception, whereas the unique contribution of physiological self-regulation may require longer training periods or repeated practice to emerge.

The main concepts for gamification proposed by Krath, Schurmann, and von Korflesch (2021) are the affective or motivation, cognitive and behavioral elements. The affective or motivational elements in the Calm the Waves are the task itself that is presented as a challenge: to make your waves flat by managing your emotions and thoughts. Then comes the next level in which the task consists of making a tree grow, by controlling arousals. The tree itself works as a reward, as the participant can receive that image as a product of their self-regulation. The cognitive elements relate with the explanation of the task, that in the first moment, can be a challenge to be understood as to have a wave that moves according to the way you feel is, usually, not a common experience. In addition, after some practice, the participants can realize that if they get distracted with intrusive thoughts or emotional variation, the waves will start to move again. As for the third element, the behavioral ones, the participants receive an instruction to avoid moving, as it may interact with their waves, and the main outcome is a clear relaxation response. In addition, after finishing the task, participants receive different types of feedback on their performance, such as a color-coded bar showing red as an increasing arousal, yellow when the arousals are kept at a same level, and finally, green when arousals are decreasing; these results are stored as points called relax points, control points and balance points, that will indicate in which level the participant is in the training.

Applying the same concepts to hidden objects task, the affective and motivation can be described as the challenge that the game proposes: to screen the image and look at the object in the clustered image. Once the participant finds an object, a new image comes with it getting more challenging. This relates with the emotional aspect, as by finding the object the participants could experience a spectrum of feelings such as surprise, frustration, and so forth. The behavioral outcome of the task is staying still looking at the images for 2 minutes, and particularly in this case, the possibility of keeping the hand in the water for longer.

Although participants reported lower pain during the gamified interventions, mean EDA did not differ significantly across conditions. Electrodermal activity reflects sympathetic arousal rather than pain intensity alone and is influenced by cognitive effort, emotional engagement, novelty, and attentional processes. Consequently, reductions in subjective pain may occur without corresponding differences in average tonic EDA. A few other elements may be worth mentioning as reasons why the biofeedback task wouldn't outperform the visual task such as this was a pilot study including only 20 participants, results should be carefully interpreted as they may not be generalizable broadly, as well as the proportion of experts and untrained participants were heterogeneous. Furthermore, because the sample consisted exclusively of healthy adults, emotional regulation and pain modulation may have been comparatively easier than would be expected in clinical populations.

Contrary to our initial hypothesis, participants with previous CTW training did not differ significantly from beginners in either subjective pain ratings or mean EDA. Nevertheless, exploratory visual inspection of the individual EDA trajectories suggests that experienced participants tended to exhibit smoother physiological responses and fewer abrupt fluctuations during both CTW and the Visual Search Task. These observations may reflect a greater ability to maintain stable autonomic regulation, potentially acquired through previous biofeedback training. However, because these patterns were not quantified statistically, they should be interpreted cautiously and considered hypothesis-generating rather than confirmatory. Future studies with larger samples and dedicated analyses of EDA dynamics, such as slope, variability, or the frequency of phasic responses, could determine whether prior biofeedback training promotes more stable physiological regulation even when average arousal levels remain unchanged. This interpretation is consistent with the theoretical aim of CTW, which is to strengthen effortful control and emotion regulation rather than simply reduce overall arousal. Consequently, the benefits of training may be reflected in the stability and adaptability of physiological responses instead of lower average EDA values.

Exploratory correlational analyses further suggested that individual differences in generalized anxiety and fear of pain did not substantially influence the observed intervention effects. Neither GAD-7 scores nor dispositional fear of pain, as measured by the FPQ, were significantly associated with subjective pain ratings or with the magnitude of pain reduction achieved during either the CTW or Visual Search conditions. These findings should be interpreted in the context of the study sample, which consisted of psychologically healthy adults, with participants presenting clinically relevant anxiety symptoms excluded during recruitment. Consequently, the restricted variability in anxiety and pain-related fear may

have reduced the likelihood of detecting meaningful associations between these psychological characteristics and pain outcomes. Nevertheless, the absence of these relationships suggests that the analgesic effects observed in the present study were not primarily driven by differences in generalized anxiety or fear of pain. Previous research has demonstrated stronger associations between anxiety, pain-related fear, and pain perception in clinical populations or individuals with elevated psychological distress (Vlaeyen& Crombez, 2020). Future studies should therefore examine whether gamified biofeedback interventions produce differential benefits among populations characterized by higher levels of anxiety, pain-related fear, or pain catastrophizing.

The present findings suggest that gamified engagement itself may represent an important mechanism underlying acute pain modulation. However, unlike conventional distraction tasks, CTW integrates real-time physiological feedback that encourages users to actively regulate their autonomic state. Although this additional component did not confer a measurable short-term advantage in the present study, it may facilitate the acquisition of transferable self-regulation skills that become increasingly relevant with repeated training or in clinical populations.

Conclusion

The present findings suggest that gamified interventions are associated with reduced subjective pain during acute pain exposure. Although CTW did not demonstrate a measurable short-term advantage over a gamified visual distraction task, it may represent a promising biofeedback strategy for acute pain management by promoting effortful control and self-regulation. Larger studies are needed to determine whether CTW provides additional benefits beyond cognitive distraction alone, particularly following longer training periods or in clinical populations.

This study contributes to the growing body of research exploring the integration of electrodermal activity (EDA) biofeedback and gamification for pain management. Building upon theoretical frameworks such as the Pain Gate Theory and the neuromatrix model of pain (Melzack, 1999), our findings support further investigation of innovative, non-pharmacological approaches to pain modulation, particularly given the substantial global burden of pain conditions.

Finally, it is important to emphasize that the observed changes in electrodermal activity should be interpreted as reflecting sympathetic activation associated with the painful task rather than as a direct measure of pain itself. Future research should investigate whether more dynamic EDA indices, such as response variability or trajectory characteristics, provide greater sensitivity to the effects of biofeedback training than mean EDA alone.

Limitations

This is a pilot study with several limitations. The most prominent one was the recruiting of participants for a pain study, even though it was openly mentioned that the cold water doesn’t cause any harm. It is important to mention the intrinsic limitations that come with a within subject design - the learning or

habituation effect, to highlight the most relevant in our study. It seems that after the second trial a habitation effect took place, and it might have affected the pain self-report. Additionally, the relatively small sample size reduced statistical power, particularly for detecting interaction effects and individual-difference correlations. All these limitations, on the other hand, open a prominent venue for further studies also with clinical population under painful procedures, for example.

Further directions

This pilot study, with a within subject, opens possibilities for further explorations, using different designs, such as control trials and recruiting population with pain conditions. Other measurements might provide interesting results, such as gender, cultural and other individual differences in pain, deeper exploration of emotional and cognitive aspects such as anxiety and fear of pain, to cite a few.

Declarations

Conflict of interest statement

András Veres is the developer of the Calm the Waves (CTW) biofeedback system used in this study. The remaining authors declare no competing interests.

Declarations

Competing Interests

V.A. is the developer of the Calm the Waves (CTW) biofeedback system used in this study. The remaining authors declare no competing interests.

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No funding was received for this research.

Author Contribution

A.M.D.V. wrote the main manuscript text, conducted data analysis, prepared table 1. S.A. Reviewed manuscript, prepared figure 1 and supported data analysis. V.A. Reviewed the manuscript, supported data extraction and EDA data extraction. S.S. Reviewed manuscript, extracted EDA data and conducted initial data treatment.

Data Availability

Data is available at OSF (https://doi.org/10.17605/OSF.IO/BGMY7)

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Figures

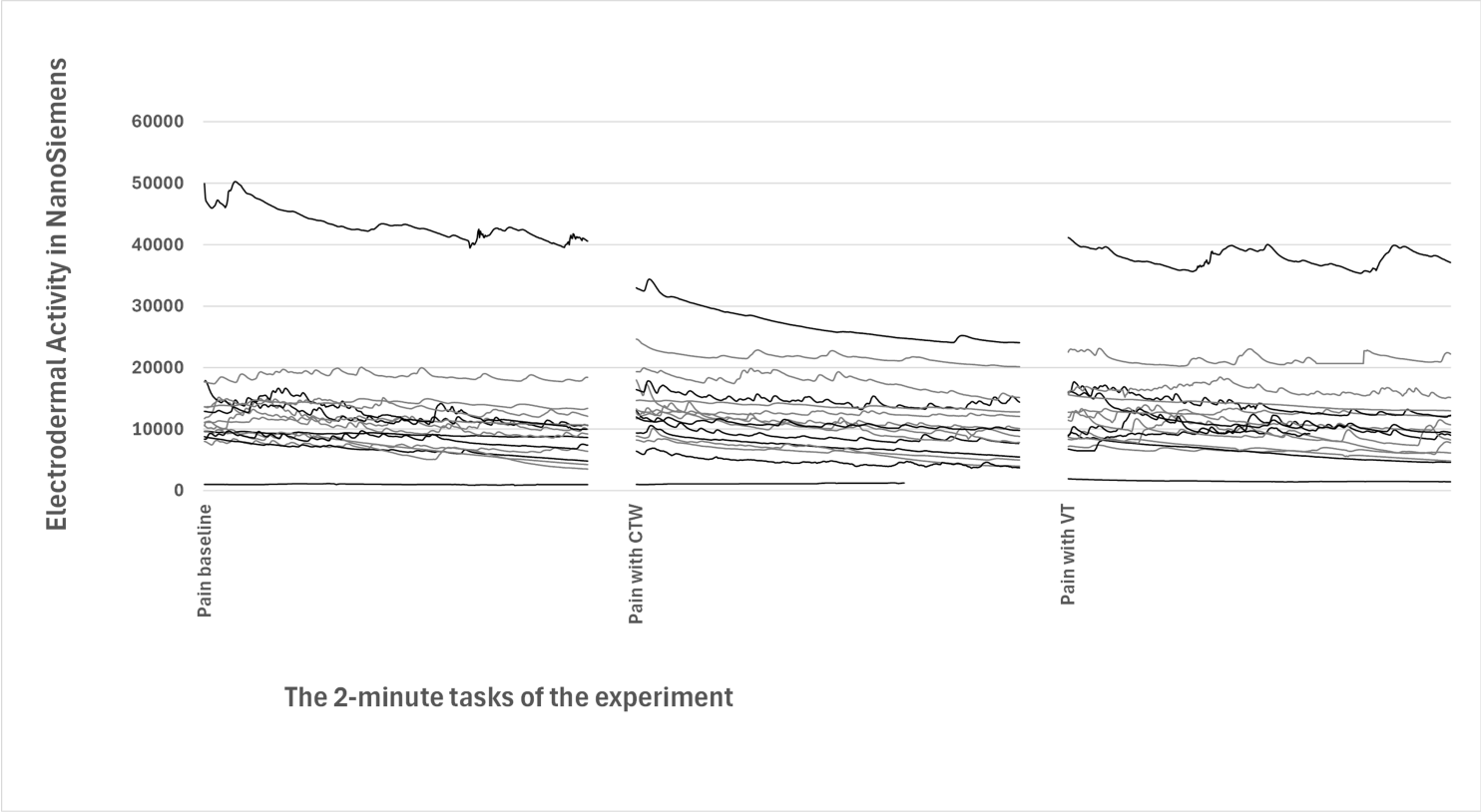


Figure 1

Individual electrodermal activity trajectories across the three experimental conditions. Each line represents one participant. Conditions were completed by each of the 20 subjects, with CTW and Visual Search tasks counterbalanced.