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# The effect of threat on attentional interruption by pain

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## Introduction

There is a growing consensus surrounding the importance of attentional processes in pain [6]; [15]. Pain functions to warn of potential danger and promote analgesic behaviour in oneself and from others. A reason for this interference effect is because attention has limits [11]; [17]; [26]. When competing demands are presented preferential selection occurs, and this is usually towards pain [33].

Although studies show that task performance deteriorates under painful conditions [4]; [7]; [8], such effects are not always found, and can depend on task-related factors [2]; [35]. For example, when measuring attention span, Bingel, et al. [2] found an effect of laser-induced pain on a more complex 2-back task, but not the 1-back task. To help explain this discrepancy, Legrain et al. [15] suggest that there is a range of influences, including top-down motivational characteristics (e.g., avoidance of harm and threat value) as well as bottom-up characteristics of the stimulus (e.g., intensity and novelty). Bottom-up factors are proposed to alert a person to the salience of pain and top-down factors to control pain. The question now turns to identifying under which conditions pain interference is more likely to occur.

One line of research has been to investigate whether there are certain tasks that are more or less susceptible to pain-related interference. Moore et al. [25] found that heat-induced pain affected performance on complex tasks such as divided attention, switching and attention span, but not on simpler tasks such as those involving continuous performance. One explanation is that these more complex tasks reflect a general attentional deficit. An alternative explanation is that tasks which require more complex, executive-like, demand show the greatest interruption effect from pain. Indeed, Miyake et al. [22] suggested that executive function is made up of shifting/switching (i.e. switching task), inhibition and updating (i.e. n-back task). These are exactly the higher order cognitive functions implicated in attention to pain [8,14].

Although higher-order executive-like tasks seem to be vulnerable to pain interference effects, it is likely that other contextual factors may increase or decrease this vulnerability. For example, if a person finds themselves in a threatening situation then the presence of threat can increase susceptibility to pain interference [5]; [14]; [30]; [31]. The threat of pain differs from the sensation of pain by adding psychological distress to nociception and can operate in the anticipation of pain as well as the presence of it. It is possible therefore that pain-related interference of executive-type tasks may be particularly pronounced under conditions of high threat. The aim of the current study was to examine whether situational threat moderates pain-related interference on executive-like cognitive tasks. We sought to address this question by employing similar cognitively demanding tasks to those used previously [25], and combine them with an experimental manipulation of mild pain related threat used in previous studies [14]; [33]. We hypothesised that pain will have a significant interference effect on these tasks, and threat will increase this interference effect.

## Methods

### *Design*

In a mixed-groups design participants were assigned randomly to either a threat condition or a control condition. After randomisation all participants completed three cognitive tasks on two occasions: once while experiencing a mild painful sensation, and once without a pain sensation (control). The dependent variables were performance indicators (e.g., reaction time, accuracy) derived from the three tasks.

*Participants*

Fifty adult participants (21 male) were recruited into the study from the University of Bath staff and student population. Their mean age was 22.06 (SD=5.35). Participants reported that they were not currently in pain, had no existing chronic pain condition, and were not taking analgesic medication. Participants also reported no skin complaints or sensitivity, and all were paid a modest sum for participation.

*Attention tasks*

Three tasks were used in the current study, all of which were drawn from those used in a previous study [25]. The tasks were designed and controlled using E-Prime II professional software [29]. Stimuli were presented on a Iiyama prolite B1902S TFT monitor, which was powered by a Viglen genie desktop computer with a 3GHz Pentium Intel Core 2 duo processor and 2Gb of RAM. Responses were made using a PST model 200a serial response box. The three tasks were as follows:

*Attention span task:* Attention span is the amount of information that can be processed at any one time [16]. The n-back task was used, as it measures attention span by asking participants to indicate if a current stimulus matches one presented previously. Participants were presented with a stream of 90 letters, each for 500ms, followed by a 1500ms blank screen. Participants' task was to report whether the current letter matched the letter presented two letters previously. Participants pressed one key if the letter was the same, and another if the letter was different. There were 30 target stimuli presented and 60 non-target stimuli randomly distributed through the task, and the task lasted approximately 3 minutes. The outcome variables for the n-back task were the number of correctly identified targets (hits), number of missed targets (misses), number of times non-targets were identified as targets (false alarms) and the number of non-targets correctly identified (correct rejections). In the current study the n-back task was considered to be a measure of attention span related to executive functioning [3; 18]. Although the n-back task is also used as a measure of working memory (e.g., [10; 12]) and may involve some of these components, the correlation between the n-back task and other working memory measures has been shown to be low (e.g., [9; 13]).

*Attentional switching task:* Attentional switching is the process of alternating between multiple separate attentional tasks. Responses after task switches are typically slower and less accurate than task repetitions. These *switch costs* reflect an aspect of executive control processing, with some suggesting that task-switch costs in response time (RT) reflect the duration of an executive control process [20]; [23]; [28]. The present switching task is based on that of a previous study [1] in which a simple single digit is presented to participants who have to classify this as higher or lower than 5 or odd/even depending on secondary cues. This was conducted using a task-cueing paradigm [20] in which participants are cued to which task to perform on each trial. The task cueing approach was developed as an alternative to predict sequence task switching (i.e. AABBAABB). There is some evidence that using random trial orders as in the task-cueing paradigm can result in greater switch costs than using predictable runs [24].

In the current task, participants were presented with single digit numbers (1, 2, 3, 4, 6, 7, 8, 9) which occupied .7$^{0}$ of visual angle on the screen. On some trials participants indicated whether the number was odd or even, whereas on other trials they indicated whether the number was greater or less than 5. A response box was used to collect responses, which consisted of five buttons, numerically labelled one through to five. Participants were asked to press the 'one' key on the response box if the number was odd, and the 'five' key if the number was even. In the 'high vs. low' task they pressed the 'one' key if the number was less than 5, and the 'five' key if the number was greater than 5. For each trial, the task could either remain the same as the one just completed, or randomly switch to the alternative task. A priming screen was presented for 500ms, before the presentation of the numbers, which indicated how participants should respond (odd/even or high/low). Target stimuli were presented to participants until response. A total of 200 trials were presented, with a total duration of approximately 6 minutes. The outcome variables for this task were reaction time and accuracy.

*Divided attention task:* Divided attention is the ability to process more than one source of information simultaneously [38]. The divided attention task used in the current experiment was based on one previously used in a study of the effects of alcohol on divided attention [21]; [25]. Participants were presented with a display consisting of a central number and two lines which could be either horizontal or vertical in orientation. They were then presented with 400 displays, each display being presented for 1 second. The central number occupied .7$^{o}$ of visual angle and the lines were presented 14.2$^{0}$ from the centre. For the numbers task participants' responded with a single key press when three consecutive odd or even digits were presented. The other task involved responding with the same key used for the numbers task when the two lines were presented in different orientations. Participants were asked to respond with the same response when either a number target was presented or when a line target was presented. There were 8 numbers and 8 lines targets per 80 displays, and numbers and lines target were never both presented on the same trial. The task lasted approximately 7 minutes. The outcome variable was accuracy.

*Pain manipulation*

Pain stimulation was achieved through the use of a Medoc PATHWAY - Advanced Thermal Stimulator (ATS). This has been designed for use in clinical and research settings, and induces pain through a metal plate, which is placed on the skin. The temperature of the plate increases or decreases, and is delivered and controlled through specialist hardware and software, designed for experimental purposes.

Individual pain thresholds were generated using a search protocol. A 30mm x 30mm thermode was attached to the participant's right ankle. The thermode started from a baseline temperature of 32$^{0}$C and participants altered the temperature using two buttons, one to increase the temperature and one to decrease the temperature. Participants were asked to increase the temperature to a level which was 'just painful'. This was then monitored for 15 seconds and participants were asked again if this was 'just painful', if the participant reported that this level was still correct this was taken to be the participant's threshold, if not then participants were asked to adjust the temperature and this check was performed again.

Once an individual thermal pain stimulation level was identified this was used to design a protocol for use during the experimental tasks, again using the PATHWAY ATS. Two heat conditions were used in the present study. The first of these was a baseline condition in which no additional stimulation was delivered to participants. In the second, the pain condition, the temperature increased at a rate of $8^0$C/second to $1^0$C above participants set pain threshold (up to a maximum of $48^0$C, all participants with thresholds higher than this were tested with a temperature of $48^0$C) this then oscillated between $1^0$C above and $1^0$C below the participant's pain threshold at $8^0$C/second for 10 oscillations before returning to the baseline temperature ($32^0$C) at a rate of $8^0$C/second. This procedure was repeated on a continuous cycle throughout each task. This resulted in a series of painful episodes punctuated by short period of non-pain. Therefore, this pain cycle was present throughout each of the cognitive tasks. This procedure was used to ensure that participants did not habituate to the painful stimulus.

*Threat manipulation*

Participants were also randomly assigned to either a threat or a control condition. The threat manipulation protocol was achieved through the use of different verbal instructions, and closely followed the threat induction procedures used by Van Damme at al. [34] McGowan et al. [19], and Karsdorp et al. [14]. Participants were given standard instructions about the heat pain induction protocol. This indicated that the heat protocol was a common and safe method of conducting pain research and that they would experience a painful sensation “a little like passing their hand over a candle”. Both groups were informed that whilst most people respond to this with slight reddening of the skin, in some rare cases this could result in a burn. Those allocated to the threat condition were told that they would be participating in a ‘vaso-contraction task’, and reiterated the point that that excessive heat exposure can result in blisters and burns. Participants were then told that it would be necessary to check their skin resistance (via the thermode) to ensure it was safe for them to continue into the study (this check was a foil). Following Van Damme at al. they were informed that their ‘skin resistance is rather low but just within the limits to allow you to take part in the vaso-contraction task’. Participants in the threat condition were told between each cognitive task that they would have to move the location of the thermode as their resistance was very close to threshold to reaffirm the threat throughout the study. Participants in the control condition were also given standard instructions about the heat pain induction protocol (that it was a common and safe method of conducting pain research and that they would experience a painful sensation). Those in the control condition were just asked to move the thermode after each task.

All participants were reminded that they were free to withdraw at any time for any reason without any consequences.

*Visual Analogue Scales (VAS)*

To examine the effect of the threat manipulation participants were also asked to complete a number of 100mm Visual Analogue Scales (VAS). Participant anxiety was examined at six time points during the experiment. Two time points were during the non-pain trials; these were before and after completing the cognitive tasks. During the pain trials participants were asked to complete the VAS four times: these were (1) before determination of pain threshold (baseline), (2) after the threat manipulation (or control), (3) after the cognitive tasks and (4) after debriefing. At each time point participants were asked *'How anxious do you feel right now?'*.

In addition to the six VAS measuring anxiety during the experiment, participants were asked to complete three additional 100mm VAS on a single occasion after the pain trials. Participants were asked (1) How much pain did you feel during the task? (2) How much distress did the pain you felt cause you? (3) How aware of the pain were you during the tasks?

Finally, participants in the threat condition were also asked to indicate on a 0-10 scale how much they believed the information they were given about the threat (0 = not believed at all; 10 = completely believed the instructions).

*Procedure*

Ethical committees approval was granted. Each participant consented to undergo the procedure. Each individual pain thresholds was then calculated, and task instructions provided. Participants completed a short practice run to familiarise themselves with the task, before completing two experimental versions of the task: once without any heat stimulation, and once with a painful heat stimulus. The order of the experimental tasks was fully counterbalanced. Participants were instructed to complete the various VAS measures at the time points indicated above.

*Analysis*

The first stage of the analysis was to examine the effectiveness of the threat manipulation. To examine the direct effect of the threat manipulation on participants current anxiety, data from the current anxiety VAS were entered into a 2 (threat condition; threat vs. control) x 3 (anxiety time point; before threat manipulation vs. after threat manipulation (or control instructions) vs. post cognitive task) mixed-groups ANOVA. Then to examine for any differences between the threat and non-threat groups independent samples t-tests were used to examine for differences between VAS scores for pain intensity, pain related distress and pain awareness.

To investigate the effects of pain and threat on each of the three cognitive tasks, data for each of the tasks were entered into a series of mixed groups ANOVAs. Each of these included pain as a within subjects factor and threat as a between subjects factor. For the attentional switching and divided attention tasks additional task specific variables were added. The dependent variables for each of the tasks were different due to the different demands of each task. For the n-back task the dependent variables were the number of correctly identified occasions on which a two back target was identified. A second dependent variable was the number of false alarms when participants reported that there was a two back trial when there was not. For the attentional switching task both accuracy and reaction time were selected as dependent variables. Both of these are commonly used to examine the effects of attentional switching. For the divided attention task, accuracy for the identification of the number and lines tasks was used as a dependent variable. Where significant interactions were observed these were broken down using simple main effects analysis with a Sidak correction. Throughout the research alpha was held at .05.

## Results

*Threat manipulation*

Means and standard deviations for all anxiety measures are presented in Table 1. To examine the effectiveness of the threat manipulation, anxiety data were entered into a 2 (threat condition; threat vs. control) x 3 (anxiety time point; before threat manipulation vs. after threat manipulation (or control instructions) vs. post cognitive task) mixed-groups ANOVA. This revealed no significant difference in anxiety amongst those in the threat condition and the control condition $F(1,48)=.314$, $p=.578$. There was also no significant interaction between threat condition and anxiety $F(2,96)=.375$, $p=.688$. There was however a significant main effect of time point $F(2,96)=6.788$, $p=.002$. This was broken down using a simple main effects analysis with a Sidak correction. This revealed that participants reported significantly less anxiety (mean = 18.00) post task compared to both time points before the task (mean = 27.30, 24.56) ($p<.05$). There was, however, no difference between participant anxiety before and after the manipulation ($p=.574$).

[Table 1 here]

Means and standard deviations for all distress and pain measures are presented in Table 2. Additionally, independent t-tests were used to examine differences between the threat and non-threat conditions for measures of pain intensity, pain related distress and pain awareness. These revealed no significant differences between the two threat groups on any of the measures, pain during the task t(48)=.281, p=.780, pain related distress t(48)=.997, p=.324, awareness of pain t(48)=.860, p=.394. This suggests that the threat manipulation did not significantly change participants' subjective responses to the task.

[Table 2 here]

Participants in the threat condition were also asked to rate on a 10 point scale how believable they found the information given to them. The mean rating was 8.36 with only one participant rating below 5. We judge that our manipulation was believed by the participants in this study. This suggests that although the threat manipulation does not appear to have resulted in a significant increase in anxiety levels compared to before the manipulation or the control group it does appear that the manipulation was successful.

*Data screening*

All cognitive data were subjected to screening for parametric assumptions of GLM analyses. Outliers were found in each of the three experiments. Where violations were observed data corrections were applied. Participants were removed from the relevant task, and no participant had outlying data for more than one experiment. Means and standard deviations for all cognitive tasks are presented in Table 3.

[Table 3 here]

*Cognitive tasks*

<u>n-Back task</u>

To investigate whether pain affected 2-back task performance number of hits (correctly identified times when the current letter matched that two letters ago) were entered into a 2 (between; threat condition vs. control condition) x 2 (within; pain condition vs. control condition) mixed-groups ANOVA. There was no significant main effect of threat condition F(1,47)=2.22, p=.143. There was however a significant main effect of pain condition F(1,47)=6.82, p=.012, consistent with participants producing fewer hits in the pain condition (mean = 22.31) than in the baseline condition (mean = 23.97). There was no significant interaction between pain condition and threat condition F(1,47)=.528, p=.471. The same pattern was observed for misses (given that misses are just the maximum n – hits).

For false alarms (times that participants indicated that the current letter was the same as two letters ago when this was not the case) there were no significant main effects of either threat condition F(1,44)=.325, p=.572 or pain condition F(1,44)=.930, p=.340, and no significant interaction between these variables F(1,44)=.043, p=.837. For correct rejections (when participants indicated that the current letter was not the same as two letters ago and this was the case) there were no significant main effects of either threat condition F(1,44)=.005, p=.942 or pain condition F(1,44)=.266, p=.608, and no significant interaction between these variables F(1,44)=1.262, p=.267.

Together this suggests that although pain negatively impacts upon attention span, it does not result in participants reporting more false alarms. Additionally this effect does not appear to be moderated by threat.

Attentional switching

To investigate whether pain affected attentional switching, data were entered into a 2 (between; threat condition vs. control condition) X 2 (within; switching condition vs. repeat condition) X 2 (within; pain condition vs. non-pain condition) mixed-groups ANOVA. For reaction times this revealed a significant main effect of switching condition F(1,46)=67.69, p<.001, consistent with participants responding faster to repeat trials (mean = 721.52 ms) than to switch trials (mean = 824.76 ms). There were however no significant main effects of either pain condition F(1,46)=.372, p=.545 or threat condition F(1,46)=.216, p=.644. There were also no significant interactions; all F<1, all p>.5.

The same analysis as above was run using accuracy data. Although accuracy was high, a ceiling effect is unlikely because fewer than 7% of data points resulted in 100% performance. Here there was a significant main effect of pain condition F(1,46)=14.87, p<.001; consistent with participants performing less accurately when in the pain compared to when in the non-pain condition. There was also a significant main effect of switch condition F(1,46)=42.70, p<.001, consistent with more accurate responding on repeat trials (Mean = .94) than switch trials (Mean = .91). There was however no significant main effect of threat condition F(1,46)=.168, p=.684. There was also a significant interaction between switch condition and pain condition, F(1,46)=5.695, p=.021, see Figure 1. To examine this in more detail composite switch cost scores were calculated (repeat trials – switch trials). These data were then entered into a repeated measures t-test, which revealed that switch costs were significantly greater in the pain condition (mean = .037) than in the baseline condition (mean =.020); t(49)=2.068, p=.044. All other interactions were non-significant, all F<2, all p>.1.

This suggests that pain adversely effects participants' ability to switch between two tasks. This effect does not however appear to be modified by the threat manipulation.

<u>Divided attention</u>

To investigate whether pain or threat affected divided attention performance a 2 (between; threat condition vs. control condition) X 2 (within; numbers task vs. lines task) X 2 (within; pain condition vs. non-pain condition) mixed design ANOVA was conducted. This revealed a significant main effect of divided attention task $F(1,48)=18.471$, $p<.001$; participants performed more accurately on the lines task (Mean = .69; identifying when the two peripheral lines did not match) than the numbers task (Mean = .57; identifying three consecutive odd or even numbers). There were no significant main effects of either threat $F(1,48)=1.687$, $p=.200$ or pain condition $F(1,48)=.864$, $p=.357$. There was, however, a significant interaction between threat condition and divided attention task $F(1,48)=4.867$, $p=.032$. This interaction was broken down using a simple main effects analysis with a Sidak correction (see Figure 2). This suggested that for the threat condition the lines tasks was performed more accurately than the numbers task ($p=.035$), however this difference was not significant in the non-threat condition ($p=.146$). Additionally, the numbers task was performed significantly less accurately in the threat condition than the non-threat condition ($p=.025$). However, on the lines task there were no significant differences between the threat and non-threat conditions ($p=.511$). This suggests that the threat manipulation caused participants to be less able to focus on the numbers task. All other interactions were non-significant, all $F<2$ all $p>.2$.

## Discussion

Overall, the current study confirmed that pain appears to cause an interference effect on complex attentional tasks. This is consistent with a number of studies using similar task paradigms [4; 7; 8; 25], and supports the view that attentional interruption by pain operates for tasks with an executive component. Pain caused impaired performance for the n-back task, and resulted in larger switching costs on the attentional switching task. Pain did not, however, affect performance on the divided attention task. Therefore this finding partially replicates our previous results [25].

There are a number of possible reasons for failing to find a pain interference effect on divided attention. The first is that pain simply does not reliably affect divided attention. However, we judge this as an unlikely explanation not only because we found robust effects in our previous study, but also because it makes theoretical sense, as divided attention can be seen to be conceptually linked to executive functioning. An alternative reason could be due to differences in protocols between the studies. First, the pain model used in the previous study relied on infrequent (2-10 seconds apart) pain stimuli of 1 and 3 seconds at pain threshold. The current study used a more frequent and regular pain sensation $1^{0}$C above pain threshold. The less novel, yet more frequent, sensation used here may have reduced the salience of the pain stimuli, and so resulted in less interference (i.e., a form of habituation). A second difference was that the tasks used in the current study were presented as a battery, rather than on their own, as in our previous study. This might have affected performance for a number of reasons. First, participants completed more tasks both in absolute terms and a greater variety of tasks; this may have introduced fatigue which would affect performance on later tasks. Additionally by using a battery of tasks potential order effects might have been introduced. However, given that the current study replicated pain interference effects in the n-back and attention switching tasks, these explanations are not entirely satisfactory. Indeed, that we replicated pain interference effects in two of our three tasks within a battery format could be viewed as a positive outcome; it suggests that our tasks show a degree of consistency and can be utilised as a battery of attentional interference.

The primary goal of the current study was to consider whether pain interference would be more affected under conditions of high threat. Somewhat surprisingly the current findings suggest that threat (as instantiated in this experiment) does not significantly add to the impaired performance effects caused by pain. This is unexpected because previous research has found that attentional distraction was less successful in conditions in which pain is perceived as highly threatening [5]; [30]; [31].

One reason for this discrepancy could be linked to task complexity. For example, the distraction tasks are relatively simple to perform [34]; [36], and so it is also possible that although threat is able to add to the interruptive effect of pain on simple tasks, that the effect of pain on more complex tasks is less sensitive to top-down considerations such as threat. An additional limitation could be linked to the different indicators of interruption. For example, both speed and accuracy were used as outcomes, although not consistently across the tasks. The reason for this was because the different tasks have been created separately, and though to reflect different processes. It is possible, however, that these different indicators of interruption may reflect either different strategies or may reflect underlying features of attentional performance.

An alternative explanation could be that the threat manipulation was not effective. Indeed, examination of self-report measures indicated that those in the threat condition did not show any greater anxiety or distress related to the task. Therefore, we cannot be sure that the threat manipulation caused a significant increase in participants' perceived threat. Although the manipulation used here did not result in a significant increase in anxiety participants reported that this was believable. Furthermore others have reported success using similar methods. The threat manipulation in the current study was adapted from McGowan et al. [19] who warned participants about the effects of exposure to prolonged cold (i.e. frostbite) and Van Damme at al. [34] who told participants that their blood pressure was only just within the limits to allow them to participate. A recent study by Karsdorp et al. [14] also used a similar threat manipulation, within the context of a finger pressing task; they provided fear-inducing information associated with repetitive movements, as well as false feedback about participants muscle EMG levels i.e., that EMG levels were high, but just within acceptable limits. Collectively these approaches are designed to partially remove the safety signal inherent in laboratory techniques**.** There are alternative methods for inducing threat both in pain and other anxiety related conditions (e.g., general anxiety). For example Van Damme et al. [32] conditioned innocuous stimuli to be associated with a painful electrocutaneous stimulus. Outside of pain threat has been induced in a number of ways including social threat (participants told they will be giving a presentation) [39] or general anxiety states (by reading a series of anxiety related statements) [40]. All of these approaches have been shown to induce a mild threat which lasts for a short duration with participants showing no lasting effects of the manipulation. Future research should consider alternative methods for threat induction to examine these effects.

There are interesting directions for future research. Replication and extension studies are necessary. The pain induction method used here involved a thermal stimulus and this did not show an interaction with the threat manipulation. Future research could determine whether similar disruptive effects would be found using alternative pain models e.g., chemical or electrocutaneous. This would allow us to determine whether such effects generalise across pain types. Given the context of threatening stimuli this might be of particular interest using electrocutaneous pain because previous studies have used this to condition pain related fear [27; 32; 33] and participants may find this more threatening. In addition to the generalizability of the pain stimulus it is also important to consider the generalizability of the threat. The threat manipulation used in the current study was specific to the pain used and therefore may not fully represent the real-world threat of pain. We do however judge that there are some aspects of this manipulation which reflect real-world pain; the manipulation represented a fear of damage and extension of the pain beyond a known time period. It may also be of interest to further examine the role of perceived threat relating to pain stimuli in attentional interruption. For example, the effects of pain on attention in participants who have a pre-existing tendency to perceive pain as threatening (i.e., high pain catastrophizers) could be examined.

The current study examined the effects of pain in a battery of attentional tasks. It would therefore be of interest in future studies to examine the robustness of these tasks as a battery. We could examine whether participants who show interference effects on one task also show similar effects on the other tasks in the battery. This would allow us to examine subtypes of people in terms of attentional interruption and predictors of these subtypes.

There are other potential influences on the interruptive effect of pain on attention. For example Verhoeven et al. [36] showed that when participants are given financial motivation to distract themselves from pain that this distraction is more effective than when no motivation is given. It is therefore possible that if participants were similarly motivated that attentional interruption would be reduced. In addition, increasing the cognitive load associated with the cognitive task has also been shown to be more effective in reducing pain sensations than lower cognitive load tasks [37]. Therefore increasing the cognitive load of the tasks may alter how much interruption is achieved by pain.

In conclusion, pain interrupts performance on the n-back and attentional switching, but not divided attention. This partially supports previous findings that performance of complex attentional tasks is impaired by experimental pain. Additionally threat did not appear to increase the extent of this attentional interruption. This however could be explained by evidence that the threat manipulation may not have been completely effective. Experimentally inducing a truly threatening pain stimulus is, however, methodologically and ethically challenging. Further research is needed to examine what individual differences factors may alter these relationships.

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Table 1: Means and SD for anxiety measures taken during the experiment

| | Anxiety during pain trials | | | | Anxiety during non-pain trials | |
|---|---|---|---|---|---|---|
| | Pre test | Post manipulation | Post test | Post debrief | Pre test | Post test |
| *Threat* | 25.80 (23.37) | 21.8 (23.24) | 17.48 (24.62) | 9.84 (17.76) | 13.80 (20.94) | 16.12 (20.95) |
| *Non-threat* | 28.8 (22.19) | 27.32 (22.79) | 18.52 (19.88) | 13.00 (15.62) | 21.60 (20.01) | 21.64 (23.97) |

Table 2: Means and SD for affective measures take after cognitive testing

| | Pain during cognitive tasks | Pain related distress | Awareness of pain stimuli |
|---|---|---|---|
| *Threat* | 37.56 (14.01) | 25.28 (22.52) | 56.04 (20.09) |
| *Non-threat* | 28.72 (15.14) | 19.52 (18.07) | 50.64 (24.14) |

Table 3: Means and standard deviations for target variables for measures of cognitive functioning under threat and non-threat conditions.

| *Task* | | *Threat* | | *Non-threat* | |
|---|---|---|---|---|---|
| | | *No pain* | *Pain* | *No pain* | *Pain* |
| Two-back | Hit | 23.63 (2.50) | 21.5 (3.59) | 24.32 (4.34) | 23.12 (3.35) |
| | Miss | 6.38 (2.5) | 8.5 (3.59) | 5.68 (4.34) | 6.88 (3.35) |
| | Correct rejection | 54.74 (7.17) | 55.61 (4.53) | 56.22 (4.75) | 53.87 (12.13) |
| | False Alarm | 4.26 (5.84) | 3.52 (3.85) | 4.91 (6.40) | 4.43 (3.89) |
| Switch | Repeat (RT) | 716.56 (169.98) | 697.75 (150.97) | 738.92 (199.79) | 732.96 (192.13) |
| | Switch (RT) | 832.20 (206.77) | 797.94 (205.74) | 837.38 (274.75) | 831.51 (244.96) |
| | Repeat (accuracy) | .95 (.05) | .93 (.06) | .95 (.04) | .94 (.06) |
| | Switch (accuracy) | .93 (.05) | .88 (.08) | .92 (.05) | .90 (.08) |
| Divided attention task | Number task (accuracy) | .54 (.15) | .49 (.15) | .63 (.19) | .60 (.47) |
| | Lines task (accuracy) | .72 (.19) | .71 (.18) | .68 (.20) | .68 (.22) |

Fig 1 The interaction between switching condition and pain condition for accuracy scores

Fig 2: The interaction between divided attention condition and threat condition for accuracy scores

Fig 1

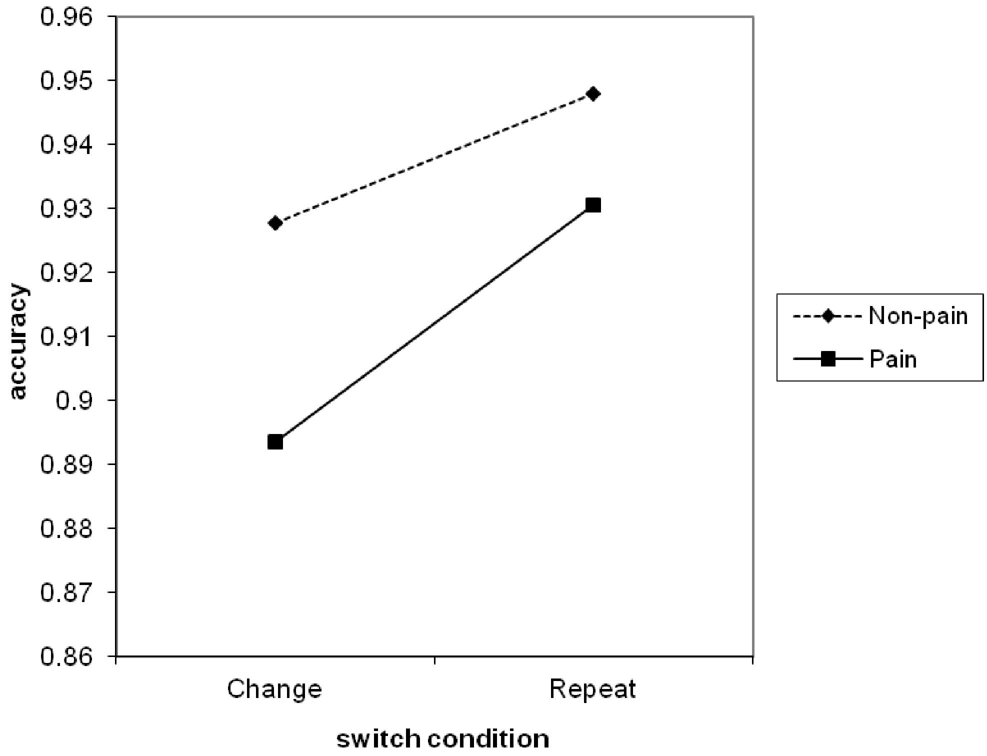
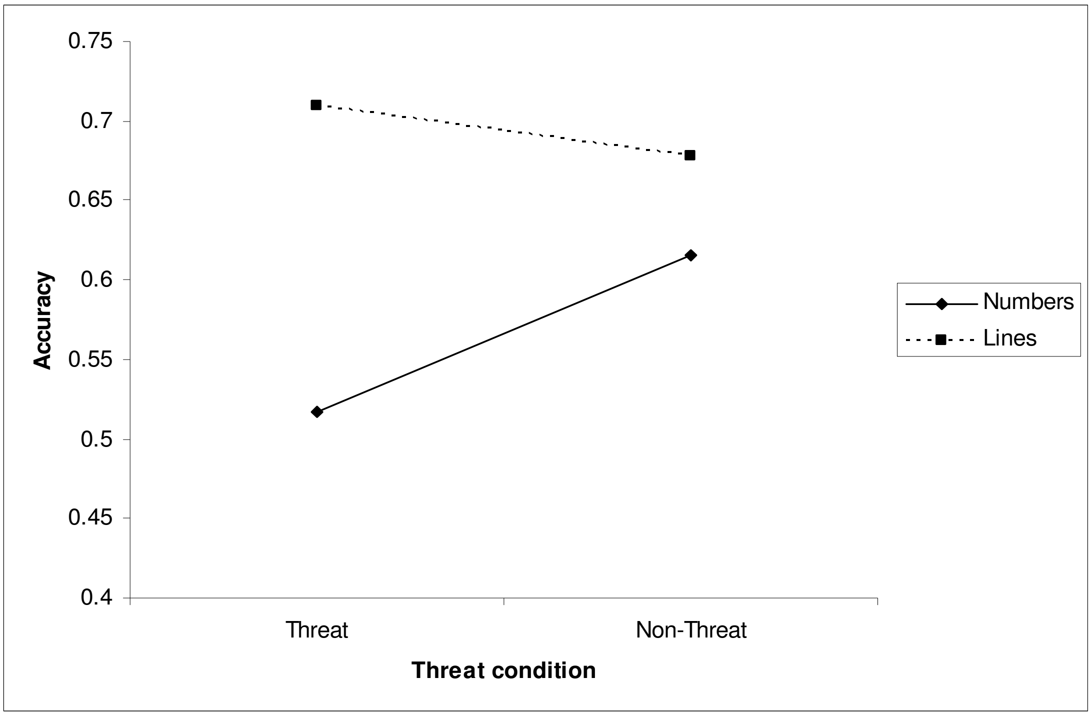

0.96
0.95
0.94
0.93
0.92
0.91
0.9
0.89
0.88
0.87
0.86
accuracy
Change
Repeat
switch condition
Non-pain
Pain

Fig 2:


0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
Accuracy
Threat
Non-Threat
Threat condition
Numbers
Lines