Headache impairs attentional performance: a conceptual replication and extension

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Abstract

Pain is thought to capture our attention. A consequence is that our performance on other tasks may suffer. Research has supported this, showing that pain disrupts our ability to perform various attention tasks. However, the specific nature of the effect of pain on attention is inconsistent, possibly due to different studies investigating different types of pain. Few studies seek to replicate basic findings. Here, we conceptually replicated and extended the headache study by Moore, Keogh & Eccleston (2013), by including two additional attention tasks, a broader sample, and measures of affect and pain cognitions. Participants performed five complex attention tasks and a choice reaction time task with and without a naturally-occurring headache. Headache slowed reaction times to four of the five complex tasks, and this could be attributed to a slower basic processing speed as measured by the choice reaction time task. Our findings differ from those of Moore et al's headache study, suggesting that the effect of pain on attention is dynamic, even within a given type of pain. While there is growing evidence that pain does disrupt attention, we cannot yet predict the specific nature of disruption in any given case.

Perspective

We extended a study investigating the effect of headache on attention. Although both studies showed attentional disruption, the specific nature differed. Research must establish when and why the effect of pain on attention varies before we will be able to develop interventions to reduce attentional disruption from pain.

Introduction

Pain imposes a priority of avoidance, escape, and analgesic behaviour [16]. While this has advantages for our immediate safety, it can be problematic in the long term if it disrupts our ability to perform other tasks that require attention. Given the high prevalence of both acute and chronic pain, these disruptive effects could have a substantial impact on people's lives.

The interference effect of pain on attention has been considered using a range of methods [2, 7, 9-12, 15, 18, 27-29, 37], including laboratory-induced pain, and more recently within common naturally-occurring pains, such as headache and menstrual pain [20, 30]. Curiously, while many of these studies find disrupted attention performance under pain, the specific nature of effects tends to vary, even when using identical tasks. For example, on an identical n-back task, thermal pain reduced overall accuracy [28], while menstrual pain increased the number of false alarms [20], and headache reduced the number of hits [30]. On a cued switching task, thermal pain increased response times (RTs) for switch but not repeat trials [28], and menstrual and headache pain decreased accuracy overall[20]. On a flanker task, thermal pain did not affect accuracy or RTs [28], but menstrual and headache pain increased RTs overall [20, 30]. Finally, on a dual task, thermal pain decreased accuracy on the peripheral task [28], menstrual pain decreased accuracy overall [20], and headache did not affect performance [30].

The inconsistent effects of pain on attention found across these studies could be due to the different types of pain used, differences in samples, or a dynamic effect of pain on attention, even within a given type of pain. The inconsistency of effects highlights the importance of replication studies, and so we conducted a conceptual replication of the headache study by Moore et al [30], where participants completed a set of four attention tasks once with and once without a naturally-occurring headache (results described above).

We extended the study in several ways. First, we included two additional attention tasks. Moore et al gave their participants a flanker task to measure selective attention, an n-back task to measure updating working memory, a switching task to measure attention shifting, and a dual task to measure divided attention [28]. Our two additional tasks were an uncued switching task (see Method) and a choice RT task. The choice RT task allowed us to examine the effect of pain on basic processing speed, and to see whether this accounted for any effects of pain on RTs on the other, more complex, tasks. Second, we included a broader sample. As well as university staff and students, we recruited members of the local community. Finally, we measured pain catastrophizing, need for cognition, affect, pain solution beliefs, and experience of pain intrusion, to explore whether any of these factors contributed to individual differences in attentional disruption from headache. For example, catastrophizing about pain may load attention.

Due to these extensions, the current study cannot be considered a direct replication of Moore et al, rather a conceptual replication and extension examining the effects of headache on attention. We expected task performance, measured by accuracy and reaction times, to be worse when participants had a headache compared to when they were pain free. However, due to the inconsistency of effects across previous studies, we could not make specific predictions about the nature of disruption on individual tasks. Given that females tend to report more pain than males and at a higher intensity [17, 31], and have higher self-reported levels of cognitive intrusion from pain than males [3], we included sex in our analyses.

Method

Design

The study followed a repeated measures design across two sessions, in one session participants attended with a headache and in the other they attended headache-free.

Ethics statement

The study was approved by the University of Bath Department of Psychology and Department for Health ethics committees. Participants gave written informed consent, were free to withdraw at any time, and were debriefed at the end of the study.

Participants

One hundred and three participants (22 male) were recruited from two universities in Bath (N = 75) via notices around campus and announcements in lectures, and from the local community in Bath and surrounding areas (N = 28) via newspaper adverts, flyers, and posters in public areas (e.g. shops, libraries). The inclusion criteria for participation were being aged 18 or over, with frequent headaches (i.e. which occur on between 1 and 15 days per month) of mild to moderate intensity. Participants did not need to have a diagnosis of a specific type of headache. Exclusion criteria included cancer, severe pain aside from headaches, chronic fatigue syndrome, neuromuscular disease, cognitive impairment, traumatic head injury, psychological issues (other than prevalent mental health issues such as depression and anxiety), substance addiction, neurological or psychiatric conditions, dyspraxia, or non-corrected visual problems. Participants were tested on two occasions: once when they reported having a headache, and once when they reported being headache free. For the headache session, participants were instructed to contact the researchers when they felt a headache starting and were available to take part. The researchers then attempted to meet the participant before the headache subsided.

Participants were randomised to complete either the headache (N = 48) or non-headache (N = 55) session first. The randomisation list was generated in Excel using the function "=RANDBETWEEN(1,2)" to decide whether each participant would complete the headache session in the first or second meeting. The list was logged with the department research manager prior to the study commencing. When participants enrolled for the study

and were assigned a participant number, the researcher checked the randomisation list to see which condition they would complete first. The researchers were therefore not blind as to which condition the participant was in at each session. Blinding would likely have been ineffective since headache sessions tended to be booked at short-notice while non-headache sessions were usually booked further in advance, and so the amount of notice given to the researchers would have revealed the condition. Furthermore, participants often displayed pain behaviours and wanted to discuss their pain during the headache sessions.

Of the 103 participants who were randomised to a condition, 19 did not complete any testing sessions, one failed to pass the inclusion/exclusion criteria check at session 1, and 24 completed session 1 but did not attend session 2 (see Figure 1). The participants who did not complete one or both testing sessions either withdrew, did not experience a headache during the study period, or testing could not successfully be scheduled when they did experience a headache.

This left 59 participants (18 male) who completed both sessions, and who constitute the final study sample. This level of drop out (40%) is comparable to Moore et al [30] (35%) and reflects the difficultly of recruiting individuals experiencing unpredictable transient pain [27]. The sex imbalance in the sample is also comparable to Moore et al [30], whose sample was 69% female compared to our 71%. All subsequent data are presented for this final sample only. The final sample had a mean age of 30.42 (*SD* = 13.60) years. Thirty-five participants completed the non-headache session first and 24 completed the headache session first. Of the final sample, 45 were from two local universities and 14 from the local community. Participants received a £25 thank you gift for participating.

Cognitive task battery

Participants were given six cognitive tasks, the order of which was Latin Square counterbalanced within each testing session. Four of these tasks (flanker, n-back, divided attention, cued switching) were identical to those used in two previous studies of naturally occurring pain [20, 30]. The two additional tasks (uncued switching and choice reaction time) were novel to this study and the reasons for their inclusion are discussed below. All tasks were presented on a Samsung laptop with a 2.5GHz processor and a 14-inch monitor using E-Prime Professional 2.0 [35]. Responses were made using the laptop keyboard. Due to the inconsistency of pain affecting accuracy and/or reaction times on these tasks in previous research, both of these outcome measures were analysed for each task here. This is with the exception of the choice reaction time task, for which only reaction times were of interest. This is because the task is designed specifically as a measure of reaction time and because our reason for including the task was specifically to see whether increases in reaction time on this task could account for increases in reaction times on the more complex task. Therefore, accuracies were not of interest for our research questions. Details of each task are provided below.

Flanker task

The flanker task was used as a measure of selective attention [6], which is the process of attending to relevant information while ignoring irrelevant information. A central fixation cross was presented for 500ms, which was then replaced by a target ("2" or "4"), which was flanked by distractors that were either the same (congruent) or the opposing (incongruent) stimuli (i.e. "2" or "4"). Participants gave a forced-choice response to indicate whether the central target had been a "2" or a "4", with no time limit. The inter-trial interval was randomly selected on each trial from 500, 1000, and 1500ms. A total of 80 trials (40 congruent; 40 incongruent) were included. Including instructions and the practice block, the

task lasted approximately 5 minutes. The measures taken were proportion of correct responses and RTs on correctly answered trials, separately for congruent and incongruent trials. Participants who are slower and/or less accurate on incongruent trials than on congruent trial are those who find it more difficult to ignore irrelevant information.

n-back task

A 2-back version of the letter n-back task was used to measure updating of working memory [8]. Participants were presented with a stream of single letters, each of which appeared for 500ms in the centre of the screen. There was an inter-stimulus interval of 1500ms during which the screen remained blank and participants could still respond. Participants gave a forced-choice response to indicate whether the letter on screen matched or did not match the letter presented two letters previously. A total of 90 stimuli (30 targets, 60 non-targets) were presented, in a random order. Including instructions and the practice block, the task lasted approximately 5 minutes. The measures taken were proportion of correct responses and RTs on correctly answered trials, separately for target (i.e. 'hits') and non-target trials (i.e. 'correct rejections'). Participant who perform better at this task are more successful at removing no-longer-relevant information from working memory and replacing it with new information.

Dual task

A dual task paradigm was used to assess participants' ability to simultaneously process more than one source of information [24]. A number between 1 and 9 appeared in the centre of the screen. At the same time two lines were displayed in the peripheral area of the screen, one to the left and one to the right of the central number. The two lines had the same orientation (i.e., both horizontal or both vertical) or different orientations (i.e., one horizontal and one vertical).

Participants were instructed to perform two tasks with equal priority. The number task required participants to press the space bar when three consecutive odd or even numbers had been presented. The lines task required them to press the spacebar when the two peripheral lines were presented in different orientations. The number and lines were displayed for 1000ms, during which participants could make a response. The number and line targets never occurred within the same trial. A total of 400 trials were presented, of which 40 were number targets and 40 were line targets. Including instructions and the practice block, the task lasted approximately 12 minutes. The measures taken were proportion of correct responses and RTs on correctly answered trials, separately for number and line target trials. Participants who perform better at this task are better able to process two sources of information simultaneously than those who perform less well.

Cued task switching

Participants tend to be slower and less accurate when switching between tasks than when repeating the same task. Various forms of switching tasks exist, and here we used two versions. Both versions required participants to respond to a series of single-digit numbers (1, 2, 3, 4, 6, 7, 8, 9) appearing in the centre of the screen for 500ms. There were two instructions for responding to the numbers: judge whether the number is lower or higher than 5 or judge whether it is odd or even.

In the cued version of the task [1, 23], participants saw an instruction before each number informing them of which instruction set they should use for that trial. For each trial, the instruction could either remain the same as the preceding trial (repeat trial), or switch to the alternative instruction (switch trial). Switches between instructions occurred at random. A total of 200 trials were presented, with repeat and switch trials appearing in a random order. Including instructions and the practice, the task lasted approximately 8 minutes. The

measures taken were proportion of correct responses and RTs on correctly answered trials, separately for switch and repeat trials. Participants who perform better at this task are better able to effectively switch their attention between two competing tasks.

Uncued task switching

Cued switching tasks such as the one described above have been suggested to underestimate the true cost of a task switch [33], whereas a predictable switching paradigm with runs of two trials may be more accurate [26]. Recently, Attridge, Keogh and Eccleston [4] investigated the effects of naturally-occurring pain on both a cued unpredictable switching task like that described above, and an uncued predictable switching task. In the uncued task, participants had to remember to switch tasks every two trials without any external reminders, and as such, the task was more complex with both a working memory requirement and a switching requirement. On both tasks, participants with pain responded more slowly than those without, but this did not differ for switch versus repeat trials. Since task performance seems to be affected by pain differently between different studies, we included the uncued switching task here to see whether the effects found by Attridge et al [4] would replicate.

The stimuli and instruction sets were identical to the cued switching task. The critical difference was that participants were informed in advance that they should use the following predetermined response sequence: AABBAABB, where A referred to the 'odd or even' instruction and B referred to the 'low or high' instruction, or vice versa. Participants were able to press a key to re-set the instructional sequence if they lost track. In this case, they were directed to a screen instructing them to continue from the beginning of the sequence, i.e. AABBAABB, when they returned to the task. This did not re-start the task, it simply reset the instruction order, so the number of trials was unaffected. A total of 120 trials were presented, and the task lasted approximately 5 minutes including instructions and a practice block. The

measures taken were proportion of correct responses and RTs on correctly answered trials, separately for switch and repeat trials. Participants who perform better at this task are more effective at switching their attention between two competing tasks, while also keeping track of which task they are supposed to be completing on each trial.

Choice reaction time

A multiple choice reaction time task (based on Deary et al [14]) was used to measure processing speed. As discussed in the introduction, this was included to allow us to investigate the effect of pain on basic processing speed, and to see whether any changes in reaction times on the more complex tasks were due to, in addition to, or unrelated to changes in basic processing speed.

A fixation cross was displayed in the centre of the monitor for one of 11 durations between 500ms and 1500ms (increasing in 100ms intervals), which was selected at random on each trial. Participants were then presented with a single-digit number (1, 2, 3, or 4). Participants identified the number presented on screen using the z, x, n and m keys on the laptop keyboard to identify the stimuli as 1, 2, 3 or 4, respectively. The stimuli were displayed until response. A total of 80 trials were presented and the task lasted approximately 3 minutes including instructions and a practice block. The measures taken were RTs on correctly answered trials for each of the inter-trial interval durations. Participants with shorter reaction times are able to process and respond to stimuli more quickly than those with longer reaction times.

Self-report measures

A battery of self-report scales designed to measure level of pain, pain cognitions and mood were administered to participants. These measures were completed during the non-

headache session, unless otherwise stated below. All of the self-report measures were administered prior to cognitive testing, in a counterbalanced order.

Demographics

Participants were asked to report their age, sex, marital status, ethnicity, highest qualification, and current job title.

Headache assessment

Participants answered a series of questions regarding their experience of headaches. This included the duration that they had experienced recurring headaches and whether they took prescription or over-the-counter medication for their headaches. Participants reported the intensity of their current and typical headache pain at both sessions using 100mm visual analogue scales anchored with the labels 'no pain at all' on the left and 'worst imaginable pain' on the right. The Headache Impact Test (HIT-6) [21] was included to assess the impact of participants' headaches on their daily lives. The HIT-6 involved participants rating the extent to which certain statements applied to them when experiencing a headache (never, rarely, sometimes, very often, always).

Medication use

At both testing sessions participants were also asked to list any medication used in the preceding 24 hours.

Affective state

The Positive and Negative Affect Schedule (PANAS) [39] was used to measure affective state. The PANAS consists of 20 mood descriptors that are markers of positive

affect (10 items) and negative affect (10 items). Participants were asked to rate the extent to which they had felt each descriptor in the past 24 hours, ranging from 1 (very slightly or not at all) to 5 (extremely). The PANAS was completed in both sessions. Positive and negative affect items were summed separately, and the difference in positive and negative affect between sessions was calculated. The Cronbach's alpha for the positive affect scale was .90 in the non-headache condition and .87 in the headache condition, and for the negative scale was .87 in the non-headache condition and .86 in the headache condition.

Experience of cognitive intrusion of pain

Attentional interruption by pain is a major component of pain and pain-related anxiety, and the Experience of Cognitive Intrusion of Pain (ECIP) scale is a measure of the phenomenology of cognitive intrusion from pain [3]. The scale consists of 10 items, which respondents rate on a scale of 0 (not at all applicable) to 6 (highly applicable). Higher scores denote greater cognitive intrusion by pain. This scale was administered twice, once during the non-headache session and once during the headache session. Scores were summed for each participant in each session. The Cronbach's alpha for this scale was .94 in the non-headache session and .95 in the headache session.

Pain catastrophizing

The Pain Catastrophizing Scale (PCS) [36] was used to measure the extent to which individuals engage in catastrophic thinking about pain. The scale includes 13 statements describing thoughts and feelings when in pain, and participants were asked to rate the extent to which they have the described thoughts and feelings when in pain by rating each statement on a 5-point Likert scale, ranging from 0 (not at all) to 4 (all the time). Scores were summed to create a total score for each participant. The Cronbach's alpha for this scale was .91.

Need for cognition

Participants' tendency to engage in and enjoy effortful cognitive endeavours was measured using the short-form Need for Cognition (NFC) scale [32]. This scale consists of 18 items, and participants are asked to rate the extent to which they believe each statement to be true of themselves on a scale of -4 (very strong disagreement) to +4 (very strong agreement). Negative keyed items were reverse-scored before all items were summed to form a single NFC score, with higher scores denoting greater enjoyment of effortful thinking. The Cronbach's alpha for this scale was .79.

Pain solutions

The Pain Solutions Questionnaire (PaSol [13]) was used to measure participants' beliefs about solutions for their pain. The PaSol was designed to measure assimilative (efforts at changing or solving pain) and accommodative (accepting that pain cannot be solved) responses to pain using 14 items. Participants indicated the degree to which each statement applied to them on a scale of 0 ("not at all applicable") to 6 ("highly applicable"). The Cronbach's alpha for this scale was .67.

Procedure

Following ethical committee approval, participants who expressed interest in the study were invited to attend a telephone briefing session with a member of the research team, in which study requirements, eligibility criteria, and procedures were explained. After giving verbal consent, participants were randomized to complete either the headache or the non-headache session first. Written informed consent was gained at the beginning of the first testing session and a screening questionnaire was completed to verify eligibility.

Testing took place at the University of Bath or another location convenient to the participant. Participants were tested at the same location in both sessions where possible, but a minority were tested in different locations for each session due to the availability of laboratories and meeting rooms when they reported with a headache. The duration between sessions varied from 1 to 250 days (median = 14 days, mean = 34 days; 94% of participants completed both sessions within 90 days).

Analysis

We ran a series of 2 (pain) × 2 (trial type) × 2 (sex) ANOVAs on accuracy scores and correct reaction times (RTs) for each task, with the exception of the choice reaction time task for which we ran a 2 (pain) × 11 (inter-trial interval) × 2 (sex) ANOVA on reaction times only. Trial type referred to congruent/incongruent trials for the flanker task, target/non-target trials for the n-back task, switch/repeat trials for the switching tasks, and number/line targets for the dual task.

For tasks where RTs were longer in the headache condition than in the non-headache condition, we investigated whether this slowing effect could be explained by a general dampening of processing speed (measured by the choice RT task), or whether there was additional slowing on the more complex tasks over and above a general dampening. For each participant we calculated a 'proportional change in RT due to headache' score for each of the tasks, as follows:

$$\frac{\text{headache RT} - \text{nonheadache RT}}{\text{nonheadache RT}}$$

We subtracted the proportional change in RT on the choice RT task (i.e. change in processing speed) from the proportional change in RT score on each of the more complex tasks, and compared the remaining RT difference due to headache to zero, for each task, using one sample t-tests with Bonferroni correction. In other words, we asked whether the

increase in RT on each task, over and above the slowing in processing speed, was significantly different from zero. If the effects of pain on RTs described above could be attributed to generally slower processing speed when experiencing headache, we would not expect the remaining RT difference due to headache scores to be different from zero. If the remaining RT difference due to headache scores were significantly larger than zero, it would suggest that headache increases RTs on more complex tasks over and above the effect on processing speed.

We also investigated the role of pain intensity in the headache session, pain catastrophizing, experience of cognitive intrusion of pain, need for cognition, beliefs about pain solutions, and changes in positive and negative affect across sessions in the effect of headache on attention. For each of the cognitive tasks we calculated accuracy and RT interference indices. As above, these were calculated as

$$\frac{\text{headache score} - \text{nonheadache score}}{\text{nonheadache score}}$$

and thus reflected the change in accuracies and RTs across sessions, as a proportion of non-headache scores. These indices were then correlated with pain intensity in the headache session and scores on the self-report affect and cognition scales, with Bonferroni correction.

Results

Data cleaning

The accuracy and RT means for correctly answered trials were screened for outliers (i.e. participants with average scores more than three standard deviations from the group mean). Outliers were identified and removed from the flanker task (accuracy N =2, RTs N = 3), n-back task (N = 8 for both accuracy and RTs, and 2 additional for accuracies), dual task (N = 6 for both accuracy and RTs), cued switching task (accuracy N = 3, RTs N = 4) and uncued switching task (N = 4 for both accuracy and RTs).

Accuracy scores were also examined to identify participants who failed to perform above chance level. On the n-back task, 13 participants did not perform above chance level (6 at baseline only, 6 in pain only, and 1 in both conditions) and their data for that task was removed. On the dual task 24 participants did not perform above chance level (5 at baseline only, 9 in pain only, and 10 in both conditions) and their data were removed. No other tasks suffered from below chance performance by any participant. The fact that the majority of participants who did not score above chance in one session did score above chance in the other session, and that failure to score above chance was not limited to the headache session, suggests that this was not due to characteristics of individual participants themselves, or to pain. However, of the 12 participants who failed to score above chance level on the n-back task in only one session, 9 failed to score above chance in the first session (regardless of whether it was with a headache or headache free) while only 3 failed to score above chance in the second session. On the dual task, of the 15 participants who did not score above chance in only one session, 12 failed to score above chance in the first session and 3 in the second session. This may suggest that the n-back and dual tasks were simply very difficult, and that participants took a lot of practice to become proficient with them. This is consistent with comments made by several participants during testing.

Headache characteristics

Participants reported the duration that they had been experiencing recurring headaches and responses were coded into four groups: up to one year (N = 12), up to five years (N = 19), up to 10 years (N = 13) and over 10 years (N = 12). Eight participants (14%) were taking prescription medication for their headaches, and 18 (31%) had taken prescription headache medication in the past. Thirty-six participants (61%) reported taking over-the-counter medication for headaches. In the 24 hours before the headache session, twelve

participants had taken analgesics: five had taken paracetamol, five had taken ibuprofen and two had taken unspecified over the counter analgesics. In the 24 hours before the non-headache session, eight participants had taken analgesics: two had taken paracetamol, four had taken ibuprofen, one had taken aspirin and one had taken sumatriptan.

Scores on the Headache Intensity Test ranged from 44 to 74 (possible range 36 to 78, $M = 60.08$, $SD = 5.60$) and did not differ between females ($M = 60.97$, $SD = 5.10$) and males ($M = 58.19$, $SD = 6.31$), $t(48) = 1.67$, $p = .102$ (9 participants were excluded for missing out one or more questions).

Typical headache pain VAS ratings did not differ between the headache ($M = 55.88$, $SD = 20.04$) and non-headache sessions ($M = 56.08$, $SD = 19.52$), $t(57) = .07$, $p = .941$, suggesting consistency in participants' perceptions of their typical headache (one participant did not complete the VAS scales in the non-headache session). As expected, current pain VAS ratings were significantly higher in the headache session ($M = 52.76$, $SD = 20.22$) than in the non-headache session ($M = 4.92$, $SD = 12.75$), $t(57) = 18.89$, $p < .001$. There was no difference between current and typical pain ratings in the headache session, $t(58) = 1.24$, $p = .220$, suggesting that the headaches participants presented with at testing did not differ from their typical headache in intensity. Women had significantly higher current pain intensity ratings in the headache session ($M = 55.88$, $SD = 18.82$) than men ($M = 44.60$, $SD = 21.58$), $t(57) = 2.03$, $p = .047$.

Experience of cognitive intrusion of pain

Participants completed the ECIP scale at both sessions, which allowed us to compare ratings when participants were with and without headache pain. Scores were significantly higher when participants had a headache ($M = 34.14$, $SD = 11.04$) compared to when they were pain free ($M = 29.11$, $SD = 13.47$), $t(55) = 4.17$, $p < .001$, although scores across

sessions were highly correlated, $r(56) = .75$, $p < .001$ (three participants were excluded for missing out one or more questions on the scale). The difference between sessions was small and the correlation high, suggesting that participants can reliably report their usual level of experience of cognitive intrusion from pain, even when they are not experiencing pain.

Effects of pain on cognitive task performance

Flanker

For accuracy (N = 57 after outliers were excluded), there was a significant main effect of trial type, $F(1,55) = 54.20$, $p < .001$, $\eta^2_p = .496$, with higher accuracy for congruent trials ($M = .99$, $SD = .02$) than for incongruent trials ($M = .96$, $SD = .03$). There was no main effect of headache, $F(1,55) = 1.81$, $p = .184$, $\eta^2_p = .032$ and no main effect of sex, $F(1,55) = .001$, $p = .981$, $\eta^2_p < .001$. There was no interaction between headache and trial type, $F(1,55) = 2.38$, $p = .129$, $\eta^2_p = .041$, no interaction between headache and sex, $F(1,55) = .21$, $p = .647$, $\eta^2_p = .004$, no interaction between sex and trial type, $F(1,55) = 1.44$, $p = .235$, $\eta^2_p = .025$, and no three way interaction, $F(1,55) = .01$, $p = .913$, $\eta^2_p < .001$.

For correct RTs (N = 56 after outliers were excluded), there was a significant main effect of congruency, $F(1,54) = 152.69$, $p < .001$, $\eta^2_p = .739$, with longer RTs for incongruent trials ($M = 535.52$ms, $SD = 101.56$) than for congruent trials ($M = 485.00$ms, $SD = 94.36$). There was also a significant main effect of headache, $F(1,54) = 14.44$, $p < .001$, $\eta^2_p = .211$, with RTs being longer when participants had a headache ($M = 536.60$ms, $SD = 136.50$) than when they were headache free ($M = 483.93$ms, $SD = 74.16$). There was no main effect of Sex, $F(1,54) = .94$, $p = .336$, $\eta^2_p = .017$. There was no interaction between congruency and headache, $F(1,54) = .01$, $p = .911$, $\eta^2_p < .001$, no interaction between sex and headache, $F(1,54) = .20$, $p = .659$, $\eta^2_p = .004$, no interaction between sex and congruency, $F(1,54) = 3.58$, $p = .064$, $\eta^2_p = .062$, and no three way interaction, $F(1,54) = .58$, $p = .449$, $\eta^2_p = .011$.

n-back

For accuracy (N = 37 after outliers and participants who did not score above chance level were excluded), there was a significant main effect of trial type, $F(1,35) = 212.83$, $p < .001$, $\eta^2_p = .86$, with non-target trials correctly categorised more often ($M = .85$, $SD = .10$) than target trials ($M = .49$, $SD = .10$). There was no main effect of headache $F(1,35) = .23$, $p = .633$, $\eta^2_p = .007$, and no main effect of Sex, $F(1,35) < .001$, $p = .999$, $\eta^2_p < .001$. There was no interaction between headache and sex, $F(1,35) = 1.10$, $p = .302$, $\eta^2_p = .030$, no interaction between trial type and sex, $F(1,35) = 2.91$, $p = .097$, $\eta^2_p = .077$, no interaction between headache and trial type, $F(1,35) = 2.45$, $p = .126$, $\eta^2_p = .066$, and no three way interaction, $F(1,35) = .41$, $p = .526$, $\eta^2_p = .012$.

When participants who did not perform above chance level were included, the results remained the same (in this analysis, $N = 49$).

For correct RTs (N = 37 after outliers and participants who did not score above chance level were excluded), there was no main effect of trial type, $F(1,35) = 1.29$, $p = .264$, $\eta^2_p = .036$, no main effect of headache, $F(1,35) = 3.18$, $p = .083$, $\eta^2_p = .083$, but a significant main effect of sex, $F(1,35) = 5.74$, $p = .022$, $\eta^2_p = .141$, with women having longer RTs ($M = 622.35$, $SD = 153.80$) than men ($M = 515.95$, $SD = 221.98$). There was no interaction between headache and trial type, $F(1,35) = 1.48$, $p = .232$, $\eta^2_p = .040$ and no interaction between trial type and sex, $F(1,35) = 1.83$, $p = .184$, $\eta^2_p = .050$, but there was a significant interaction between headache and sex, $F(1,35) = 4.68$, $p = .037$, $\eta^2_p = .118$. Paired t-tests showed that in men, RTs did not significantly differ between the headache ($M = 512.05$, $SD = 114.11$) and no headache ($M = 519.84$, $SD = 134.01$) conditions, $t(11) = .45$, $p = .660$, but in women, RTs were longer in the headache condition ($M = 662.68$, $SD = 153.31$) than in the no headache condition ($M = 582.02$, $SD = 137.07$), $t(24) = 3.00$, $p = .006$. Independent samples

t-tests showed that men's and women's RTs did not differ in the baseline condition, $t(35) = 1.30$, $p = .202$, but women's RTs were longer than men's in the headache condition, $t(37) = 3.18$, $p = .003$.

When participants who did not perform above chance level were included, the results remained the same, apart from the interaction between headache and sex, which lost significance (in this analysis, $N = 51$).

Cued switching

For accuracy (N = 56 after outliers were excluded), there was a significant main effect of trial type, $F(1,54) = 38.78$, $p < .001$, $\eta^2_p = .418$, with higher accuracy for repeat trials ($M = .95$, $SD = .05$) than for switch trials ($M = .92$, $SD = .05$). There was also a significant main effect of headache, $F(1,54) = 4.37$, $p = .041$, $\eta^2_p = .075$, with higher accuracy in the no headache condition ($M = .95$, $SD = .05$) than the headache condition ($M = .93$, $SD = .05$). There was no main effect of sex, $F(1,54) = .05$, $p = .819$, $\eta^2_p = .001$. There was no interaction between headache and trial type, $F(1,54) = 2.68$, $p = .107$, $\eta^2_p = .047$, no interaction between headache and sex, $F(1,54) = .34$, $p = .561$, $\eta^2_p = .006$, and no interaction between sex and trial type, $F(1,54) = 1.26$, $p = .267$, $\eta^2_p = .023$. There was no three way interaction, $F(1,54) = 1.35$, $p = .250$, $\eta^2_p = .024$.

For correct RTs (N = 55 after outliers were excluded), there was a significant main effect of trial type, $F(1,53) = 27.73$, $p < .001$, $\eta^2_p = .343$, with longer RTs for switch trials ($M = 819.50$ms, $SD = 209.97$) than repeat trials ($M = 763.19$ms, $SD = 194.23$). There was also a significant main effect of headache, $F(1,53) = 21.17$, $p < .001$, $\eta^2_p = .285$, with longer RTs when participants had a headache ($M = 854.12$ms, $SD = 256.96$) compared to when they were headache free ($M = 728.56$ms, $SD = 183.69$). There was no main effect of sex, $F(1,53) = 1.22$, $p = .275$, $\eta^2_p = .022$. There was no interaction between headache and trial type, $F(1,53)$

= 2.08, p = .155, η^2_p = .038, no interaction between headache and sex, F(1,53) = .19, p = .667, η^2_p = .004, no interaction between sex and trial type, F(1,53) = .05, p = .816, η^2_p = .001, and no three way interaction, F(1,53) = .007, p = .932, η^2_p < .001.

Uncued switching

For accuracy (N = 55 after outliers were excluded), there was a significant main effect of trial type, F(1,53) = 12.24, p = .001, η^2_p = .188, with higher accuracy for repeat trials (M = .94, SD = .05) than for switch trials (M = .91, SD = .07). There was no main effect of headache, F(1,53) = 1.11, p = .297, η^2_p = .021, and no main effect of sex, F(1,53) = .84, p = .363, η^2_p = .016. There was no interaction between headache and trial type, F(1,53) = .005, p = .944, η^2_p < .001, no interaction between headache and sex, F(1,53) = .51, p = .478, η^2_p = .010, no interaction between sex and trial type, F(1,53) = .35, p = .559, η^2_p = .006, and no three way interaction, F(1,53) = .22, p = .639, η^2_p = .004.

For correct RTs (N = 55 after outliers were excluded), there was a significant main effect of trial type, F(1,53) = 111.76, p < .001, η^2_p = .678, with longer RTs for switch trials (M = 1073.24ms, SD = 380.12) than repeat trials (M = 845.39ms, SD = 283.97). There was also a significant main effect of headache, F(1,53) = 12.71, p = .001, η^2_p = .193, with longer RTs when participants had a headache (M = 1027.34ms, SD = 396.06) compared when they were headache free (M = 891.29ms, SD = 309.07). There was no main effect of sex, F(1,53) = .76, p = .388, η^2_p = .014. There was no interaction between headache and trial type, F(1,53) = .245, p = .623, η^2_p < .001, no interaction between headache and sex, F(1,53) = .001, p = .972, η^2_p < .001, no interaction between sex and trial type, F(1,53) = .007, p = .934, η^2_p < .001, and no three way interaction, F(1,53) = .85, p = .360, η^2_p = .016.

Dual task

For accuracy (N = 29 after outliers and participants who did not score above chance level were excluded), there was a significant main effect of trial type, $F(1,27) = 4.83$, $p = .037$, $\eta^2_p = .152$, with higher accuracy on line targets ($M = .77$, $SD = .18$) than on number targets ($M = .64$, $SD = .22$). There was no main effect of headache, $F(1,27) = 2.03$, $p = .166$, $\eta^2_p = .070$, but there was a significant main effect of sex, $F(1,27) = 5.35$, $p = .029$, $\eta^2_p = .165$, with males having a higher accuracy ($M = .76$, $SD = .12$) than females ($M = .65$, $SD = .11$). There was no interaction between headache and trial type, $F(1,27) = .17$, $p = .687$, $\eta^2_p < .001$, no interaction between headache and sex, $F(1,27) = .98$, $p = .330$, $\eta^2_p = .035$, no interaction between sex and trial type, $F(1,27) = .16$, $p = .696$, $\eta^2_p = .006$, and no three way interaction, $F(1,27) = .66$, $p = .423$, $\eta^2_p = .024$.

When participants who did not perform above chance level were included several results changed (in this analysis, $N = 53$). The main effect of Trial Type became non-significant, $F(1,51) = 1.54$, $p = .221$. The main effect of Sex also became non-significant, $F(1,51) = .143$, $p = .707$. However, the effect of headache became significant, $F(1,51) = 5.60$, $p = .022$, $\eta^2_p = .099$. Accuracies were lower in the headache condition ($M = .56$, $SD = .20$) than in the non-headache condition ($M = .60$, $SD = .20$).

For correct RTs (N = 28 after outliers and participants who did not score above chance level were excluded; one additional participant was excluded in the RT analysis because they did not find any number targets in the non-headache condition and so did not have an RT score, yet were above chance and not an outlier overall and so were not excluded above), there was a significant main effect of trial type, $F(1,26) = 314.46$, $p < .001$, $\eta^2_p = .924$, with longer RTs on line targets ($M = 724.81$ms, $SD = 58.61$) than on number targets ($M = 517.63$m, $SD = 56.13$). There was no main effect of headache, $F(1,26) = 2.90$, $p = .101$, $\eta^2_p = .100$, and no main effect of sex, $F(1,26) = 1.08$, $p = .307$, $\eta^2_p = .040$. There was no interaction between headache and trial type, $F(1,26) = 1.51$, $p = .230$, $\eta^2_p = .055$, no

interaction between headache and sex, $F(1,26) = .15$, $p = .704$, $\eta^2_p = .006$, no interaction between sex and trial type, $F(1,26) = .15$, $p = .705$, $\eta^2_p = .006$, and no three way interaction, $F(1,26) = .08$, $p = .785$, $\eta^2_p = .003$.

When participants who did not perform above chance level were included the results remained the same (in this analysis, $N = 50$).

Choice reaction time

For correct RTs (no missing data; N = 59), there was a significant main effect of inter-stimulus interval, $F(10,570) = 2.20$, $p = .017$, $\eta^2_p = .037$, with a linear trend, $F(1,57) = 18.74$, $p < .001$, $\eta^2_p = .247$, where RTs decreased as the inter-stimulus-interval increased. There was a significant main effect of headache, $F(1,57) = 21.23$, $p < .001$, $\eta^2_p = .271$, with longer RTs in the headache condition ($M = 639.45$ms, $SD = 166.10$) than the no headache condition ($M = 573.33$ms, $SD = 111.17$). There was no main effect of sex, $F(1,57) = 2.19$, $p = .144$, $\eta^2_p = .037$. There was no interaction between headache and trial type, $F(10,570) = .44$, $p = .925$, $\eta^2_p = .008$, no interaction between headache and sex, $F(1,57) = 1.40$, $p = .242$, $\eta^2_p = .024$, no interaction between sex and trial type, $F(10,570) = .83$, $p = .603$, $\eta^2_p = .014$, and no three way interaction, $F(10,570) = .70$, $p = .729$, $\eta^2_p = .012$.

Additional analyses

Since some participants rated their current pain as greater than zero in the non-headache session, we re-ran the task performance analyses excluding five participants who gave VAS ratings of 10 or higher. This produced essentially the same pattern of results, with two exceptions. The interaction between headache and sex on n-back RTs lost significance, $p = .071$, and the main effect of headache on dual task RTs gained significance, $F(1,25) = 4.44$,

p = .045, η^2_p = .151. RTs were longer when participants had a headache (M = 629ms, SD = 48ms) than when they did not (M = 613ms, SD = 57ms).

When participants who had taken analgesics in the 24 hours prior to testing were excluded from the task performance analyses, the pattern of results remained the same with three exceptions: for the flanker RT analysis, the interaction between congruency and sex gained significance, $F(1,36) = 4.54$, p = .040. However, post-hoc t-tests showed that both men and women had faster RTs on congruent trials than on incongruent trials, both ps < .001, and there was no significant difference between men and women on either congruent, p = .549, or incongruent trials, p = .885. For the cued switching task accuracy analysis, the main effect of headache lost significance, $F(1,38) = 1.85$, p = .182. For the n-back RT analysis, the interaction between headache and sex lost significance, $F(1,23) = 1.49$, p = .235. Since the main findings remained in this additional analysis, i.e. that headache increased RTs on the flanker, cured switching and uncued switching tasks, medication usage does not seem to be an important factor in explaining our findings.

General dampening of RTs or task-specific effects?

For each task, except the dual task, participants responded more slowly when they had a headache compared to being headache free (although this was limited to females on the n-back task). Next we investigated whether this was due to a dampening of processing speed or whether there was additional slowing on the more complex tasks over and above the change in processing speed.

On all four tasks, the remaining proportional RT difference over and above proportional change in processing speed was not significantly different from zero (Bonferroni corrected α = .0125): flanker (M = -.002, SD = .126), $t(55) = -.136$, p = .892; n-back (females only, M = .009, SD = .220), $t(24) = .19$, p = .849; cued switching (M = .072, SD = .217), t(54)

= 2.46, p = .017; uncued switching (M = .046, SD = .262), $t(54)$ = 1.30, p = .199. Therefore, we did not find evidence for any additional slowing in RTs on these four tasks over and above the slowing in basic processing speed.

Psychological factors in attentional disruption

To investigate the relationship between attentional disruption from headache and our affect and cognition scales, we ran a series of correlation analyses. Proportional changes in accuracy on the attention tasks due to headache were not related to any of the affect or cognition scales, all ps > .071 (α = .01 after Bonferroni correction for correlating each scale with performance on five tasks, see Table 1). Proportional change in RTs on the attention tasks due to headache were also not related to any of the affect or cognition scales, all ps > .021 (α = .0083 after Bonferroni correction for correlating each scale with performance on six tasks, see Table 2).

Pain intensity and task performance

Tables 1 and 2 also include the correlations between pain intensity during the headache session and proportional change in accuracy and RT scores on the attention tasks. Surprisingly, pain intensity was only correlated with proportional accuracy difference due to headache on the flanker task, r = .29, p = .031, and proportional RT difference due to headache on the cued switching task, r = -.27, p = .045. All other correlations were non-significant, ps > .080.

Discussion

Multiple previous studies [2, 7, 9-12, 15, 18, 27-29, 37] have documented a detrimental effect of pain on attention, but the specific nature of the effect is inconsistent. Here, we conceptually

replicated the headache study by Moore et al [30] with the same type of pain and the same attention tasks, and extended it with a more diverse sample, two additional tasks, and several individual difference measures. Our data showed that headache slowed reaction times on the flanker, n-back (in females only), cued switching, uncued switching and reaction time tasks (but not the dual task). Headache also reduced accuracy on the cued switching task. However, pain intensity was unrelated to the majority of task disruption measures, suggesting that simply having a headache affected task performance regardless of the intensity. Interestingly, once we controlled for participants' change in basic processing speed due to headache, the remaining changes in RTs on the more complex tasks were not significantly different from zero. This suggests that the effect of headache on RTs on the complex attention tasks could be attributed to a slowing of basic processing speed. We also examined the relationships between scores on our affect and cognition scales and attentional disruption on the tasks. This did not reveal any evidence that the effect of headache on attention was moderated by individual differences in factors such as pain catastrophising or positive/negative affect.

Our findings regarding the effects of pain on task performance, and those from three previous studies that used four of the same tasks [20, 30], all differ (see Introduction). These inconsistencies are intriguing; on the one hand, pain does seem to disrupt attention across multiple studies, but on the other hand the specific nature of the effect varies. Differences in samples may account for some of the variation; Keogh et al's [20] menstrual study of course had only female participants, the current study had both male and female participants from two universities and the community, while the thermal pain [28] and first headache studies [30] had male and female participants from one university. However, the fact that we only found a sex difference in disruption on one task (on the n-back task only females were slowed by headache), and no relationships between our individual difference measures and disruption, makes this explanation seem insufficient. It is also unsatisfactory to suggest that the

differences in disruption are due to the different types of pain studied, since two studies investigating the effect of headache on performance on the same tasks have shown different patterns of disruption. Furthermore, Attridge et al [5] compared participants experiencing different types of pain within the same study, and found no difference between the groups in performance on an n-back task. Some of the inconsistencies may be partially explained by task impurity or insufficient reliability of the attention tasks: executive function tasks tend to recruit multiple processes and have low test-retest reliability, which may allow for significant variation in how an individual approaches the task across, or even within, testing sessions [19, 25].

There may be many other factors that could influence the nature of attentional disruption from pain at any given time. For example, Kucyi and Davis[22] discussed the dynamic and spontaneously fluctuating communication between pain- and attention-related brain networks. The implication is that while pain often disrupts task performance as hypothesised [16], we cannot yet predict the extent and nature of this disruption in any given case. This makes it difficult to draw conclusions for how people will be affected at work when they have a headache, and how factors such as motivation to complete the task are implicated, for example. It also makes it difficult to develop interventions to reduce attentional disruption, or to assess the effectiveness of interventions. It is also possible that the effects are a statistical epiphenomenon. An important challenge for future research will be to confirm that the effect of pain on attention varies even within a certain type of pain, using direct replications, and to explain why.

We found that pain increased RTs on the flanker, n-back (in females only), cued switching, uncued switching and choice RT tasks, and interestingly, that the increase in RTs on the complex tasks could be accounted for by the slowing in basic processing speed as reflected by the choice RT task. In other words, pain slowed processing speed, and there was

no additional slowing on the more complex tasks over and above this effect. The slowing in processing speed during headache could reflect any of several possible changes to cognitive processing, such as slower processing of stimulus features, slower decision making in how to respond to the stimulus, or a slower execution of the physical response. Our data do not allow us to distinguish between these possibilities, but RT is an important part of cognition. For example, it has been argued that slower and more variable processing is the basis of age-related declines in higher-level cognitive functions [34]. Slower RTs during pain could not only lead to problems performing complex time-dependent tasks such as driving, but also have implications for other aspects of cognitive function, such as the various aspects of attention that were affected here.

We found that on the n-back task only females had slower RTs with headache compared to without headache. Females also reported higher intensity current pain in the headache session than males. These findings are consistent with previous findings that females report more pain than males, and at a higher intensity [17, 31]. However, we did not find any other interactions between sex and headache on task performance and it should be noted that our sample contained fewer males (N = 18) than females (N = 41). The sex split was particularly unequal for the n-back analysis (11 males and 24 females).

Participants reported medications they had taken in the 24 hours prior to each session. This timeframe was chosen to allow for complete washout of any effects, however, reporting the approximate time that each medication was taken may be useful in future studies.

A large proportion of participants did not score above chance level on the dual and n-back tasks, reducing the sample size for these analyses. There are several possible reasons for this. It may be that the complexity of these tasks led to some participants disengaging. It is also possible that participants did not understand the task instructions, although this is unlikely given that they saw detailed instructions, could perform as many practice blocks as

they wanted, and were accompanied by a researcher and able to ask for clarifications at any time. The number of participants who failed to score above chance level was similar in the headache and non-headache conditions, so it is also unlikely that the issue is due to headache preventing above chance performance.

The most likely explanation seems to be that these tasks in particular were very difficult, and some participants took longer than others to get to grips with them. This is indicated by the larger number of participants who failed to score above chance in session 1 than in session 2 on both tasks. Most participants who did not score above chance in session 1 did so in session 2, which suggests that they were not incapable of performing the tasks and that the tasks themselves were not inherently flawed. This issue has been seen before with non-student samples. For example, in a sample of healthy older adults (aged 62 to 77 years) mean scores on a set of n-back tasks were below 60% [38].

The loss of data when applying cognitive tests with real-world pain is an important issue. We run the risk of examining effects in a high functioning sub-group. Of course, there are advantages to extending laboratory research beyond student samples and into the general public, but certain considerations should be taken into account, such as the substantial additional time required for recruitment and testing and the need to aim task instructions at a more naïve audience. It may be useful in future research to require participants to surpass a given accuracy threshold in practice blocks before allowing them to begin the main task.

By extending the study into the community, we sacrificed experimental control in favour of a more diverse sample. Participants were tested in a variety of locations, but despite this, the disruptive effect of pain on attention was still apparent.

In conclusion, we have shown that headache increased RTs on several attention tasks, but that this effect could be attributed to a slowing in basic processing speed as opposed to any task-specific effects. The flanker task has seen the most consistent effects of pain across

multiple studies ([20, 30], here), in the form of increased RTs, which may make it a useful tool for future research on pain and attention. Despite variation in the specific nature of the effects, pain has consistently disrupted attention in multiple studies, and this effect may have a negative impact on daily life for people in pain in the real world.

Disclosures

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Figure 1. Number of participants included at each stage of recruitment and testing.

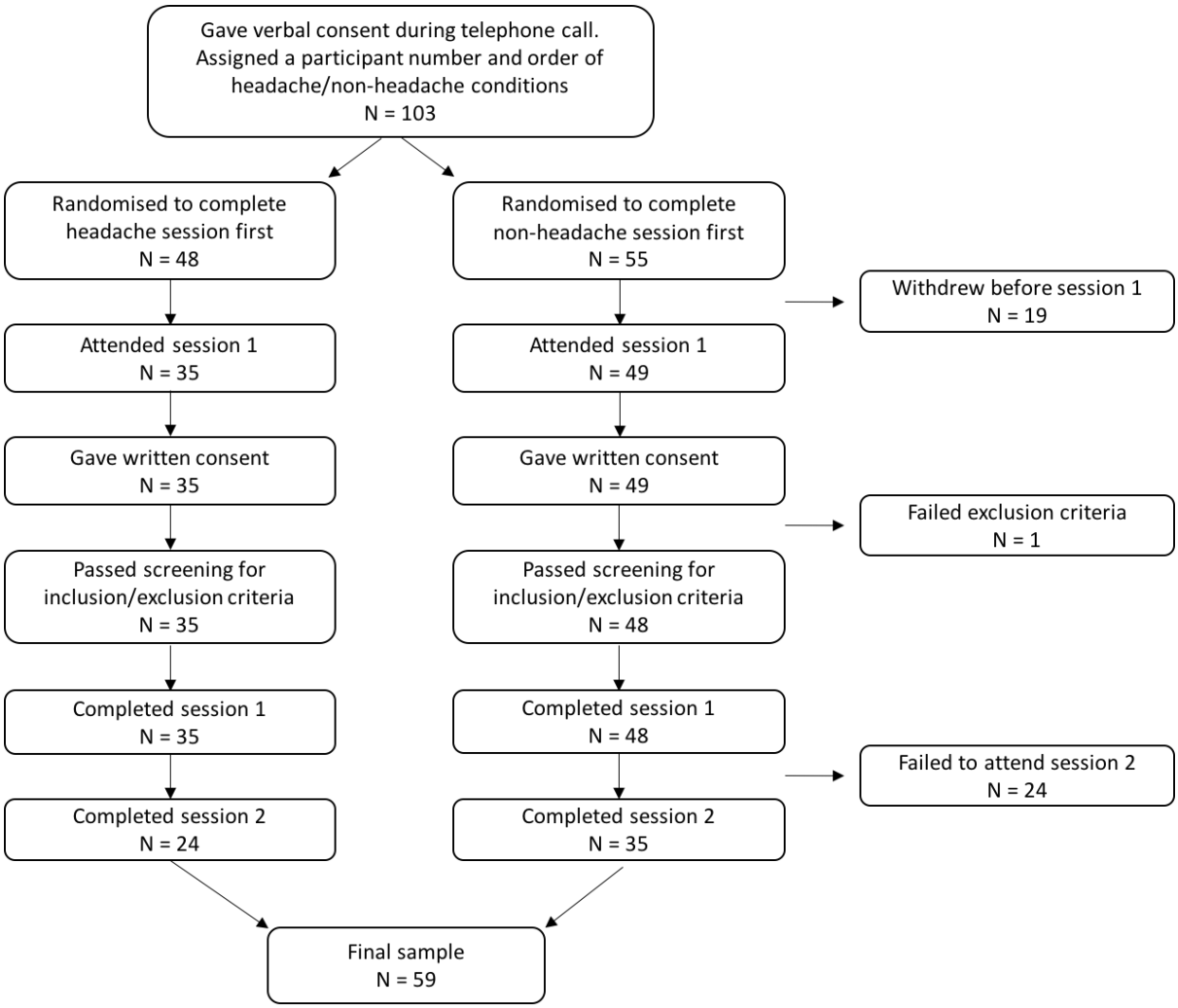

Table 1. Correlations between affect and cognition scales and proportional differences in task accuracy due to headache.

	Flanker (diff due to headache)	n-back (diff due to headache)	Cued switching (diff due to headache)	Uncued switching (diff due to headache)	Dual (diff due to headache)
Positive affect	*r* = -.08	*r* = .11	*r* = .01	*r* = .05	*r* = .11
	N = 52	*N* = 35	*N* = 52	*N* = 50	*N* = 27
Negative affect	*r* = -.04	*r* = -.06	*r* = .22	*r* = -.03	*r* = .02
	N = 53	*N* = 35	*N* = 53	*N* = 51	*N* = 27
Need for cognition	*r* = .18	*r* = .01	*r* = .15	*r* = -.03	*r* = -.28
scale	*N* = 55	*N* = 36	*N* = 54	*N* = 53	*N* = 29
Pain catastrophizing	*r* = .24	*r* = .15	*r* = .18	*r* = .05	*r* =-.26
scale	*N* = 54	*N* = 35	*N* = 53	*N* = 52	*N* = 28
Pain solutions	*r* = -.11	*r* = -.07	*r* = -.13	*r* = -.12	*r* = .28
questionnaire	*N* = 55	*N* = 36	*N* = 55	*N* = 53	*N* = 29
ECIP with headache	*r* = .10	*r* = -.22	*r* = -.01	*r* = .09	*r* = -.16
	N = 57	*N* = 37	*N* = 56	*N* = 55	*N* = 29
ECIP without	*r* = .15	*r* = -.18	*r* = .01	*r* = -.02	*r* = -.06
headache	*N* = 54	*N* = 36	*N* = 54	*N* = 52	*N* = 28
Pain intensity	*r = .29**	*r = -.26*	*r = .17*	*r = .16*	*r = -.33*
	N = 57	*N = 37*	*N = 56*	*N = 55*	*N = 29*

* $p < .05$

Table 2. Correlations between affect and cognition scales and proportional differences in task reaction times due to headache.

	Flanker (diff due to headache)	n-back (diff due to headache)	Cued switching (diff due to headache)	Uncued switching (diff due to headache)	Dual (diff due to headache)	Processing speed (diff due to headache)
Positive affect	*r* = .02	*r* = .30	*r* = -.03	*r* = -.06	*r* = -.16	*r* = .15
	N = 51	*N* = 35	*N* = 52	*N* = 50	*N* = 26	*N* = 51
Negative affect	*r* = .01	*r* = -.20	*r* = -.05	*r* = .01	*r* = -.13	*r* = -.25
	N = 52	*N* = 36	*N* = 53	*N* = 51	*N* = 27	*N* = 53
Need for cognition	*r* = -.15	*r* = .05	*r* = -.12	*r* = -.04	*r* = -.05	*r* = -.10
scale	*N* = 54	*N* = 36	*N* = 54	*N* = 53	*N* = 28	*N* = 54
Pain catastrophizing	*r* = -.22	*r* = -.17	*r* = -.10	*r* = -.18	*r* = .09	*r* = -.24
scale	*N* = 53	*N* = 35	*N* = 53	*N* = 52	*N* = 27	*N* = 53
Pain solutions	*r* = .06	*r* = -.03	*r* = -.18	*r* = -.05	*r* = -.10	*r* = -.07
questionnaire	*N* = 54	*N* = 36	*N* = 55	*N* = 53	*N* = 28	*N* = 54
ECIP with headache	*r* = -.31†	*r* = -.24	*r* = -.22	*r* = -.27†	*r* = .23	*r* = .04
	N = 56	*N* = 37	*N* = 55	*N* = 55	*N* = 28	*N* = 51
ECIP without headache	*r* = -.21	*r* = -.24	*r* = -.13	*r* = -.31†	*r* = .12	*r* = -.06
	N = 53	*N* = 36	*N* = 54	*N* = 52	*N* = 27	*N* = 53
Pain intensity	*r = -.03*	*r = .05*	*r = -.27**	*r = -.24*	*r = .28*	*r = .03*
	N = 56	*N = 37*	*N = 55*	*N = 55*	*N = 28*	*N = 59*

* $p < .05$. † $p < .05$, however, our Bonferroni corrected alpha level was set at 0.0083 so we do not consider these relationships significant.