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Effects of acute pain and pain-related fear on risky decision-making and effort during cognitive tests

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ABSTRACT

Introduction: The experience of acute pain and pain-related fear negatively impact cognition and behavior; however, little research has examined their impacts on risky decision-making and effort. The present study investigated the effects of acute pain and pain-related fear on risky decision-making and effort during cognitive tests.

Method: Levels of pain-related fear were assessed. Healthy participants (n = 146) experienced acute pain induced via cold pressor task, and then were randomly assigned to one of the four conditions to induce pain-related fear: Pain Threat (n = 36), Pain Threat with Control (n = 39), Cognitive Threat with Control (n = 34), and Control (n = 36). Participants then completed measures of effort (Word Memory Test [WMT]), self-reported effort and risky decision-making (Iowa Gambling Task [IGT], Balloon Analogue Risk Task [BART]).

Results:Collapsed across condition, participants did not learn to decide advantageously on the IGT following an acute pain experience. During the early trials (1–40) on the IGT, participants in the Pain Threat condition made riskier decisions. Higher levels of pain during the cold pressor task predicted less risky decisions on the BART, and participants in the Cognitive Threat with Control condition self-reported lower effort on cognitive tests, yet no group-based differences were seen in WMT performance. Greater pain-related fear predicted greater self-reported effort and better WMT performance, but no effects were seen on decision-making task performance.

Conclusions: The experience of pain and the threat of additional pain can lead to changes in risky decision-making and effort on cognitive tasks. This threat of additional pain could activate underlying pain-related fear, creating hypervigilance to and avoidance of pain that affects subsequent task performance. Implications for research and clinical evaluation of acute pain and pain-related fear are discussed.

Pain can have significant effects on everyday life. Pain can serve as a warning of danger, and pain can also disrupt attention and cognitive processing, in turn interfering with task completion (Price, 1988). The perception of pain can have as much of an impact on the experience of pain as actual tissue or nerve damage (McGrath, 1994). A current or recent experience of pain can lead to pain-related fear, in turn leading to changes in cognition and behavior (Leeuw et al., 2007; McGrath, 1994). Pain-related fear is characterized by a negative orientation to pain and its consequences, as well as pessimistic beliefs about one’s ability to cope with pain (Leeuw et al., 2007). Collectively, these components can predict increased pain experience (Leeuw et al., 2007). Pain-related fear can lead to negative outcomes including increased emotional distress, increased analgesic intake, longer length of hospitalization, and greater degree of functional limitation (Crombez, Eccleston, Van Damme, Vlaeyen, & Karoly, 2012). However, the mechanisms by which pain-related fear contributes to these and other behaviors remain unclear. One possibility is that pain-related fear exerts a negative impact on the decision-making process, leading individuals to make risky, health-compromising decisions over those that are relatively safer and health-promoting. Support for this idea comes from research identifying higher attentional bias (Asmundson, Norton, & Norton, 1999; Pincus & Morley, 2001; Van Damme, Legrain, Vogt, & Crombez, 2010) and physiological distress (Vowles, Zvolensky, Gross, & Sperry, 2004) among individuals with higher levels of pain-related fear. However, to date, no research has directly examined the association between pain-related fear and decision-making in the context of
an acute pain experience. In addition, it is possible that the experience of fear and subsequent pain-related fear could lead to lower effort on cognitive tasks, due to avoidance of task demands. The present study investigated the effects of acute pain and pain-related fear on risky decision-making and effort during cognitive tests.

**Acute versus chronic pain**

The long-term negative consequences of chronic pain can have wide-reaching impacts on physical, psychological, and economic well-being. Much of the research to date has focused on the negative effects of chronic pain on brain health and function (Apkarian et al., 2004; Grachev, Fredrickson, & Apkarian, 2000), cardiovascular health (Bruehl, Chung, Jirjis, & Biridepalli, 2005), mood and mental health (Gureje, Von Korff, Simon, & Gater, 1998; Kinney, Gatchel, Polatin, Fogarty, & Mayer, 1993; Ratcliffe, Enns, Belik, & Sareen, 2008), sexual functioning (Ambler, Williams, Hill, Garmacy, & Cratchley, 2001), sleep (Morin, Gibson, & Wade, 1998), and overall quality of life (McCarberg, Nicholson, Todd, Palmer, & Penles, 2008; Sheu et al., 2008; Smith et al., 2001). Other research has identified the negative impact of chronic pain on various cognitive processes including attention (Dohrenbusch, Buchanan, Lipka, & Ott, 2008), working memory (Dick & Rashiq, 2007; Dohrenbusch et al., 2008), and decision-making (Apkarian et al., 2004; Elvemo, Nilsen, Landro, Borchgrevink, & Häberg, 2014; Legrain et al., 2009; Tamburin et al., 2014; Verdejo-Garcia, López-Torrecillas, Calandre, Delgado-Rodriguez, & Bechara, 2009; Walteros et al., 2011).

The impact of chronic pain on measures of risky decision-making, such as the Iowa Gambling Task (IGT; Bechara, Damasio, Damasio, & Anderson, 1994), is particularly relevant to the present study. Briefly, the IGT tasks participants with making selections from four decks of cards. Unknown to participants, and learned through feedback, two decks are advantageous (lower immediate gains and lower losses) and two decks are disadvantageous (higher immediate gains but greater losses). The experience of chronic pain is associated with increased risky decision-making on this task. Specifically, pain intensity was positively associated with risky decision-making on the IGT, whereas performance on measures of attention, short-term memory, and general intelligence were not affected (Apkarian et al., 2004). Risky decision-making on the IGT, in that participants showed a preference for disadvantageous over advantageous decks, was also found among individuals experiencing chronic low back pain (Tamburin et al., 2014). The authors referred to participants’ pattern of IGT deck selections as indicative of a failure to learn to decide advantageously compared to the healthy control comparison group. This failure to learn on the IGT marks an important transition from decision-making under ambiguity to decision-making under risk (Brand, Recknor, Grabenhorst, & Bechara, 2007). Decision-making under ambiguity includes the beginning trials of the measure in which participants are still learning the relative risks and benefits associated with each deck. During these trials, outcome probabilities are not completely known, and as such, decision-making relies on uninformed strategies (Brevers et al., 2012). Decision-making under risk occurs during the remaining trials, and is so named because participants should be aware of the outcome probabilities associated with each deck that can lead to more advantageous or riskier performance. Among individuals with fibromyalgia, a chronic pain condition, this failure to learn on the IGT is evident as participants continue to prefer disadvantageous decks even during the decision-making under risk trials (Muñoz Ladrón de Guevara, Fernandez-Serrano, Reyes del Paso, & Duscheck, 2018). Thus, chronic pain appears to negatively impact IGT performance by disrupting learning of risks and benefits associated with decision choices. Less is known, however, about the effects of acute pain on decision-making on the IGT and other tasks. Acute pain can not only lead to chronic pain, but it can also significantly impact psychosocial functioning at the time of injury.

To date, research has shown acute pain can have a negative impact on mood and emotion (Edwards, Gatchel, Adams, & Stowell, 2006; Vangrantsveld, Morley, Peters, Vlaeyen, & Goossens, 2011) and cognitive processes such as attention (Crombez, Eccleston, Baeyens, & Elen, 1996, 1998a; Eccleston & Crombez, 1999; Moore, Keogh, & Eccleston, 2012; Vancleef & Peters, 2006) and decision-making (Koppel et al., 2017; Porcelli & Delgado, 2009). Koppel and colleagues examined the effects of acute pain, induced via thermal heat stimulation to the forearm, on both a delay discounting task and a monetary-based decision-making task in which participants made selections from safe and risky gain/loss options. Results indicated participants experiencing acute pain made riskier monetary decisions when choosing from gain but not loss options, and showed a preference for smaller, immediate rewards over larger but distant rewards. The authors theorized the participants were motivated by monetary gains to offset their aversive acute pain state (Koppel et al., 2017). In other words, individuals experiencing acute pain might be driven to engage in compensatory behavior to “avoid” pain, regardless of whether this behavior is health-promoting or health-compromising.

This finding is similar to previous research examining effects of social pain, such as following a manipulation of
ostracism. Neural structures sensitive to physical pain are also sensitive to social pain (Eisenberger, 2012; Eisenberger & Lieberman, 2004; MacDonald & Leary, 2005), and analgesics such as acetaminophen can reduce social pain (DeWall et al., 2010). Experiencing ostracism, as compared to social inclusion, resulted in increased risky decisions (Buelow, Okdie, Brunell, & Trost, 2015; Buelow & Wirth, 2017; Duclos, Wan, & Jiang, 2013) and unhealthy behaviors (Hayman, McIntyre, & Abbey, 2015; Salvy et al., 2011). In a recent study, participants asked to recall burdensome social media friends reported greater levels of physical pain and negative affect (Okdie & Wirth, 2018). In addition, the participants engaged in more exclusionary behaviors, in order to “avoid” additional pain associated with the burdensome friend. For an individual in acute pain, health-compromising behaviors may be more likely to occur as the immediate rewards (reduction in pain) outweigh the long-term negative consequences. However, it is also possible that other aspects of the pain experience, such as pain-related fear, may affect the decision-making process.

**Pain-related fear**

Individuals experiencing high levels of pain-related fear may experience functional limitations, due at least in part to hypervigilance to the experience of pain at the expense of attentional resources (Crombez, Eccleston, Van den Broeck, Goubert, & Van Houdenhove, 2004; Van Damme, Crombez, & Eccleston, 2002). Pain-related fear can also lead to avoidance of future behaviors in order to prevent further injury (kinesiophobia; Fritz, George, & Delitto, 2001; Vlaeyen & Linton, 2000). Pain-related fear can lead to the development and maintenance of chronic pain (Crombez et al., 2004; Crombez, Van Damme, & Eccleston, 2005; Forster, Thomas, Bishop, Dunn, & Main, 2010; Lautenbacher et al., 2010; Peters, Vlaeyen, & Kunnen, 2002). How pain-related fear leads from acute to chronic pain, and how it affects cognition, is vital for pain researchers and clinicians alike to understand in order to improve treatment outcomes.

Peters et al. (2002) examined hypervigilance to somatosensation as a possible mechanism by which pain-related fear contributes to chronic pain in patients with low back pain. They found that patients with greater pain-related fear showed faster reaction times on an auditory discrimination task, and pain-related fear was a stronger predictor of reaction times than self-reported level of pain. Pain-related fear promoted habitual attention to the pain experience over other attention-demanding tasks, to the extent that it negatively affected task performance (Peters et al., 2002). Similarly, Crombez et al. (1998a) induced acute pain in healthy undergraduate student participants, finding that acute pain led to attentional interference during an auditory discrimination task amongst only those with high pain-related fear. Taken together, these studies demonstrate the ability of pain-related fear to overload attentional resources, decreasing performance on cognitive tasks. It may be the case that these negative effects are more pronounced on tasks that require more attentional resources and cognitive control, or on tasks that require effort to complete.

Given the potential physical and psychological consequences of pain-related fear, individuals may avoid situations to prevent further injury. Avoidance behavior includes, but is not limited to, decreased physical motion or muscle exertion (Pfingsten et al., 2001; Trost, France, & Thomas, 2011), decreased ability to sustain attention (Suhr & Spickard, 2012), and decreased participation in daily life activities (Fujii, Matsudaira, & Oka, 2013; Zale & Ditre, 2015). In the short term, avoidance behavior can be adaptive, promoting health by reducing physical exposure to and psychological distress associated with potentially harmful stimuli. However, in the long term, these behaviors can instead lead to increased fear of engaging in behaviors that might lead to additional pain, increased physical limitations, and increased disability (Zale & Ditre, 2015). Pfingsten et al. (2001) examined avoidance behavior in patients with chronic low back pain, finding that when primed with the potential for additional pain, reductions in the movement were observed on a leg-flexion task among those with pain-related fear (i.e., participants avoided physical activity to avoid additional pain). Trost et al. (2011) examined avoidance behavior, physical performance on a maximal trunk strength task, and pain-related interference effects in healthy participants. Avoidance behavior occurred in participants with higher pain-related fear, significantly predicting reduced maximal strength production and increased interference in daily living activities one day after induction of acute pain. Across these studies, decreased physical motion was a consequence of increased avoidance behavior. Precisely how avoidance behavior influences performance on cognitive tasks is unclear. At its root, avoidance behavior associated with pain-related fear drives behavior centered on avoiding additional pain and associated psychological distress. Thus, when threatened with the potential for additional pain, avoidance behavior could result in improved performance on cognitive tasks as a way to prevent additional “injury.” Suhr and Spickard (2012) examined the effects of cogniphobia, a form of pain-related fear associated with pain due to cognitive exertion, on frequent headache
sufferers. They found that higher levels of avoidance were associated with worse sustained attention but no changes on a measure sensitive to effort on cognitive tasks. Thus, the relationship between pain-related fear, cognitive task performance, and effort is likely complex.

**The present study**

The present study examined the influence of acute pain and pain-related fear on risky decision-making and effort during cognitive tests. Previous research has documented the effects of pain-related fear on attention, finding that hypervigilance to pain can lead to decreased attentional resources and impaired task performance (Van Damme et al., 2002, 2004). Pain-related fear can also impact behavior by increasing avoidance of a physical or cognitive activity to prevent additional injury, protect physical health, and diminish psychological distress (Fritz et al., 2001; Suhr & Spickard, 2012; Vlaeyen & Linton, 2000). Precisely how pain-related fear functions in more complex cognitive processes, such as decision-making and effort on cognitive tasks, is unknown.

In the present study, participants were given a set of instructions to follow after first completing a cold pressor task. The instructions were either designed to increase pain-related fear or serve as the control group comparison. Performance on decision-making tasks and measures sensitive to effort was then assessed. Several hypotheses and study aims were examined. First, it was hypothesized that individuals who experienced mild physical pain (e.g., completion of the cold pressor task) will exhibit risky decision-making. As a second component of this hypothesis, level of reported pain during the cold pressor task will be negatively associated with task performance. Second, we examined the influence of pain-related fear on the decision-making process. As the relationship between pain-related fear and decision-making has not been directly examined in the literature to date, two different hypotheses were proposed. High levels of pain-related fear could lead to riskier decision-making and low effort due to hypervigilance to pain. Because hypervigilance to the pain experience involves a preoccupation of attentional resources to the pain itself at the expense of other tasks (Van Damme et al., 2002, 2004), it could be the case that limited attentional resources adversely impact decision-making and self-reported effort. Conversely, high levels of pain-related fear could lead to improved decision-making and effort due to pain avoidance. In order to avoid future pain experiences, those high in pain avoidance may be likely to perform better on decision-making tasks and show increased effort when instructed that improved task performance may prevent future acute pain experiences (Fritz et al., 2001; Vlaeyen & Linton, 2000). In addition, we examined whether the specific instruction given to manipulate pain-related fear would predict decision-making task performance and effort. Based on previous work showing the threat of pain can impair task performance (Crombez et al., 1998b), we hypothesized that participants who experienced a threat of additional physical pain with no ability to change their performance (i.e., the pain occurred based on previous task performance) would make riskier decisions and show lower effort than participants who experienced the same threat but with the ability to change their performance (i.e., the pain occurred based on upcoming task performance). When given the ability to correct performance to avoid additional physical pain, task performance should improve. We also included a threat of additional cognitive pain (e.g., completion of a complex cognitive task) to examine whether the predicted relationship between pain-related fear and task performance is limited to physical pain.

**Method**

**Participants**

The present study was approved by the university’s Institutional Review Board. All participants provided informed consent and were debriefed at the end of the study. A power analysis conducted in G*Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007) indicated a sample of 129 participants was needed to detect a medium effect with \( \alpha = .05 \), power = .95, in a linear regression with four predictors. To detect a small effect, 929 participants were instead required.

A total of 146 participants, all over the age of 18 (\( M_{age} = 19.32, SD_{age} = 3.33 \); 44.3% male; 61.4% Caucasian) and enrolled in psychology courses, completed the present study. The following exclusion criteria were utilized (participants self-reported their status): (a) current diagnosis of a heart condition or experience of chest pain, or current prescription for a blood pressure medication or heart condition; (b) current difficulties with balance, dizziness, or loss of consciousness; (c) diagnosis of a lung condition interfering with daily activities; (d) current neurological condition resulting in muscle weakness or loss of skin sensation; (e) current treatment for diabetes; (f) history of frostbite; and (g) current pregnancy.

**Measures**

The study measures appear in the same order in which they were presented during the study sessions. See Figure 1 for the study timeline.
**Tampa Scale of Kinesiophobia (TSK)**
Participants completed the 17-item TSK to assess subjective fear of pain (Miller, Kori, & Todd, 1991). Participants responded to the items on a scale from *Strongly Disagree* (1) to *Strongly Agree* (4), with total scores ranging from 17 to 68. Higher scores on the TSK are indicative of greater fear avoidance behavior. Internal consistency was moderately strong (α = .731) for the present study. Previous research with the TSK demonstrated both adequate test–retest reliability and validity (Woby, Roach, Urmston, & Watson, 2005), and the measure continues to be used in clinical settings to detect kinesiophobic behavior.

**Pain Catastrophizing Scale (PCS)**
Participants completed the 13-item PCS to assess pain catastrophizing, magnification, and rumination (Sullivan, Bishop, & Pivik, 1995). Participants responded on a scale from *Not At All* (0) to *All The Time* (4) to items assessing associated cognitive experiences of pain sensitivity and/or the tendency to display an exaggerated negative perception of painful stimuli. A total score was calculated, with higher scores indicative of greater pain catastrophizing (internal consistency: α = .940). Previous research with the PCS demonstrated adequate test–retest reliability and validity, and the measure continues to be used in both clinical and non-clinical populations (Sullivan et al., 1995).

**Positive and Negative Affect Schedule (PANAS)**
Participants completed the 20-item PANAS to assess subjective positive (10 items) and negative (10 items) mood state during the testing session (Watson, Clark, & Tellegen, 1988). Responses on the positive and negative subscales were averaged separately, with higher scores indicative of greater positive or negative mood. For both subscales, internal consistency was strong (α = .785 – .899). Previous research has shown the validity of the PANAS to assess state-dependent mood (see Heilman, Crisan, Houser, Miclea, & Miu, 2010; Wendrich, Brauchle, & Staudinger, 2010, for a review).

**McGill Pain Questionnaire-short form (MPQ)**
Participants completed the 15-item Pain Rating Index of the MPQ Short Form to assess subjective experience of pain (Burckhardt & Jones, 2003; Melzack, 1987). Participants responded to a series of sensory (11 items) and affective (4 items) adjectives that could describe pain. Responses ranged from *None* (0) to *Severe* (3), and a summed total score was calculated (higher scores indicate greater pain experience). Previous research with the MPQ short form demonstrated validity, reliability, and sensitivity to pain (e.g., Hawker, Mian, Kendzerska, & French, 2011; Lovejoy, Turk, & Morasco, 2012; Melzack, 1987). Across administrations, internal consistency was strong (α = .856 – .901).

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**Figure 1.** Study timeline.
**Pain Anxiety Symptom Scale (PASS)**
Participants completed the 40-item PASS to assess four components of subjective fear of pain: (a) cognitive anxiety symptoms related to pain; (b) escape and avoidance responses to pain; (c) intensity of fearful appraisal of pain; and (d) somatic anxiety symptoms related to pain (McCracken, Zayfert, & Gross, 1992). Participants self-reported their responses on a scale from Never (0) to Always (5); higher summed scores were indicative of greater pain anxiety. Internal consistency was high (α = .926). Previous research with the PASS demonstrated validity via strong correlations with measures of anxiety, depression, and disability (Burns, Mullen, Higdon, Wei, & Lansky, 2000; McCracken et al., 1992).

**Cold pressor task**
Participants completed a cold pressor task to induce mild to moderate pain. Participants placed their non-dominant hand and forearm in a cold water bath (held to 32–45 degrees Fahrenheit; M = 39.38 degrees) for 60 seconds. During the task, participants were left alone in the room and a recording instructed participants when to place an arm in the water bath and when to rate their levels of pain. Participants were asked to rate their level of pain on a scale from No Pain (0) to Extreme Pain (10) every 20 seconds, with higher numbers indicative of greater levels of acute pain.

**Word Memory Task (WMT)**
Participants completed Green’s WMT to assess level of effort on cognitive tasks (Green, 2003). Participants learned a list of word pairs, and their memory of these word pairs were tested at 30- and 60-minute intervals. Previous research has demonstrated the efficacy of the WMT to detect malingering and enhance diagnostic accuracy across diverse clinical populations (e.g., Bauer, O’Bryant, Lynch, McCaffrey, & Fisher, 2007; Green, 2003). Immediate Recall (IR), Delayed Recall (DR), and Consistency (CNS), all calculated by the WMT scoring program, were used in the remaining analyses. Scores of 90 or higher indicated sufficient effort on the task, whereas scores falling below 90 were indicative of suspect or insufficient effort on the task.

**Iowa Gambling Task (IGT)**
Participants completed the standard computerized version of the IGT to assess risky decision-making (Bechara, 2007; based on Bechara et al., 1994). Participants started with a loan of $2,000 and were given instructions to maximize profit over 100 trials by selecting from four decks of cards (Decks A, B, C, and D). Selections from A and B resulted in an average profit of $100 per selection whereas C and D resulted in an average profit of $50 per selection. After making 10 selections from Decks A and B, participants incurred a net loss of $250. After making 10 selections from Decks C and D, participants instead incurred a net gain of $250 (Bechara et al., 1994). Thus, Decks A and B are “disadvantageous” and Decks C and D are “advantageous.”

Previous research indicated that the type of decision-making assessed on the IGT changes as the task progresses. Early trials of the IGT can be considered decision-making under ambiguity (Brand et al., 2007), as participants do not know much about the relative risks and benefits of each deck. The later trials (60 [Brand et al., 2007] or 40 [Ko et al., 2010; Noël, Bechara, Dan, Hanak, & Verbanck, 2007]) are instead termed decision-making under risk, as decisions are made with an understanding of the relative risks and benefits. For the present study, the number of advantageous minus disadvantageous selections were calculated for the early (Trials 1–40) and later (Trials 41–60) selections, with continued selections from the disadvantageous decks defining risky decision-making.

**Balloon Analogue Risk Task (BART)**
Participants completed the standard computerized version of the BART to assess real-world risky decision-making (Lejuez et al., 2002). Participants were presented with 30 balloons, one at a time, and were tasked with earning money by pumping up the balloons. However, the balloon pops if pumped too much, resulting in a loss of accumulated money from that trial. Successful completion of the BART includes banking the accumulated money before the specific balloon pops because once banked, money cannot be lost on subsequent balloons that pop. Unbeknownst to participants, each balloon has an explosion point ranging from 1 to 128 pumps (average = 64 pumps; Lejuez et al., 2002). On the BART but not the IGT, risk-taking behavior is rewarding: more pumps result in both more money and more risk of the balloon popping. As such, risky decision-making on the BART was defined as a higher average number of pumps per unexploded balloon (as it is unknown how far the participant would have gone on an explosion trial if the balloon had not popped).

**Self-reported measure of effort**
Participants completed a self-reported measure of effort during the post-manipulation tasks. Participants self-reported their effort on a scale ranging from No Effort At All (0) to The Most Possible Effort (100).
**Procedure**

After providing informed consent, participants completed an assessment of demographic variables and subjective pain-related fear (TSK, PCS) as part of a separate study. In the next study session, and after providing additional informed consent, participants completed the PANAS, MPQ-SF, PCS, and PASS prior to completing the cold pressor task (see Figure 1 for study timeline). For the cold pressor, participants were instructed to submerge their non-dominant hand and forearm into a cold water bath for 60 seconds. During this time, they were left alone in the lab and the instructions for the cold pressor task were played via an audio recording. Participants were asked to rate their level of pain every 20 seconds. After completion of the cold pressor task, participants completed a second administration of the PANAS and MPQ-SF prior to the study manipulation.

For the study manipulation, participants received one of four sets of instructions to follow for the remaining tasks. In the first manipulation (Pain Threat, $n = 36$), participants received a threat of additional physical pain, in that they might need to repeat the cold pressor task based on previous questionnaire responses (see Table 1 for complete instructions for all conditions). In this condition, participants were not allowed to “correct” their performance to avoid a second cold pressor task. In the second manipulation (Pain Threat With Control, $n = 39$), participants were again told they might need to complete a second cold pressor task, based instead on performance on the upcoming cognitive tasks (i.e., participants could avoid additional physical pain by altering task performance). In the third manipulation (Cognitive Threat With Control, $n = 34$), the threat of physical pain was replaced with threat of cognitive “pain” (i.e., the completion of a paced auditory serial addition task). As in the second manipulation, performance on upcoming cognitive tasks determined if participants would have to complete the cognitive pain task. The final manipulation was a control condition (Control, $n = 36$), in which there was no threat of additional pain. Following the study manipulation, participants completed the WMT, IGT, BART, and self-reported assessment of effort on cognitive tasks. At the end of the study, participants were debriefed and course credit was assigned.

**Data analysis**

Several analyses were conducted. To assess the first hypothesis, one-sample t-tests examined whether participants exhibited a preference for advantageous decks on the IGT. In addition, linear regressions were conducted with group assignment and average level of pain during the cold pressor task as the predictors and the following outcome variables: self-reported effort, WMT (IR, DR, CNS), IGT (Trials 1–40, 41–100), and the BART. As group assignment was a categorical variable, a series of dummy-coded variables were included in the regression models as follows: Group 1 ($1 = \text{Pain Threat}$, $0 = \text{all other conditions}$), Group 2 ($1 = \text{Pain Threat With Control}$, $0 = \text{all other conditions}$), and Group 3 ($1 = \text{Cognitive Threat With Control}$, $0 = \text{all other conditions}$). The Control condition served as the comparison group for these analyses. Finally, additional linear regressions were conducted with pain-related fear variables (TSK, PCS, PASS) as the predictors for performance on cognitive tasks.

**Results**

Means and standard deviations for study variables are presented in Table 2. Of note, decision-making (IGT: $n = 9$; BART: $n = 2$) and effort (WMT: $n = 5$) data were missing for several participants due to computer errors. First, we examined whether individuals who experienced mild physical pain would experience a decrease in decision-making task performance (i.e., riskier decision-making), if level of reported pain during the cold pressor would be negatively associated with task performance, and how the

<table>
<thead>
<tr>
<th>Condition</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain Threat</td>
<td>At this time, I need to make several calculations based on your performance on this cold water task and your previous questionnaire responses. Depending on my calculations, you may need to complete a second cold water task, this time for a longer period of time with colder water. While I am making those calculations, I have a few additional tasks for you to work on as part of a different study. These additional tasks that you will be working on will not be used in my calculations.</td>
</tr>
<tr>
<td>Pain Threat With Control</td>
<td>At this time, I have several additional tasks for you to complete. Based on your performance on these tasks, you may need to complete a second cold water task, this time for a longer period of time with colder water.</td>
</tr>
<tr>
<td>Cognitive Threat With Control</td>
<td>At this time, I have several additional tasks for you to complete. Based on your performance on these tasks, you may need to complete an intensive working memory task in which you will need to listen to a series of numbers. While listening to those numbers, you will need to add each number to the one you heard before it.</td>
</tr>
<tr>
<td>Control</td>
<td>At this time, I have a few remaining tasks for you to complete.</td>
</tr>
</tbody>
</table>
study manipulations affected subsequent task performance. In the entire sample, no preference for advantageous decks on the IGT emerged, \( t(88) = 0.397, p = .692 \), indicating participants failed to learn to decide advantageously following an acute pain experience.

Next, associations between level of pain and task performance were examined. See Table 3 for a summary of the regression analyses. No significant findings emerged on the WMT, but group assignment was significantly predictive of self-reported level of effort on cognitive tests. Participants in the Pain Threat With Control condition reported a lower level of effort than participants in the Control condition. On the IGT, participants in the Pain Threat condition made riskier decisions during the early trials (1–40) than participants in the Control condition. On the BART, both group assignment and level of pain predicted performance. Greater levels of pain on the cold pressor were associated with less risky decisions on the BART, and participants in the Cognitive Threat with Control condition made less risky decisions than participants in the Control condition.

We also examined the relationship between pain-related fear and performance on cognitive tasks. A set of linear regressions were conducted with the pain-related fear variables (TSK, PCS, PASS) as the predictors. Of note, the PCS was completed both as part of a screening and at the start of the testing session in a subgroup of the participants (\( n = 95 \)). These scores were significantly correlated, \( r = .671, p < .001 \); however, multiple data points were lost due to computer errors in the screening, and the second PCS administration (prior to the cold pressor task) was utilized for the remaining analyses. Significant predictors again emerged for self-reported effort on cognitive tasks (see Table 4 for statistical information). Greater PASS was predictive of higher self-reported effort. On the WMT, greater TSK but lower PASS scores predicted better performance on IR, DR, and CNS. Greater PCS scores predicted better WMT DR only. No significant predictors emerged for the IGT or BART.

### Discussion

The present study examined the influence of acute pain and pain-related fear on risky decision-making and effort during cognitive tests. Several hypotheses were examined. First, we hypothesized that the experience of acute pain, independent of pain-related fear or the study manipulations, would lead to risky decision-making, and level of self-reported pain would be negatively associated with performance on the decision-making and effort measures. Contrary to these hypotheses, mild physical pain during the cold pressor was predictive of advantageous performance on the BART but not the IGT. On the IGT, participants failed to learn to decide advantageously (overall performance),

### Table 2. Means and standard deviations for study variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pain Threat</th>
<th>Pain Threat With Control</th>
<th>Cognitive Threat With Control</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>36</td>
<td>39</td>
<td>34</td>
<td>36</td>
</tr>
<tr>
<td>Age</td>
<td>20.00 (.82)</td>
<td>18.82 (1.07)</td>
<td>18.74 (0.96)</td>
<td>19.90 (4.71)</td>
</tr>
<tr>
<td>Gender (% Male)</td>
<td>47.20%</td>
<td>50.00%</td>
<td>38.20%</td>
<td>39.40%</td>
</tr>
<tr>
<td>Ethnicity (% Caucasian)</td>
<td>56.70%</td>
<td>69.40%</td>
<td>59.40%</td>
<td>58.60%</td>
</tr>
<tr>
<td>Average Pain on CP</td>
<td>5.95 (2.02)</td>
<td>6.19 (2.42)</td>
<td>6.00 (2.47)</td>
<td>6.24 (2.43)</td>
</tr>
<tr>
<td>TSK</td>
<td>38.11 (8.27)</td>
<td>37.45 (8.53)</td>
<td>37.52 (7.17)</td>
<td>39.81 (9.58)</td>
</tr>
<tr>
<td>PASS</td>
<td>60.64 (27.18)</td>
<td>62.11 (28.98)</td>
<td>63.50 (26.31)</td>
<td>76.58 (24.01)</td>
</tr>
<tr>
<td>PCS</td>
<td>15.36 (10.16)</td>
<td>12.97 (11.10)</td>
<td>16.06 (11.46)</td>
<td>20.58 (12.33)</td>
</tr>
<tr>
<td>MPQ-SF Time 1</td>
<td>2.67 (4.90)</td>
<td>1.95 (4.02)</td>
<td>1.21 (1.81)</td>
<td>1.31 (1.82)</td>
</tr>
<tr>
<td>MPQ-SF Time 2</td>
<td>7.69 (6.87)</td>
<td>7.08 (7.76)</td>
<td>6.39 (5.76)</td>
<td>6.50 (8.40)</td>
</tr>
<tr>
<td>PANAS-N Time 1</td>
<td>1.39 (0.43)</td>
<td>1.43 (0.51)</td>
<td>1.49 (0.43)</td>
<td>1.59 (0.53)</td>
</tr>
<tr>
<td>PANAS-P Time 1</td>
<td>2.89 (0.79)</td>
<td>3.09 (0.74)</td>
<td>2.84 (0.86)</td>
<td>3.06 (0.74)</td>
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<tr>
<td>PANAS-N Time 2</td>
<td>1.49 (0.51)</td>
<td>1.54 (0.65)</td>
<td>1.52 (0.60)</td>
<td>1.47 (0.55)</td>
</tr>
<tr>
<td>PANAS-P Time 2</td>
<td>2.69 (0.86)</td>
<td>2.79 (0.85)</td>
<td>2.69 (0.91)</td>
<td>2.87 (0.91)</td>
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<tr>
<td>Self-reported effort</td>
<td>74.77 (18.98)</td>
<td>72.50 (25.68)</td>
<td>80.81 (17.11)</td>
<td>82.13 (17.27)</td>
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<tr>
<td>WMT-IR</td>
<td>95.99 (6.41)</td>
<td>95.00 (7.21)</td>
<td>95.50 (5.88)</td>
<td>94.61 (11.95)</td>
</tr>
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<td>WMT-DR</td>
<td>96.94 (5.53)</td>
<td>96.42 (5.61)</td>
<td>97.67 (4.01)</td>
<td>97.66 (4.11)</td>
</tr>
<tr>
<td>WMT-CNS</td>
<td>95.36 (6.21)</td>
<td>94.03 (7.94)</td>
<td>94.36 (6.96)</td>
<td>94.14 (11.73)</td>
</tr>
<tr>
<td>IGT A-D 1–40</td>
<td>–4.71 (8.46)</td>
<td>–2.67 (8.93)</td>
<td>–0.45 (9.31)</td>
<td>0.55 (15.94)</td>
</tr>
<tr>
<td>IGT A-D 41–100</td>
<td>3.43 (21.41)</td>
<td>2.22 (18.84)</td>
<td>3.61 (17.92)</td>
<td>6.36 (22.77)</td>
</tr>
<tr>
<td>IGT Total</td>
<td>–1.29 (26.50)</td>
<td>–0.44 (22.69)</td>
<td>3.16 (21.28)</td>
<td>6.91 (33.52)</td>
</tr>
<tr>
<td>BART</td>
<td>25.80 (13.95)</td>
<td>26.05 (15.30)</td>
<td>23.06 (11.44)</td>
<td>30.47 (14.52)</td>
</tr>
</tbody>
</table>

CP = cold pressor task, average pain on 0 (no pain) to 10 (high level of pain) scale; TSK = Tampa Scale of Kinesiophobia; PASS = Pain Anxiety Symptoms Scale; PCS = Pain Catastrophizing Scale; MPQ-SF = McGill Pain Questionnaire Short Form, Pain Rating Index; PANAS = Positive and Negative Affect Schedule, Positive and Negative subscales; WMT = Word Memory Test, Immediate Recall, Delayed Recall, Consistency; IGT = Iowa Gambling Task, Advantageous minus Disadvantageous selections by blocks of trials; BART = Balloon Analogue Risk Task, average adjusted pumps per balloon.
but individual differences in self-reported level of pain did not predict this impaired performance. Our findings diverge from Koppel et al. (2017), who found acute pain led to riskier monetary decisions when the decisions involved potential gains instead of potential losses. However, Koppel et al. utilized a risky gains task whereas the present study utilized the IGT and BART to assess risky decision-making. On the risky gains task, participants chose between safe and risky decisions, and decisions were made over a twelve-second period in which participants were forced to make a decision before time expired. There are no time restrictions on the IGT or BART, which could account for some of the differences between study findings. In addition, it is impossible to tell from the present study if participants focused on potential gains or potential losses while deciding on the IGT and BART, whereas on the risky gains task, this focus is testable. The method used to induce acute pain also varied between the studies. Finally, Koppel et al. examined decision-making during the acute pain induction, whereas we assessed decision-making following both the acute pain induction and pain-related fear manipulation. Inducing pain during a decision-making task might result in a more attentionally salient, distracting situation that could result in increased cognitive load (and thus impaired task performance). However, future research is needed to better tease apart how acute pain impacts decision-making task performance at different points in the decision-making process, as well as on other decision-making tasks such as the Columbia Card Task (Figner, Mackinlay, Wilkening, & Weber, 2009), Game of Dice Task (Brand et al., 2004), and other financial and risky decision-making tasks.

Next, we assessed the hypothesis that individuals experiencing a threat of additional pain without control over the threat (Pain Threat) would make riskier decisions and exert less effort than participants with the same threat but control over it (Pain Threat With Control). Group assignment predicted self-reported level of effort on cognitive tests, but not performance on a formal measure of effort (WMT). The effect on self-reported effort was due to participants in the Pain Threat with Control condition reporting less effort than those in the Control condition. In the pain-threat manipulations, participants were told that they may need to repeat the cold pressor task.
a second time, based on their performance on previously completed tasks/questionnaires (Pain Threat) or on upcoming tasks (Pain Threat With Control). Participants in the Pain Threat With Control manipulation had the ability to change their exposure to future pain based on their upcoming task performance. However, these participants failed to put forth greater effort on subsequent tasks. It may be the case that the threat of additional pain, coupled with performance demands to avoid future pain, was burdensome to participants and reduced self-reported effort. These findings may suggest the overall negative impact of physical pain threat on task performance, and provide additional evidence that the thought of pain can occupy attentional resources to the detriment of task completion (Crombez, Eccleston, Baeyens, & Eelen, 1998b). Attentional preoccupation with the threat of additional pain may have affected level of self-reported effort on cognitive tasks, but, consistent with Suhr and Spickard (2012), this was not shown on the WMT, possibly due to difficulties differentiating subtle changes in effort.

In terms of the effects on decision-making, several predictors of performance on the IGT and BART emerged. During the early IGT trials (1–40), participants in the Pain Threat condition made riskier decisions than participants in the Control condition. On the BART, participants in the Cognitive Threat with Control condition made less risky decisions than participants in the Control condition. The threat of pain, and not the experience of acute pain itself, lead to riskier decision-making. Coupled with our previously discussed findings regarding the influence of high levels of pain resulting in less risky decision-making on the BART, we see a pattern in which risky decision-making on this task became less risky when individuals experienced pain and were threatened with additional pain and given the opportunity to avoid future pain. Previous research has shown that on simple discrimination tasks, increased pain led to worse performance (Crombez et al., 1998a, 1998b), yet pain and the threat of additional pain improved performance on a complex decision-making task. Similar to the present study’s findings, work by Porcelli and

| Table 4. Pain-related fear and task performance. |
|-----------------|-----------------|-----------------|-----------------|
| Criterion       | Predictor       | F   | p   | R²  | B   | t   | p   |
| Self-reported effort | TSK            | 2.029 | .115 | .057 | 0.100 | 1.020 | .310 |
|                 | PCS            | –0.207 | –1.377 | .172 |
|                 | PASS           | 0.311 | 2.059 | .042 |
| WMT-IR          | TSK            | 7.478 | <.001 | .180 | 0.358 | 3.924 | <.001 |
|                 | PCS            | 0.251 | 1.816 | .072 |
|                 | PASS           | –0.434 | –3.108 | .002 |
| WMT-DR          | TSK            | 3.726 | .014 | .101 | 0.221 | 2.292 | .024 |
|                 | PCS            | 0.317 | 2.146 | .034 |
|                 | PASS           | –0.390 | –2.622 | .10 |
| WMT-CNS         | TSK            | 5.469 | .002 | .141 | 0.306 | 3.244 | .002 |
|                 | PCS            | 0.219 | 1.520 | .132 |
|                 | PASS           | –0.397 | –2.735 | .007 |
| IGT A-D 1–40    | TSK            | 0.637 | .593 | .019 | –0.132 | –1.296 | .198 |
|                 | PCS            | 0.061 | 0.389 | .691 |
|                 | PASS           | –0.007 | –0.047 | .963 |
| IGT A-D 41–100  | TSK            | 0.635 | .594 | .019 | –0.104 | –1.023 | .309 |
|                 | PCS            | –0.079 | –0.518 | .605 |
|                 | PASS           | –0.004 | –0.029 | .977 |
| BART            | TSK            | 1.027 | .384 | .029 | –0.154 | –1.551 | .124 |
|                 | PCS            | 0.063 | 0.421 | .675 |
|                 | PASS           | 0.049 | 0.325 | .746 |

TSK = Tampa Scale of Kinesiophobia; PASS = Pain Anxiety Symptoms Scale; PCS = Pain Catastrophizing Scale; WMT = Word Memory Test, Immediate Recall (IR), Delayed Recall (DR), Consistency (CNS); IGT = Iowa Gambling Task, Advantageous minus Disadvantageous selections by blocks of trials; BART = Balloon Analogue Risk Task, average adjusted pumps per balloon.
Delgado (2009) examined financial decision-making, finding that participants in the cold pressor task condition exhibited advantageous decision-making with gains compared to participants in a control (no cold pressor task) condition. The authors explained this result in the context of dual-process theory, which posits that decision-making functions according to an automated, effortless intuitive system and a controlled, effortful reflective system (Frankish, 2010). When experiencing stress (e.g., acute pain from cold pressor task), the reflective system is theorized to be inhibited, leading to increased risk taking in the loss domain but decreased risk taking in the gain domain (Frankish, 2010; Porcelli & Delgado, 2009).

Utilizing the IGT, previous researchers have shown stress can decrease performance (i.e., lead to riskier decisions) on the task (Cella, Dymond, Cooper, & Turnbull, 2007; Pabst, Brand, & Wolf, 2013; Pabst, Schoofs, Pawlikowski, Brand, & Wolf, 2013), as can the experience of chronic pain (Apkarian et al., 2004; Muñoz Ladrón de Guevara et al., 2018; Tamburin et al., 2014). Our findings during the early trials of the IGT (1–40) replicate and expand these findings, showing that threat of pain without control led to riskier decision-making. However, on the BART, if the threat of experiencing additional pain is conceptualized as a stressful situation, then this threat did not lead to a change in task performance consistent with previous research. The threat of cognitive pain with control led to improved decision-making on the BART, indicating participants might have actually relied more on the reflective than intuitive system when making these decisions. Additional research is needed to tease apart the reasons why the threat of additional physical and cognitive pain, when the participants were both able and unable to control the situation (i.e., could not change their outcome based on task performance), would lead to different decision-making profiles on the IGT and the BART.

It is interesting to note that no significant findings emerged on the later IGT trials (Trials 41–100). Examining the group means, all groups showed an improvement (i.e., a preference for advantageous decks) in the later trials compared to the earlier trials. But, total performance falls short of the recommended cut-off for advantageous performance on the task (i.e., total score of 10 or higher across all 100 trials; Bechara et al., 2001), even among those in the control group. These findings are, however, consistent with Steingroever, Wetzels, Horstmann, Neumann, and Wagenmakers (2013), who found evidence that more recent samples of healthy control participants show lower total IGT performance and greater variability in scores than among participants in the earlier IGT studies. This variability in scores across healthy control undergraduate students participants might have contributed to our relative lack of findings with this measure.

We also examined the potential influence of pain-related fear on decision-making and effort. No specific hypothesis was made, but rather two potential directions were assessed: (1) high pain-related fear could lead to riskier decision-making and low effort on tasks, and (2) high pain-related fear could lead to improved decision-making and effort on tasks. Our results supported the second direction. Greater PASS was predictive of higher self-reported effort. On formally assessed measures of effort (WMT), greater TSK but lower PASS scores predicted better performance on IR, DR, and CNS. Greater PCS scores predicted better WMT DR only. No significant predictors emerged for the IGT or BART. This second set of evidence instead indicates high pain-related fear could result in improved effort on tasks. There were some fluctuations in pain-related fear across the randomized conditions, which could be due to the PCS detecting variations in pain sensitivity among healthy control participants (e.g., Fillingim et al., 2005; Seminowicz & Davis, 2006; Sullivan et al., 1995). Future research should replicate and expand on this work with use of multiple formal measures sensitive to effort on cognitive tasks that would better elucidate this complex relationship.

The present study has several important limitations to consider when interpreting the results. First, participants were a sample of convenience which may limit generalizability. However, utilizing a non-patient sample allowed us to examine more directly the separate influence of acute pain on cognition, rather than the influence of acute pain in someone with a history of chronic pain (which would potentially be the case if a patient sample was obtained). In addition, our sample size limited our ability to detect small effects. Our exclusion criteria limited participation to those without significant medical histories, and it would be interesting to see the effects of pain-related fear on effort and decision-making in participants with such a history. Potential confounding variables such as anxiety, current life stress, and depression were not assessed in the present study. Future research should account for these variables to better discern how each impacts the acute pain experience, pain-related fear, and subsequent task effort and decision-making. We also did not assess the extent to which our cognitive pain manipulation was actually viewed by participants as cognitively painful, which could have affected our findings in this group. Our Pain Threat and Pain Threat with Control...
manipulations might have been subtle to participants, and more robust findings could occur with a less subtle manipulation. The researcher left the room during the cold pressor task so as not to bias perceptions of pain; however, that meant there was no way to confirm that participants actually kept their arms submerged for the full 60 seconds. We relied on participant self-report but future research should utilize a more empirical means to assess completion of the cold pressor. Finally, we limited our assessment of risky decision-making to the IGT and BART, and of effort to the WMT and a self-reported measure. The IGT and BART do not assess overlapping components of decision-making (Buelow & Blaine, 2015) and do not adequately assess the entire constructs of decision-making or risky decision-making. In addition, the WMT, though a standard in the neuropsychology field, is not the only assessment of effort and should be utilized in conjunction with other formal measures of effort. Using an array of decision-making and effort tasks could help better pinpoint the effects of acute pain and pain-related fear on specific elements of task performance.

Taken together, these results indicate that the experience of acute pain can have an effect on decision-making, and the threat of additional pain, coupled with high levels of pain-related fear, can affect both decision-making and effort on cognitive tasks. These results provide some guidance to future studies aimed at investigating how pain-related fear may be seen as beneficial to individuals in the short-term despite long-term negative outcomes. Additionally, these results add to the existing literature on hypervigilance and avoidance of the pain experience, highlighting the complicated function of pain-related fear on complex cognitive processes. Future research is needed to better tease apart hypervigilance to and avoidance of a pain experience on cognitive tests, including type and nature of acute pain, time of acute pain induction during task completion, presence of threat during task completion, and the inclusion of additional decision-making and effort indices. In short, the present study highlights the need to continue examining pain-related fear outcomes in physical and cognitive domains to capture the complete picture of its effects on task performance in both healthy and patient populations.

Disclosure statement

No potential conflict of interest was reported by the authors.

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