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Does Working Memory Moderate the Within-Person Associations between Pain Intensity and Negative Affect and Pain's Interference with Work Goal Pursuit?

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Abstract

Objectives: Chronic pain exerts a pervasive negative influence on workers' productivity. However, a paucity of research has addressed the mechanisms underlying the pain → productivity relation. In the present study using intensive daily diary data, we examined whether working memory (WM) moderates the positive within-person associations between (a) morning pain intensity and (b) morning negative affect and later day pain's interference of work-goal pursuit.

Methods: A community sample of 131 adults with chronic pain completed a battery of questionnaires, laboratory-measured WM, and a 21-day daily diary.

Results: WM did not moderate the positive within-person association between morning pain intensity and afternoon/evening ratings of pain's interference with work goal pursuit. However, individuals with higher WM showed significantly attenuated positive within-person association between morning negative affect and pain's interference with afternoon/evening work goal pursuit.

Discussion: WM appears to protect goal-relevant information from distractions due to negative affective arousal. The continued use of ecologically valid observational and intervention studies would shed further light on the influence of WM on the pursuit of valued work goals in the face of pain and negative affect.

Keywords

Chronic pain; goal pursuit; negative affect; working memory; emotion-regulation; daily diary

Introduction

Chronic pain is a major socioeconomic health issue. The estimated annual cost of treating chronic pain is \$635 billion, which surpasses the annual cost of treating any other chronic illness.¹ Cost related to loss of work productivity represents one of the largest proportion of the total societal cost caused by chronic pain.² It is estimated that lost work productivity brought about by chronic pain costs up to \$61.2 billion per year, accounting for almost 30%

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of the total work-related burden of pain conditions in the United States.³ Yet, although the association between chronic pain and lost worker productivity is well established^{4–7}, the mechanisms that undergird this relationship remain to be fully articulated.

One avenue for investigating how the experience of persistent pain negatively influences vocational commitments and actions is to compare the attitudes, beliefs, and motivational styles of persons with chronic pain who have remained at work with those who have either disengaged from work due to pain or who are pain free. For example, drawing from a nationally representative sample of U.S. adults with chronic pain by means of random digit dialing procedures, Karoly, Ruehlman and Okun⁸ found that continued employment, in contrast to being on disability, was negatively related to a belief in a medical cure for pain and to the tendency to catastrophize. Attitudes reflecting task persistence (e.g., “I do not let my pain get in the way of what I want to do”) positively predicted continued employment. In a separate study focusing on a national sample of working adults, Karoly and Ruehlman⁹ compared the responses of managers with persistent or episodic pain to those with no pain on the Goal Systems Assessment Battery (GSAB). Inspired by a cybernetic model of adaptive control systems¹⁰, the GSAB gauges a set of governing functions underlying the process of goal regulation and pursuit. The Directive Function consists of measures of Value (This goal is important to me) and Self-Efficacy (I possess the necessary skills to attain this goal). The Control Function assesses Goal Planning, Self-Criticism, and Self-Reward. The Arousal Function includes measures of goal-related Positive and Negative Affect. They found (among other things) that those with pain tended to report lower levels of goal-centered self-efficacy along with heightened levels of goal-based self-criticism and negative arousal. Although some motivational and attitudinal patterns have been reported in cross-sectional surveys¹¹, these findings provide limited understanding of *how* momentary experiences of pain adversely influence certain individuals more than others in their work.

In contrast to static, cross-sectional surveys and between-group comparisons, recently researchers have used daily diaries to explore the within-person dynamics of goal-related thought, affective reactions, and vocational performance as they unfold in real time. For example, Karoly, Okun, Enders, and Tennen¹² asked adults with chronic pain who were working full- or part-time to complete a telephonic diary for 21 days. Each morning, participants answered questions about their anticipatory goal cognitions (or *goal schemas*) that assess the extent to which participants think their self-selected work-related and lifestyle goals are important, their planning for how to pursue them, and their expectancy about having opportunities to pursue these goals. In addition, pain intensity levels were measured three times per day (morning, afternoon, and evening) and work and lifestyle goal pursuit were assessed in the afternoon and evening. Multilevel modeling revealed that when a participant experienced greater than usual pain intensity in the morning, he or she reported less positive schematic thoughts about work and lifestyle goals, which was then related to decreased likelihood of goal pursuit in the afternoon and evening.

The Role of Negative Affect

Although some intriguing relationships between momentary pain and work-related goal schema and goal pursuit emerged from the above-noted analyses, other factors may likewise

figure prominently in the process of goal pursuit among workers with chronic pain. Negative affect represents one such potentially important state-level factor. For example, the momentary experience of high negative affect can activate an information processing bias which may render individuals *hyper-vigilant* for potential threat.^{13,14} It has been also suggested that negative affect functions as part of a harm-avoidance motivational system^{15,16} that biases overall information processing and that can constrain one's choice of goals and impact self-regulation.¹⁷ Thus, it is reasonable to presume that negative affect can function as a potential disruptor of daily goal pursuit.

Working Memory as a Moderator

Self-regulation refers to the processes involved in motivating goal-directed perceptions, thoughts, actions, emotions, and physiological reactions in response to contextual challenges via the mobilization of specific skills, resources, and strategic knowledge^{18–21}. Workers with chronic pain face a great many daunting regulatory challenges to the flexible and effective performance of their job-related duties including pain-derived threats to their ability to control their attentional focus and to access goal-relevant information in support of vocational objectives. A specific cognitive resource system believed to enable people to stay on course toward their goals (of whatever sort) in the face of interference from within (e.g., pain) or from external sources (e.g., distraction) has been labeled *working memory* (WM).^{22,23}

WM has been defined as a “system comprising encoding, maintaining, and retrieving from long term memory the information, goals, and strategies necessary to perform a task.”²³ The importance of WM for goal pursuit was demonstrated in a study by Avery, Smillie and de Fockert²⁴ in which the experimental loading of WM led to performance decrements in the pursuit of achievement goals. WM is also considered particularly important as a clinical target because it is presumed to play a key role in avoiding errors in the planning, management, and execution of complex behaviors. Moreover, there are also a number of studies that have examined the effects of working memory on pain and negative affect. For instance, Legrain, Crombez, Verhoeven, and Mouraux (2011)²⁵, experimentally demonstrated that working memory can prevent participants from experiencing involuntary attention capture by acute nociceptive stimuli while maintaining attention to non-pain goals. Also, individuals with higher working memory capacity are less likely to report negative affective reactions induced by the cold-pressor task.²⁶ Hence, having measured several so-called “executive functions” in our pre-diary assessment, we elected to examine WM as a potential moderator of the effects of pain intensity and negative affect on work-goal interference.

The present study

Our previous study²⁷ examined the effect of morning pain and affect on afternoon pain's interference with work goal pursuit and evening work goal progress, as well as the moderating effects of pain acceptance and pain catastrophizing in a community sample of adults who completed 21-day diary. The hypotheses tested in the present study are derived from the same data set, but extend this work by focusing on whether WM moderates the within-person associations between both morning pain and morning negative affect and

pain's interference with work goal pursuit in the afternoon and evening. Although the outcome of the present study (i.e., a composite of afternoon and evening pain's interference with work goal pursuit) is slightly different from that employed in the Mun et al. study²⁷ (i.e., afternoon pain's interference with work goal pursuit), we nonetheless expect that both morning pain and morning negative affect will be positively associated with pain's interference with work goal pursuit in the afternoon and evening.

We hypothesized that the significant, positive within-person associations between (a) pain intensity and (b) negative affect and pain's interference with work goal pursuit in the afternoon/evening would be moderated by WM. Individuals with higher WM were expected to be less impacted than those with lower WM by the experience of greater than usual pain and negative affect in the morning for the following reasons: (1) WM is known to assist the active mental representation of personal goals and values^{28–30} and (2) WM functions as a top-down source of resistance to extraneous, attention-capturing stimuli^{31,32} and may act to shield goal-relevant information from interference.³³ In testing these hypotheses, several individual difference factors known to exert some influence on WM and on pain intensity, negative affect, and goal pursuit served as control variables, including sleep quality, level of emotional distress (i.e., depression, anxiety, and stress), chronic pain severity, duration of chronic pain, age, and gender^{34–40}. Figure 1 depicts the hypothetical model tested in the present study.

Methods

Participants

Eligible individuals were obtained by a local telephone survey organization which used computer-based random-digit dialing to generate phone calls to residents in selected zip codes in the Phoenix metropolitan area located within approximately 20 miles of the study research facility. Residents who answered the phone were screened by the recruiters using a script designed by the authors. To be eligible, individuals were required to (a) be between 25 and 70 years old (this age limit was based upon the national norms of the Profile of Chronic Pain, which was used to determine the study eligibility for chronic pain), (b) have experienced physical pain almost every day for the past six months, (c) be able to read English at least a third grade level, (d) not be color blind, (e) work at a paid job during the day either full-time or part-time, (f) not have taken illegal substances in the past 12 months, and (g) be able to complete three diary calls every day for 21 days. In addition, potential participants were screened using a 4-item self-report chronic pain severity questionnaire (i.e., Profile of Chronic Pain-Screen). Cut off scores for inclusion in the study were determined separately by age and sex based on a national normative study.^{41,1}

Among the 318 adults who were eligible to participate, 155 (48.7 percent) declined participation. The remaining 163 eligible persons who agreed to participate were scheduled for a laboratory appointment. Sixteen participants (9.8 percent) never appeared for any scheduled appointments (even after several attempts at re-scheduling). Among the 147

¹The chronic pain severity cut off scores are as follows: age 25–44 (male: 10.74 and female: 11.38); age 44–65 (male: 11.38 and female: 13.17); age 65–80 (male: 9.25 and female: 12.74).

subjects who arrived for their initial assessments, 16 (10.9 percent) were found to be ineligible for one of the following reasons: (a) not currently working, (b) unable to articulate an important work goal, or (c) not able to complete phone-based diaries 3 times a day for 21 days. Thus, the final sample for the current study consists of 131 participants. Participant status (refusals, no shows, and disqualifications) did not significantly differ by age, sex, gender, ethnicity, or zip code. A more detailed result on the representativeness of the final sample is available in our previously published manuscripts.^{12,27}

Procedure

All procedures employed in this study were approved by the Institutional Review Board at Arizona State University. Participants provided written informed consent. Participants were paid \$45 for participating in a 150-minute lab visit; and subsequently up to \$155 if almost all diaries were completed. During the lab visit, participants received a hands-on demonstration and practice session regarding the special features of the interactive voice response (IVR) system for collection of diary data. Participants were told that they would be called via the IVR system three times a day for 21 consecutive days, placing a total of 63 diary calls of about 5 minutes each. If they were unavailable at the time of the call, participants were able to complete the diary by calling back during fixed time windows. During face-to-face training, research staff explained the required time windows for placing the morning (6:00 to 10:00 AM), afternoon (noon to 4:00), and evening calls (7:00 to 11:00 PM). During the practice session, participants took part in an automated interview answering the questions via the telephone number pad. Staff members also showed the participant the diary interview scripts containing the questions for each time of day. After participants indicated they felt confident with using the IVR system, a staff member conducted a goals elicitation interview.

Participants were asked to list important work and life style goals that fit the following criteria: (a) highly valued, (b) realistically obtainable, (c) concrete and measurable, and (d) pursued almost every day for the next 21 days. From the list generated, the most important work goal and the most important life style were identified by the participant. Work goals were defined as “a personally valued outcome toward which effort is consistently directed while you are on the job.” Lifestyle goals were defined as “things that make your life better such as goals for physical health, mental health, social relationships, intellectual pursuits, hobbies, recreation, spirituality, or community service.” Because the present report focuses on work goal pursuit, only data pertaining to work goals were included in the analyses.

Next, participants were presented with the first half (90 items) of the study questionnaire that includes demographic data, personality characteristics, and pain experiences. After completing the first half of the questionnaire, participants performed a WM task (described below) and three other executive function tasks (i.e., Stroop Test, Wisconsin Card Sorting Test, and Verbal Fluency Test) that were administered in random order by research staff. Note that the present study focused only on the WM task for pragmatic reasons (i.e., the results of a large number of interactions can often be misleading) and because the self-regulation of work-related goals clearly depends upon the individual’s ability to maintain access to delayed intentions while effectively performing non-goal related activities. After

completing the cognitive tasks, participants responded to the second half (117 items) of the study questionnaire.

To conclude the lab visit, research staff gave participants a take-home packet of information with detailed instructions for completing diary calls using the IVR system, a copy of the diary interview script, and a wallet card with essential information needed to place diary calls (IVR phone number, log-in procedures and participant-identified goals).

IVR Technology

The present study was conducted using IVR technology hosted by the University of Connecticut Health Center. The IVR technology entailed a system that combined telephone service with computer-administered questionnaires. The system was interfaced with local area network stations for data input, storage, and backup. Participants called a toll-free number and provided their participant identification number. Then, participants answered pre-recorded questions by pressing numbers on the keypad of their touch-tone telephones.

Research staff monitored IVR system activity and identified participants who missed several calls in a row, so that friendly reminder calls could be made when needed. After the first 14 days of the 21-day diary period were completed, a “Thank You” note was mailed acknowledging the participant’s effort in complying with the diary procedure. Across all occasions and days, participants, on average, completed 89.5% of the interviews.

Chronic Pain Severity Screen

The Chronic Pain Severity Screen was administered during the telephone recruitment and typically one week later as part of the study questionnaire. It consisted of four questions⁴¹: (1) “Over the past 6 months, how often did you have this pain” with response options ranging from 0 (never) to 6 (daily)?” (2) “What was your AVERAGE level of pain on days when you had pain during the past six months, where zero means very little pain and nine means unbearable pain?” (3) “How often during the PAST 6 MONTHS have you had at least one hour’s worth of pain that hinders you from accomplishing your daily tasks with response options ranging from 0 (never) to 6 (daily)?” (4) “What was the GREATEST amount of pain you have had over the PAST 6 MONTHS, where zero means very little pain and nine means unbearable pain?” The correlation between the two assessments of the Chronic Pain Severity Screen was .68. The mean Chronic Pain Severity Screen score was 22.33 ($SD = 4.28$) at time 1 and 21.98 ($SD = 3.89$) at time 2, respectively. Mean scores on the Chronic Pain Severity Screen were consistent over time, $t(131) = 1.19$, $p > .05$. For the questionnaire version of the Chronic Pain Severity Screen, the internal consistency reliability, as indexed by coefficient alpha, was .69.

Measures

Work Goal Content—Participants provided a diverse listing of their most important work goals. Overall, work goals tended to be either task-oriented or interpersonally-oriented. Examples of task-oriented work goals include: “Create 4 new training modules for team members”, and “Prepare instructor materials for fall semester, and spend at least 3 hours per day doing this.” Examples of interpersonally-oriented work goals include: “Demonstrate

respectful tone when dealing with co-workers”, and “Manage emotional reactions when speaking on phone with other hospital personnel about patient medications.” Owing to their content heterogeneity, the work goals were not further sub-categorized.

Diary Measures

Pain Intensity: Participants answered the following question about morning pain intensity: “If a zero means no pain, and nine means pain as bad as it could be, on a scale from 0–9, what is your level of pain right now?” Note that afternoon and evening pain intensity were assessed, but not used in the present analyses.

Negative Affect: Negative affect was assessed with four items (i.e., nervous, upset, angry, and fearful) from the Positive and Negative Affect Schedule – Expanded Form (PANAS-X).⁴² Because fear is an important emotional aspect in chronic pain research, the ‘fearless’ item from the PANAS-X was reversed to ‘fearful’. Participants were asked to rate the intensity of each negative affect over the past 30 minutes using a scale ranging from 0 (not at all) to 9 (extremely). A morning negative affect score was formed by averaging ratings of the four items. The reliability of negative affect was computed at the between-person level (i.e., average of morning negative affect across 21-days). The value of the coefficient alpha assessed in this manner was 0.88 for the morning negative affect scale. Note that afternoon and evening negative affect were also assessed. Whereas afternoon NA was examined in post hoc analyses, evening negative affect was not used in the present study.

Pain Interference with Work Goal Pursuit: Interference with the most important work goal was assessed by asking participants to rate how much their pain interfered with their ability to effectively pursue their most important work goal, using a scale ranging from 0 (not at all) to 9 (extremely). Note that before participants were asked to rate pain interference they first responded to another item, called “Goal Pursuit”, that asked whether or not they had pursued their most important work goal in the afternoon or evening. Only participants who indicated that they had pursued their most important work goal in the afternoon or evening rated pain interference. For the entire sample, the percent of days that work goals were pursued in the afternoon and the evening were 54.2 percent and 49.9 percent.² Because afternoon and evening ratings of pain interference with work goal pursuit were highly correlated, $r = 0.71$, the mean of the two ratings was used as the outcome variable in the present study.

Working Memory Task and Procedure

Operation Span (OSPAN): OSPAN is a widely used measure of WM that has good reliability and is correlated with numerous real-world cognitive tasks such as reading comprehension and note-taking.^{43–46} In OSPAN tasks, participants solve simple arithmetic problems and recall words. Performance on the arithmetic problems is assumed to require the allocation of processing resources and thus captures attention that otherwise could be devoted to remembering the words. For this reason, the number of correct solutions on the

²Full-time and part-time employees did not differ in the percentage of days they did not pursue their work goals in the afternoon [$\chi^2(1) = 2.71, p = .10$] and in the evening [$\chi^2(1) = 2.39, p = .13$].

arithmetic problems is referred to as *processing* performance. The arithmetic problems constitute a *secondary* task designed to induce interference with the memory task. In contrast, remembering the list of words in the order that they appear involves storage of the words, accurate maintenance of previously exposed words while doing the arithmetic problems, and updating the list of remembered words as the participant is exposed to new words. Recall of words in their order of presentation is referred to as *storage* performance. Thus, recall of words in their order of presentation is the *primary* task. Structurally, the OSPAN task is comprised of *items*. An item can consist of 2 or more arithmetic problems and an equal number of words to be remembered in their order of presentation. The number of arithmetic problems (and words) varies, and, in our study, ranged from 2 to 6. We used a total of 10 items: 2 items consisted of 2 arithmetic problems and 2 words, 2 items consisted of 3 arithmetic problems and 3 words, 2 items consisted of 4 arithmetic problems and 4 words, 2 items consisted of 5 arithmetic problems and 5 words, and 2 items consisted of 6 arithmetic problems and 6 words. Thus, participants were exposed to a total of 40 arithmetic problems and 40 words. Each item presented different arithmetic problems and words.

The OSPAN task was administered by computer. Participants were given instructions and a practice item. Then, the order of the 10 items was randomly determined for each participant. Consider, for example, an item with two math problems and two words. Initially, a simple math problem was presented (e.g., $[5 \times 2] + 5 = 15$).

Each participant had 10 seconds to indicate whether the answer was correct or incorrect by pressing different keys. Then, the participant received feedback on whether his or her answer was correct. Next, a word-to-be-remembered appeared on the screen. This was followed by a second math problem and feedback on whether the answer was correct. Then, a second word to-be-remembered appeared on the screen. Finally, participants were asked to recall out loud the two words in the exact order that they appeared on the screen. Participants' oral recall of the words was recorded by the research staff and later scored as correct or incorrect.

The measurement of our moderator variable was derived from performance on the serial order recall of the words (i.e., the storage component of the task). To assess storage performance, we followed Conway, Kane, Bunting, Hambrick, Wilhelm, and Engle's recommendation⁴⁴ and used partial credit unit scoring. With partial credit unit scoring, for each item, we calculated the proportion of words that were correctly recalled in their serial order. These proportions were then summed across the 10 items. Finally, this sum was converted to a mean by dividing by 10. Thus, our storage performance measure represents the mean proportion of words within items that were correctly recalled in their serial order.

Conway and colleagues⁴⁴ recommended using processing performance scores as an exclusion variable. More specifically, they suggested discarding the entire OSPAN data set for any subject whose processing performance fell below 85% in order to ensure that participants were fully paying attention to all aspects of the WM task. To this end, our exclusion variable was calculated by dividing the number of correct answers on the math problems by .40.

In the present study, 32 individuals (about 24% of the sample) scored less than 85% on the processing performance test, and therefore the OSPAN data of these individuals was discarded.

Covariates

Chronic Pain Severity: The chronic pain severity measure from the Profile of Chronic Pain: Screen³⁷ was used to screen the current participants. It is computed as the average of four pain severity items.

Depression, Anxiety and Stress: Depression, anxiety and stress were measured using the Depression Anxiety Stress Scales (DASS).⁴⁷ Each item is rated on a 4-point Likert scale ranging from 0 (Never) to 3 (Almost Always). Examples of items for each subscale are: “I couldn’t seem to experience any positive feeling at all” (Depression); “I experienced trembling (e.g., in the hands)” (Anxiety); and “I tend to over-react to situations” (Stress). All three subscales have been shown to have excellent reliability as well as convergent and discriminant validity.^{47,48} The range of possible scores for each subscale extends from 0 to 21. The Cronbach’s alphas for depression, anxiety and stress subscales were .89, .79, and .84, respectively. Because the DASS subscales were highly correlated (i.e., Pearson r ranging from .60 to .64), the total mean score was used in the present study.

Mean Sleep Quality: To measure sleep quality, participants were asked to rate how restful their sleep was last night every morning using a scale ranging from 0 (not at all) to 9 (extremely). This measure was averaged across 21-days to compute mean sleep quality covariate.

Demographic covariates: Demographic variables, including the age, gender (0 = female; 1 = male), and duration of chronic pain, were included as level-2 covariates in the multi-level model.

Analytic Plan

Multilevel Modeling (Hierarchical Linear Modeling) was used to examine the hypothesized model. The analyses were conducted by IBM SPSS Statistics 22⁴⁹ using its MIXED commands.

Centering—Both level-1 (within-person) and level-2 (between-person) predictors were centered for two reasons. First, for the level-1 variables, it was expected that daily score values would depend on other scores of the same cluster (i.e., person). For instance, the interpretation of any daily pain score (e.g., a rating 4 out of 9) depends on the overall mean of a participant’s daily pain ratings (that is, a score of 4 is considered low if the person mean is 8, but is high if the person mean is 2). Thus, person-mean centering was used for level-1 predictors. In the case of level-2 variables, grand-mean centering was employed because the interpretation of score values does not depend on other scores of the same cluster (i.e., it reflects trait-like variation). Second, by centering the level-1 and level-2 predictors, the relationship between the two becomes orthogonal. To be specific, the level-1 predictors were centered at the person means⁵⁰ by subtracting each individual’s average rating for a variable

from the daily rating. The level-2 predictors were grand mean centered by subtracting mean of all the individuals from each individual's rating. Employing this strategy, we can assess the unique influence of level-1 and level-2 predictors on the outcome variable.

Overview of Multilevel Model—We tested a random intercept and random slope multilevel model for pain interference with work goal pursuit as the outcome. Note that, as shown in the Figure 1, the current model considers WM to be a moderator for two relationships: (1) morning pain and pain's work goal interference in the afternoon and evening; and (2) morning negative affect and pain's work goal interference in the afternoon and evening. The equation for this model is as follows:

$$Y_{ij} = \beta_0 + \beta_1 \text{Pain}_{ij} + \beta_2 \text{NA}_{ij} + \beta_3 \text{WM}_j + \beta_4 \text{Pain Severity}_j + \beta_5 \text{DASS}_j + \beta_6 \text{SleepQual}_j \\ + \beta_7 \text{Gender}_j + \beta_8 \text{Age}_j + \beta_9 \text{Pain Duration}_j + \beta_{10} (\text{Pain}_{ij})(\text{WM}_j) + \beta_{11} (\text{NA}_{ij})(\text{WM}_j) + \\ b_{0j} + b_{1j}(\text{Pain}_{ij}) + b_{2j}(\text{NA}_{ij}) + e_{ij}$$

Note. NA = morning negative affect, Pain Severity = Pain severity score from PCP:S; DASS = average of depression, anxiety, and stress score; SleepQual = 21-day average of sleep quality.

In this model, Y_{ij} is the outcome score (i.e., pain interference with work goal pursuit) at day i for person j . The intercept (β_0) quantifies the expected value (conditional mean) of afternoon pain interference with work goal pursuit for days where persons are at their average of the level-1 variables and at the grand mean of level-2 variables. β_{1-2} are coefficients for the level-1 predictors. β_{3-9} are the regression coefficients of the level-2 predictors. β_{10-11} are the coefficients of the cross-level interactions. Finally, b_{0j} is a random intercept that captures between-person variation in the outcome means, and e_{ij} is the level-1 residual.

We planned to probe significant cross-level interaction effects using procedures recommended by Aiken and West.⁵¹ More specifically, we planned to carry out a simple slope analysis to identify how the within-person association varied among participants (a) low, (b) medium, and high (c) in WM.

We also investigated random slopes in order to examine whether the influence of the level-1 predictors varied across persons. Likelihood ratio tests from restricted maximum likelihood estimation revealed that daily morning pain ratings, $\chi^2(2) = 17.02$, $p < .001$ and morning negative affect scores, $\chi^2(2) = 5.56$, $p = .062$ (marginally significant), required a random slope (i.e., the association between afternoon pain interference with work goal pursuit and morning pain and negative affect varied across persons). b_{1j} and b_{2j} are the random slopes for the level-1 predictors.

Results

Demographics of the Sample

Table 1 shows the sample demographic characteristics. Participants were predominantly middle-aged Caucasian with approximately 56% of the sample either married or partnered.

A majority of participants had a post high school education and reported experiencing chronic pain for two or more years. The most common diagnoses of chronic pain were back-injury related pain and osteoarthritis.

Preliminary Analysis

Means and standard deviations were calculated for both level-1 measures and for the level-2 measures. Intraclass correlations were calculated for level-1 measures. The inter-correlations between the level-1 variables and between the level-2 variables were also calculated. Results of these descriptive statistics are presented in Table 2. The correlations between morning pain, morning negative affect, and pain interference with work goal pursuit were all significant. The inter-correlations of the between person-level variables indicated that WM had moderate correlations with the outcome variable. The outcome variable was also moderately correlated with several covariates including pain severity, DASS total mean score, and mean sleep quality. WM was significantly, negatively correlated with chronic pain severity but not with the other covariates.

Attrition Analysis of OSPAN

We conducted attrition analyses in order to examine if a systematic sample bias existed among those whose OSPAN data had to be discarded. One-way ANOVAs were used when the dependent variables were continuous (i.e., age, average of morning pain, average of morning negative affect, and pain's interference of work goal pursuit in the afternoon and evening) and chi-square tests were used when the dependent variables were categorical (i.e., sex and ethnicity). The effect of Participant Status (those who scored 85% or higher in processing performance vs. who scored less than 85%) on age [$F(1, 129) = .04, p = .85$], average of morning pain [$F(1, 129) = .14, p = .71$] average of morning negative affect [$F(1, 129) = .213, p = .15$], and average of pain's interference with work goal pursuit in the afternoon and evening [$F(1, 129) = 2.31, p = .13$] were not significant. Furthermore, the association between Participant Status and Gender (male versus female) and Ethnicity (White vs. others) were not significant, $\chi^2(1) = 0.01, p = 1.00$, and $\chi^2(1) = 3.46, p = .06$, respectively.

Findings of the Multilevel Model

Effects of Morning Pain Intensity and Negative Affect on Pain's Interference with Work Goal Pursuit in the Afternoon and Evening—Table 3 gives the parameter estimates, standard errors, and t tests from the multilevel model described above. Compared to the unconditional model, which does not include any predictors, the level-1 predictors and cross-level interaction terms reduced the within-person variance from 2.16 to 1.44 (a 33.3% reduction). With respect to the main effects of the level-1 predictors, we found a significant positive coefficient for morning pain intensity, such that when a participant experienced greater than usual morning pain intensity, he or she reported more pain interference with work goal pursuit ($p = .003$) over and above morning negative affect. Also, morning negative affect was also positively associated with pain interference with work goal pursuit ($p = .017$), suggesting that on days with greater than average negative affect in the morning, people reported higher pain interference with work goal pursuit over and above morning

pain intensity. These associations suggest that on days when pain intensity increases by 1-point, pain's interference with work goal pursuit increases by a little over one-tenth of a point. And similarly, on days when negative affect increases by 1-point, pain's interference with work goal pursuit increases by one-tenth of a point. Although these increases in pain interference with work goal pursuit are modest, it is important to note that such changes, accumulating over time, could significantly undermine work productivity.

Moderation by Working Memory—The level-2 predictors including cross-level interaction terms reduced the between-person variance from 3.17 to 2.30 (a 27.5% reduction). Chronic pain severity ($p < .001$), DASS mean score ($p = .039$) and mean sleep quality ($p = .028$) were significant level-2 covariates. WM did not significantly moderate the within-person relation between morning pain and pain interference with work goal pursuit ($p = .719$) while controlling for all other covariates. On the other hand, WM moderated the within-person relation between morning negative affect and pain interference with work goal pursuit ($p = .038$) while controlling for all other covariates.

Simple Slopes Analysis—We carried out a simple slopes analysis to aid in the interpretation of this cross-level moderation effect and to provide a means of clarifying how the relationship between morning negative affect and pain interference with work goal pursuit tends to differ among participants with low, medium, and high WM (see Figure 2). A significant positive association between morning negative affect and pain's interference with work goal pursuit emerged when the participants' WM was (a) at the mean (simple slope $B = 0.10$, $SE = .04$, $p = .025$) and (b) one standard deviation below the mean (simple slope $B = 0.18$, $SE = .06$, $p = .003$). However, the association was not significant when participants' WM was one standard deviation above the mean (simple slope $B = 0.01$, $SE = .06$, $p = .805$). Thus, for participants one standard deviation below the mean on WM, on days when negative affect increases by 1-point, pain's interference with work goal pursuit increases by almost two-tenths of a point. Yet, for participants one standard deviation above the mean on WM, on days when negative affect increases by 1-point, pain's interference with work goal pursuit increases by only one-hundredth of a point.

The potential influence of cross-level interactions between level-2 covariates and morning negative affect (NA) were also examined. Even after controlling for all additional cross-level interaction terms in the model (i.e., NA x chronic pain severity, NA x DASS total score, NA x mean sleep quality, NA x age, NA x gender, and NA x duration of chronic pain), the interaction between morning NA and WM remained statistically significant ($B = -.55$, $SE = .27$, $p = .048$).

Post-hoc Analyses—We explored whether the proximal experience of negative affect is more strongly associated with pain's interference with work goal pursuit. We reasoned that this post-hoc test would shed further light on the idea of negative affect as a harm-avoidance motivational system that can interrupt important goal pursuit. Not surprisingly, the association between negative affect and pain's work goal pursuit interference was stronger when negative affect was assessed in the afternoon ($B = 0.14$, $SE = 0.04$, $p = 0.002$) as opposed to in the morning ($B = 0.10$, $SE = 0.04$, $p = 0.017$). Interestingly, when both morning and afternoon negative affect variables were included in the same model, the

association between morning negative affect and pain's interference with work goal pursuit remained statistically significant ($B = 0.09$, $SE = 0.04$, $p = 0.012$) indicating a robust effect of morning negative affect on pain's interference with work goal pursuit.

Discussion

Previous studies revealed that chronic pain tends to have an adverse effect on individuals' work performance, productivity, and motivation.^{3,5,6} However, there has been a dearth of studies examining how momentary aversive experiences such as pain and negative affect can undermine individuals' day-to-day work-related aspirations, and whether these associations can be moderated by working memory (WM). Using a community sample of individuals with chronic pain who completed a 21-day diary, the findings of the present study did not support our hypothesis that WM would moderate the within-person association between morning pain intensity and pain's interference with work goal pursuit in the afternoon. On the other hand, the findings did support our hypothesis that WM would moderate the within-person association between morning negative affect and pain's interference with work goal pursuit in the afternoon.

Negative Affect and Goal Interference

Above and beyond pain intensity, negative affect appears to have a unique effect on pain's interference with work goal pursuit. This result is consistent with previous findings suggesting that negative affect can interrupt or distort normative information processing.^{13,14} To be specific, when individuals are in a negative affective state, their field of attention is thought to become significantly narrowed and focused on signals of potential harm or threat (e.g., pain) so that they may be better prepared to avoid them.^{15,16,52,53} However, this attentional narrowing comes at a cost. That is if individuals become more hyper-vigilant to pain signals, this process can induce a reprioritization of personal goals and substantially interfere with on-going goal pursuit.⁵⁴ Our post-hoc finding, which reveals that the more proximal experience of negative affect is more strongly associated with pain's interference with work goal pursuit, further supports this theoretical argument. Hence, in addition to pain flares, *state negative affect* seems to serve a critical role in influencing daily work goal pursuit among individuals with chronic pain.

The Moderating Role of Working Memory

The significant main effect of state negative affect on pain's interference with work goal pursuit varied among individuals differing in working memory. Importantly, this cross-level interaction was robust even after controlling for potential confounding interaction effects that include pain severity, sleep quality, emotional distress, duration of pain, age, and gender. This finding provides initial evidence that WM may serve as a protective factor in mitigating the deleterious effect of state negative affect on goal pursuit in a non-laboratory setting.

Numerous studies suggest that individuals with higher WM can successfully inhibit unwanted stimulus information and that they are able to monitor and maintain ongoing goal information (see 28, 55). However, to date, the role of WM in emotion-regulation has been rarely tested outside of the laboratory. By integrating both laboratory measured WM and the

real-time, real world assessment of pain, affect, and goal pursuit, the present study begins to address this gap in the literature.

The finding that the association between negative affect and pain's interference with work goal pursuit was not significant among individuals with high WM is particularly intriguing. It corroborates previous experimental findings of WM's effect on the regulation of aversive emotional expression, experience, and recovery. For instance, Schmeichel, Volokhov, and Demaree⁵⁶ conducted a series of studies showing that individuals with high WM were better able to suppress facial expressions of both negative and positive emotion, and were more capable of remaining unemotional while viewing both positive and negative emotional stimuli. Furthermore, based upon a spontaneous emotion-regulation paradigm (i.e., self-enhancement in response to negative feedback), Schmeichel and Demaree⁵⁷ also found moderation effects of WM, such that individuals with high WM displayed a greater tendency for self-enhancement and reported less negative affect when they received negative feedback. More recently, Madeline, Koval, Houben, Erbas, Champagne, and Kuppens⁵⁸ found that individuals with high levels of WM were able to more quickly and successfully recover from their reactions to intense aversive emotional stimuli. In sum, these findings imply that the capacity to maintain and update information in memory in the face of distractions or challenges is important for the successful self-regulation of emotion.

Contrary to our prediction, WM did not significantly moderate the relationship between pain intensity and pain's interference with work goal pursuit. One possible explanation for this finding is that, in contrast to negative affect, pain is a highly salient biological threat signal.⁵² Consequently, WM may play a less significant role in mitigating pain's deleterious effect on goal pursuit. Furthermore, and related to the first point, we found in the present study that the mean level of morning pain (3.34 out of 9) was noticeably higher than that of morning negative affect (1.31 out of 9). Therefore, WM may possess a greater potential to moderate the influence of aversive states on goal pursuit when these states are at *low* levels.

Implication for Future Research

Individuals with chronic pain tend to experience negative emotion more frequently and more intensely than do healthy individuals.^{59–61} As the present study demonstrates at the within person level, increases in negative affect are associated with increases in pain's interference with work goal pursuit. Such a finding holds important implications for workers' productivity, performance, and well-being. Therefore, helping individuals with chronic pain to successfully manage their negative affect in addition to coping with pain flares appears to be a worthy clinical objective. Although the present findings are preliminary, WM may eventually be shown to serve as a resource that promotes successful emotion-regulation in the face of increased state negative affect.

Recently, enthusiasm has grown for testing whether WM training can assist individuals to manage their impulses⁶² and their emotional eating.⁶³ However, data relevant to the extended transfer effects (i.e., effects that go beyond the trained domain) of WM training have yielded mixed findings (e.g., 64, 65). A recent meta-analysis of WM training studies suggests that effect sizes for general fluid intelligence and cognitive control are small.⁶⁶ Nonetheless, given the simplicity of implementing WM training with various populations

(e.g., older adults, children, individuals with cognitive impairment), it may be worth exploring the utility of using WM training for preventing or reducing pain's interference with everyday work goal pursuit.

From the perspective of traditional clinical interventions, mindfulness-based interventions (MBIs)^{67, 68} may be a promising candidate for researchers to employ. Rather than focusing on reducing pain or negative affect, MBIs target the promotion of individuals' momentary awareness and attention to any emotion or thought without judgment. Fundamentally, MBIs are designed to help individuals to reorient their attention back to present moment. In fact, a number of studies have demonstrated that mindfulness training can improve individuals' attention as well as their WM.^{69–73} Further, some recent meta-analyses suggest that MBIs yield large effect sizes in reducing anxiety and depression.^{74,75} Still to be explored is how an increase of WM through mindfulness training can help individuals with chronic pain to successfully pursue their important personal goals.

Although our analysis was post hoc, we found that morning negative affect significantly predicted afternoon/evening pain's interference with work goal pursuit even controlling for afternoon negative affect. This finding suggests that the *timing* of intervention delivery may be critical in maximizing its benefits. Perhaps, decreasing negative affect by boosting positive affect *early in the day* might be more effective in mitigating work goal interference than doing so in the afternoon. Thus, another potential future research avenue would be to examine the differences in individuals' reports of goal interference as a function of when they received an intervention for decreasing negative affect.

Strengths and Limitations

Our study possesses a number of notable strengths in method and design. First, data were collected from a representative community sample of persons with chronic pain using random digit dialing, rendering our findings more generalizable than those of studies using convenience samples. Second, ours is the first study that integrated laboratory-measured working memory with daily measures of pain, affect, and goal pursuit. Likewise in the present study various potential confounders were controlled that have not typically been addressed.

The present study, however, is not without limitations. First, a more objective measure of work goal pursuit interference is suggested for future studies. For instance, it would be useful to collect peer or supervisors' reports of participants' work goal progress or interference. Second, questions remain regarding the construct validity of WM.⁷⁶ For example, a meta-analysis showed that, on average, complex span and n-back measures of WM share only 4 percent of the variance.⁷⁷ Third, the overall level of negative affect was comparatively low in the present sample, which is not uncommon among community samples of chronic pain participants who complete daily diaries (cf., 78, 79). Therefore, it is possible that working memory may not moderate the within-person relation between negative affect and pain's interference with work goal pursuit in samples of chronic pain patients who report high levels of negative affect. Fourth, factors such as medication use (e.g., anxiolytics, opioids, etc.) that were not measured may influence the precise assessment of individuals' WM. Finally, we examined the within-person association between pain

intensity and pain's interference with work goal pursuit using the days for each person on which they reported pursuing their most important work goal. If individuals are likely to forego the pursuit of their most important work goal on days with higher than usual pain intensity, we may have underestimated the within-person association between morning pain intensity and pain's interference with work goal pursuit. However, it is worth noting that Karoly et al.¹² did not find such a relationship using the sample employed in the present study.

Conclusions

The present study was designed to test whether the effects of morning pain intensity and negative affect upon pain's interference with afternoon and evening work goal pursuit were moderated by individual difference in WM. We expected WM to serve a critical role in protecting goal-relevant information from distractions that result from higher than usual negative affective arousal and from pain intensity. WM did not moderate the within-person association between morning pain intensity and afternoon/evening ratings of pain's interference with work goal pursuit. Yet it nonetheless attenuated the positive association between morning negative affect and afternoon and evening pain's interference with work goal pursuit. Thus, our findings provide a warrant for other ecologically nuanced observational or intervention studies to further explore the influence of WM on the ongoing pursuit of important personal goals in the face of pain and negative affect.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

1. Gaskin DJ, Richard P. The economic costs of pain in the United States. *The Journal of Pain*. 2012 8;13:715–24. [PubMed: 22607834]
2. Patel AS, Farquharson R, Carroll D, Moore A, Phillips CJ, Taylor RS, Barden J. The impact and burden of chronic pain in the workplace: a qualitative systematic review. *Pain Practice*. 2012;12:578–89. [PubMed: 22462774]
3. Stewart WF, Ricci JA, Chee E, Morganstein D, Lipton R. Lost productive time and cost due to common pain conditions in the US workforce. *JAMA*. 2003;290:2443–2454. [PubMed: 14612481]
4. Blyth FM, March LM, Nicholas MK, Cousins MJ. Chronic pain, work performance and litigation. *Pain*. 2003;103:41–47. [PubMed: 12749957]
5. Gaskin DJ, Richard P. The economic costs of pain in the United States. *J Pain*. 2012;13:715–24. [PubMed: 22607834]
6. Teasell RW, Bombardier C. Employment-related factors in chronic pain and chronic pain disability. *Clin J Pain*. 2001;17:39–45.
7. Leeuwen MT, Blyth FM, March LM, Nicholas MK, Cousins MJ. Chronic pain and reduced work effectiveness: the hidden cost to Australian employers. *Eur J Pain*. 2006;10:161–166. [PubMed: 16310720]

8. Karoly P, Ruehlman LS, Okun MA. Psychosocial and demographic correlates of employment vs disability status in a national community sample of adults with chronic pain: Toward a psychology of pain presenteeism. *Pain Med.* 2013;14:1698–1707. [PubMed: 24010682]
9. Karoly P, Ruehlman LS. Motivational implications of pain: chronicity, psychological distress, and work goal construal in a national sample of adults. *Health Psychol.* 1996;15:383–390. [PubMed: 8891717]
10. Ford DH. *Humans as self-constructing living systems: A developmental perspective on behavior and personality.* Hillsdale, NJ: Erlbaum; 1987.
11. de Vries HJ, Reneman MF, Groothoff JW, Geertzen JH, Brouwer S. Factors promoting staying at work in people with chronic nonspecific musculoskeletal pain: a systematic review. *Disabil Rehabil.* 2012;34:443–458. [PubMed: 22035099]
12. Karoly P, Okun MA, Enders C, Tennen H. Effects of pain intensity on goal schemas and goal pursuit: a daily diary study. *Health Psychol.* 2014;33:968–976. [PubMed: 25180547]
13. Geisser ME, Robinson ME, Keefe FJ, Weiner ML. Catastrophizing, depression and the sensory, affective and evaluative aspects of chronic pain. *Pain.* 1994;59:79–83. [PubMed: 7854806]
14. Watson D, Pennebaker JW. Health complaints, stress, and distress: exploring the central role of negative affectivity. *Psychol rev.* 1989;96:234–254. [PubMed: 2710874]
15. Gray JA. Personality dimensions and emotion systems. In: Davidson PERJ, ed. *The nature of emotion: Fundamental questions* New York: Oxford University Press; 1994:329–331.
16. Lang PJ, Bradley MM, Cuthbert BN. Emotion, motivation, and anxiety: brain mechanisms and psychophysiology. *Biol psychiatry.* 1998;44:1248–1263. [PubMed: 9861468]
17. Hamilton NA, Karoly P, Kitzman H. Self-regulation and chronic pain: The role of emotion. *Cognit Ther Res.* 2004;28:559–576.
18. Karoly P. Mechanisms of self-regulation: A systems view. *Annu Rev Psychol.* 1993;44:23–52.
19. Karoly P. A goal systems-self-regulatory perspective on personality, psychopathology, and change. *Rev Gen Psychol.* 1999;3:264–291.
20. Karoly P. Goal systems and self-regulation: An individual differences perspective In: Hoyle RH, ed. *Handbook of personality and self-regulation.* Malden, MA: Wiley-Blackwell; 2010:218–242.
21. Self-regulation Karoly P. In: O'Donohue W & Fisher JE, eds. *Cognitive behavior therapy: Core principles for practice.* Hoboken, NJ: John Wiley; 2012:183–213.
22. Broadway JM, Redick TS, Engle RW. Working memory capacity: self-control is (in) the goal. In: Hassin R, Ochsner KN, Trope Y, eds. *Self-control in society, mind, and brain.* New York, NY: Oxford University Press; 2010:163–173.
23. Ilkowska M, Engle RW. Trait and state differences in working memory capacity In: Gruszka A, Matthews G, Szymura B, eds. *Handbook of individual differences in cognition.* Springer New York; 2010:295–320.
24. Avery RE, Smillie LD, de Fockert JW. The role of working memory in achievement goal pursuit. *Acta psychol.* 2013;144:361–372.
25. Legrain V, Crombez G, Verhoeven K, Mouraux A. The role of working memory in the attentional control of pain. *Pain.* 2011;152:453–459. [PubMed: 21238855]
26. Verhoeven K, Dick B, Eccleston C, Goubert L, Crombez G. The role of executive functioning in children's attentional pain control: an experimental analysis. *Pain.* 2014;155:413–421. [PubMed: 24231653]
27. Mun CJ, Karoly P, Okun MA. Effects of daily pain intensity, positive affect, and individual differences in pain acceptance on work goal interference and progress. *Pain.* 2015;156:2276–2285. [PubMed: 26469319]
28. Conway AR, Kane MJ, Bunting MF, Hambrick DZ, Wilhelm O, Engle RW. Working memory span tasks: A methodological review and user's guide. *Psychon Bull Rev.* 2005;12:769–786. [PubMed: 16523997]
29. Kruglanski AW, Shah JY, Fishbach A, Friedman R, Chun WY, Sleeth-Keppler D. A theory of goal systems In: Zanna MP, ed. *Advances in Experimental Social Psychology.* Academic Press; 2002:331–378.

30. Miller EK, Cohen JD. An integrative theory of prefrontal cortex function. *Annu Rev Neurosci.* 2001;24:167–202. [PubMed: 11283309]
31. Kane MJ, Bleckley MK, Conway AR, Engle RW. A controlled-attention view of working-memory capacity. *J Exp Psychol-Gen.* 2001;130:169–183. [PubMed: 11409097]
32. Hofmann W, Gschwendner T, Friese M, Wiers RW, Schmitt M. Working memory capacity and self-regulatory behavior: toward an individual differences perspective on behavior determination by automatic versus controlled processes. *J Pers Soc Psychol.* 2008;95:962–977. [PubMed: 18808271]
33. Shah JY, Friedman R, Kruglanski AW. Forgetting all else: on the antecedents and consequences of goal shielding. *J Pers Soc Psychol.* 2002;83:1261–1280. [PubMed: 12500810]
34. Fillingim RB, King CD, Ribeiro-Dasilva MC, Rahim-Williams B, Riley JL. Sex, gender, and pain: a review of recent clinical and experimental findings. *J Pain.* 2009;10:447–485. [PubMed: 19411059]
35. Frenda SJ, Fenn KM. Sleep Less, Think Worse: The Effect of Sleep Deprivation on working memory. *J Appl Res Mem Cog.* 2016;5:463–469.
36. Berryman C, Stanton TR, Bowering KJ, Tabor A, McFarlane A, Moseley GL. Evidence for working memory deficits in chronic pain: a systematic review and meta-analysis. *Pain.* 2013;154:1181–1196. [PubMed: 23707355]
37. Salthouse TA, Babcock RL. Decomposing adult age differences in working memory. *Dev psychol.* 1991;27:763–776.
38. Scott EL, Kroenke K, Wu J, Yu Z. Beneficial effects of improvement in depression, pain catastrophizing, and anxiety on pain outcomes: a 12-month longitudinal analysis. *J Pain.* 2016;17:215–222. [PubMed: 26542153]
39. Smith MT, Perlis ML, Smith MS, Giles DE, Carmody TP. Sleep quality and presleep arousal in chronic pain. *J Behav Med.* 2000;23:1–13. [PubMed: 10749008]
40. Speck O, Ernst T, Braun J, Koch C, Miller E, Chang L. Gender differences in the functional organization of the brain for working memory. *Neuroreport.* 2000;11:2581–2585. [PubMed: 10943726]
41. Ruehlman LS, Karoly P, Newton C, Aiken LS. The development and preliminary validation of a brief measure of chronic pain impact for use in the general population. *Pain.* 2005;113:1–10. [PubMed: 15621355]
42. Watson D, Clark LA. The PANAS-X: Manual for the positive and negative affect schedule-expanded form. Iowa City: University of Iowa; 1999.
43. Conway AR, Cowan N, Bunting MF, Theriault DJ, Minkoff SR. A latent variable analysis of working memory capacity, short-term memory capacity, processing speed, and general fluid intelligence. *Intelligence.* 2002;30:163–183.
44. Conway AR, Kane MJ, Bunting MF, Hambrick DZ, Wilhelm O, Engle RW. Working memory span tasks: A methodological review and user's guide. *Psychon Bull Rev.* 2005;12:769–86. [PubMed: 16523997]
45. Redick TS, Broadway JM, Meier ME, Kuriakose PS, Unsworth N, Kane MJ, Engle RW. Measuring working memory capacity with automated complex span tasks. *Eur J Psychol Assess.* 2014;28:164–171.
46. Unsworth N, Heitz RP, Schrock JC, Engle RW. An automated version of the operation span task. *Behav Res Methods.* 2005;37:498–505. [PubMed: 16405146]
47. Lovibond SH, Lovibond PF. Manual for the depression anxiety stress scales. 2nd ed. Sydney: Psychology Foundation; 2002.
48. Crawford JR, Henry JD. The Depression Anxiety Stress Scales (DASS): normative data and latent structure in a large non-clinical sample. *Br J Clin Psychol* 2003;42:111–131. [PubMed: 12828802]
49. Corp IBM. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp; 2013.
50. Enders CK, Tofighi D. Centering predictor variables in cross-sectional multilevel models: a new look at an old issue. *Psychol Methods.* 2007;12:121–138. [PubMed: 17563168]
51. Aiken LS, West SG, Reno RR. Multiple regression: Testing and interpreting interactions. Sage; 1991.

52. Schmitz TW, De Rosa E, Anderson AK. Opposing influences of affective state valence on visual cortical encoding. *J Neurosci*. 2009;29:7199–207. [PubMed: 19494142]
53. Talarico JM, LaBar KS, Rubin DC. Emotional intensity predicts autobiographical memory experience. *Mem Cognit*. 2004;32:1118–1132.
54. Van Damme S, Legrain V, Vogt J, Crombez G. Keeping pain in mind: a motivational account of attention to pain. *Neurosci Biobehav Rev* 2010;34:204–213. [PubMed: 19896002]
55. Barrett LF, Tugade MM, Engle RW. Individual differences in working memory capacity and dual-process theories of the mind. *Psychol bull*. 2004;130:553–573. [PubMed: 15250813]
56. Schmeichel BJ, Volokhov RN, Demaree HA. Working memory capacity and the self-regulation of emotional expression and experience. *J Pers Soc Psychol*. 2008;95:1526–1540. [PubMed: 19025300]
57. Schmeichel BJ, Demaree HA. Working memory capacity and spontaneous emotion regulation: high capacity predicts self-enhancement in response to negative feedback. *Emotion*. 2010;10:739–744. [PubMed: 21038959]
58. Madeline LP, Koval P, Houben M, Erbas Y, Champagne D, Kuppens P. Updating in working memory predicts greater emotion reactivity to and facilitated recovery from negative emotion-eliciting stimuli. *Front Psychol*. 2015;6:372. [PubMed: 25914655]
59. Bruehl S, Liu X, Burns JW, Chont M, Jamison RN. Associations between daily chronic pain intensity, daily anger expression, and trait anger expressiveness: An ecological momentary assessment study. *Pain*. 2012;153:2352–2358. [PubMed: 22940462]
60. Burke AL, Mathias JL, Denson LA. Psychological functioning of people living with chronic pain: A meta-analytic review. *Br J Clin Psychol*. 2015;54:345–360. [PubMed: 25772553]
61. Finucane AM, Dima A, Ferreira N, Halvorsen M. Basic emotion profiles in healthy, chronic pain, depressed and PTSD individuals. *Clin Psychol Psychother*. 2012;19:14–24. [PubMed: 21243706]
62. Brooks SJ, Wiemerslage L, Burch KH, Maiorana SA, Cocolas E, Schiöth HB, Kamaloodien K, Stein DJ. The impact of cognitive training in substance use disorder: the effect of working memory training on impulse control in methamphetamine users. *Psychopharmacology*. 2017;234:1911–21. [PubMed: 28324119]
63. Houben K, Dassen FC, Jansen A. Taking control: working memory training in overweight individuals increases self-regulation of food intake. *Appetite*. 2016;105:567–74. [PubMed: 27349707]
64. Jaeggi SM, Buschkuhl M, Jonides J, Perrig WJ. Improving fluid intelligence with training on working memory. *Proc Natl Acad Sci*. 2008;105:6829–6833. [PubMed: 18443283]
65. Waris O, Soveri A, Laine M. Transfer after working memory updating training. *PLoS One*. 2015;10:e0138734.
66. Soveri A, Antfolk J, Karlsson L, Salo B, Laine M. working memory training revisited: A multi-level meta-analysis of n-back training studies. *Psychon Bull Rev*. 2017;23:1–20.
67. Kabat-Zinn J. An outpatient program in behavioral medicine for chronic pain patients based on the practice of mindfulness meditation: Theoretical considerations and preliminary results. *Gen Hosp Psychiatry*. 1982;4:33–47. [PubMed: 7042457]
68. Kabat-Zinn Jon. *Full Catastrophe Living: Using the Wisdom of Your Body and Mind to Face Stress, Pain, and Illness*. Delta trade pbk. reissue. New York, N.Y: Delta Trade Paperbacks; 2005.
69. Jha AP, Stanley EA, Kiyonaga A, Wong L, Gelfand L. Examining the protective effects of mindfulness training on working memory capacity and affective experience. *Emotion*. 2010;10:54–64. [PubMed: 20141302]
70. Mrazek MD, Franklin MS, Phillips DT, Baird B, Schooler JW. Mindfulness training improves working memory capacity and GRE performance while reducing mind wandering. *Psychol Sci*. 2013;24:776–781. [PubMed: 23538911]
71. Quach D, Mano KE, Alexander K. A randomized controlled trial examining the effect of mindfulness meditation on working memory capacity in adolescents. *J Adolesc Health*. 2016;58:489–496. [PubMed: 26576819]
72. Van Vugt MK, Jha AP. Investigating the impact of mindfulness meditation training on working memory: A mathematical modeling approach. *Cogn Affect Behav Neurosci*. 2011;11:344–353. [PubMed: 21732031]

73. Zeidan F, Johnson SK, Diamond BJ, David Z, Goolkasian P. Mindfulness meditation improves cognition: Evidence of brief mental training. *Conscious Cogn*. 2010;19:597–605. [PubMed: 20363650]
74. Hofmann SG, Sawyer AT, Witt AA, Oh D. The effect of mindfulness-based therapy on anxiety and depression: A meta-analytic review. *J Consult Clin Psychol*. 2010;78:169–183. [PubMed: 20350028]
75. Khoury B, Lecomte T, Fortin G, Masse M, Therien P, Bouchard V, Chapleau MA, Paquin K, Hofmann SG. Mindfulness-based therapy: a comprehensive meta-analysis. *Clin Psychol Rev*. 2013;33:763–771. [PubMed: 23796855]
76. Kane M, Conway A, Miura T, Colflesh G. Working memory, attentional control, and the n-back task: A question of construct validity. *J Exp Psychol*. 2007;33:615–622.
77. Redick TS, Lindsey Dr. Complex span and n-back measures: A meta-analysis. *Psychon Bull Re.v*. 2013;20:1102–1113.
78. Finan PH, Zautra AJ, Davis MC. Daily affect relations in fibromyalgia patients reveal positive affective disturbance. *Psychosom Med*. 2009;71:474–482. [PubMed: 19251863]
79. Kothari DJ, Davis MC, Yeung EW, Tennen HA. Positive affect and pain: Mediators of the within-day relation linking sleep quality to activity interference in fibromyalgia. *Pain*. 2015;156:540–546. [PubMed: 25679472]

Figure 1.

Hypothesized multilevel model with cross-level interactions.

Note. Variables with rectangular shape are level-1 (day-level) variable and variables with circular shape are level-2 (person-level) variables.

Figure 2.

Slopes and intercepts portraying the effects of working memory ($-1\ SD$, mean, $+1\ SD$) on the within-person relations between morning negative affect and pain's interference with work goal pursuit in the afternoon and evening.

Note. The slope for individuals with high working memory was not statistically significant ($B = 0.01$, $SE = .06$, $p = .81$).

Table 1

Demographics and chronic pain diagnosis information

Variables	Mean (Percentage)
Age (SD)	49.49 (11.19)
Gender	
Female	61%
Education	
Completed high school or less	6.8%
Some college or Associate's degree	49%
Bachelor's degree	13.9%
Graduate or professional school degree	28.8%
Marital Status	
Single	23%
Married/partnered	56%
Divorced	18%
Widowed	3.0%
Employment	
Employed	35.9%
Not working	62.3%
Race/Ethnicity	
Caucasian	80%
Black/African American	4.0%
Asian	2.0%
Native American	2.0%
Mixed	7.0%
Other	5.0%
Chronic Pain Duration	
Two or more years	80.9%
Chronic Pain Diagnosis	
Back injury/disease	49.6%
Osteoarthritis	24.4%
Tension headaches	22.1%
Migraine headaches	21.4%
Facial/jaw pain	19.8%
Fibromyalgia	12.2%
Premenstrual syndrome	11.5%
Rheumatoid arthritis	9.9%
Pelvic injury/disease	9.9%
Cluster headaches	9.2%
Cancer	2.3%

Table 2

Descriptive statistics, inter correlations, and ICC for Within-Person Variables

Variable	1	2	3	4	5	6	7	8	9	10
1 Pain Interference with WGP	—	.66**	.26**	-.27**	.50**	.38**	-.39**	.15	.04	.15
2 Morning Pain	.16**	—	.32**	-.10	.59**	.42**	-.32**	.24*	.15	.20*
3 Morning Negative Affect	.11**	.08**	—	.03	.18	.54**	-.24*	.06	-.13	-.04
4 Working Memory				—	-.22*	-.16	.08	-.12	-.14	.08
5 Pain Severity					—	.25*	-.31**	.21*	-.02	.05
6 DASS Mean Score						—	-.32**	.20*	-.14	.10
7 Mean Sleep Quality							—	.00	.23*	-.13
8 Gender (0= male; 1= female)								—	.08	.10
9 Age									—	-.04
10 Pain Duration										—
M	1.94	3.34	1.31	0.74	5.38	0.66	5.44	0.66	49.57	3.34
SD	3.34	2.10	1.63	0.16	1.01	0.45	1.47	0.45	11.90	1.08
Skewness	0.88	0.33	1.9	-0.66	-0.66	1.32	-0.06	-0.49	-0.47	-1.52
Range	1-9	1-9	1-9	0.35-1	2.25-7.5	0-2.43	2.25-9	0-1	21-70	0-4
ICC	0.596	0.543	0.484	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Note. WGP = Work Goal Pursuit; Lower-diagonal shows correlations among level-1 variables that are person-mean centered. Upper-diagonal shows correlations between level-2 variables and day-level variables that are averaged across the 21-days.

* $p < .05$

** $p < .01$

Table 3

Parameter Estimates from Multilevel Regression Analysis

Parameter	Est.	SE	<i>t</i>	<i>p</i>
Intercept	1.86	0.27	6.92	< .001
Morning Pain Intensity (Level-1)	0.12	0.04	3.01	.003
Morning Negative Affect (Level-1)	0.10	0.04	2.45	.017
Working Memory (Level-2)	−1.62	1.07	−1.51	.134
Pain Severity (Level-2)	0.64	0.17	3.69	< .001
DASS (Level-2)	0.82	0.39	2.10	.039
Mean Sleep Quality (Level-2)	−0.27	0.12	−2.24	.028
Gender (Level-2)	0.06	0.34	0.18	.855
Age (Level-2)	0.02	0.01	1.07	.287
Pain Duration (Level-2)	0.16	0.15	1.07	.286
Pain Intensity x Working Memory	−0.09	0.25	−0.36	.719
Negative Affect x Working Memory	−0.54	0.26	−2.12	.038
Intercept Variance	2.30	0.37		
Pain Intensity Slope Variance	0.05	0.02		
Negative Affect Slope Variance	0.03	0.02		
Intercept-Slope (Pain) Covariance	0.01	0.06		
Intercept-Slope (NA) Covariance	0.03	0.07		
Residual Variance	1.44	0.07		

Note. Wald tests are invalid for variance estimates and are omitted from the table.