Health Psychology

0278-6133/18/$12.00

http://dx.doi.org/10.1037/hea0000692

The Role of State and Trait Positive Affect and Mindfulness in Affective Reactivity to Pain in Chronic Migraine

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Objective: High affective reactivity to pain (i.e., increased negative affect in response to pain) can have an adverse impact on the well-being of individuals with chronic pain. The present study examined the role of momentary and average positive affect and trait mindfulness in protecting against affective reactivity to chronic migraine–related pain. ***Methods:*** The sample included 61 adults with chronic migraine. Following the experience sampling method, participants completed smartphone-based assessments of momentary pain intensity (PI), positive affect (PA), and negative affect (NA) at nine random moments a day for 7 consecutive days. The Five-Facet Mindfulness Questionnaire was used to assess two dimensions of mindfulness: nonjudging and nonreactivity. ***Results:*** Momentary PA inversely predicted the strength of the concurrent but not the time-lagged associations between PI and NA. Average PA predicted neither the strength of the concurrent nor the time-lagged associations between PI and NA. Furthermore, the concurrent associations between PI and NA were weaker in individuals who reported higher "nonjudging" while "nonreactivity" did not significantly moderate these associations. ***Conclusions:*** Results provide partial support for the dynamic model of affect in the context of chronic migraine. State PA seems to play a larger role in momentary affective reactivity to chronic migraine–related pain than trait PA. Results also suggest that the ability to take a nonjudgmental stance toward negative experiences may lower momentary affective reactivity to pain. These factors seem promising targets for interventions aimed at improving the well-being of individuals with chronic migraine.

Keywords: affective reactivity, positive affect, mindfulness, chronic migraine, experience sampling

For individuals with chronic pain, episodes of pain can be a daily stressor that elicits a range of negative emotions (e.g., sadness, tension, frustration). Some individuals show greater affective reactivity to pain than others, displaying a higher increase in negative affect (NA) in response to pain flareups. Greater affective reactivity to daily stressors has been associated with poorer physical and mental health outcomes in healthy individuals (O'Neill, Cohen, Tolpin, & Gunthert, 2004; Piazza, Charles, Sliwinski, Mogle, & Almeida, 2013; Sin, Graham-Engeland, Ong, & Almeida, 2015; van Winkel et al., 2015) and in individuals with chronic pain (Rost et al., 2016; van Middendorp et al., 2010; Zautra & Smith, 2001). Affective reactivity may be particularly high in individuals with chronic migraine, as this condition is typically perceived as highly unpredictable and uncontrollable (Rutberg & Öhrling, 2012; Tenhunen & Elander, 2005). Yet, there is limited insight into personal resources that protect against affective reactivity in individuals with chronic migraine, while this could inform interventions aimed at improving health and well-being of these individuals.

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One factor that may act as a resource in coping with chronic pain is positive affect (PA; Dima, Gillanders, & Power, 2013; Finan & Garland, 2015). PA refers to pleasant mood or emotions, such as joy, contentment, or pride (Watson, Clark, & Tellegen, 1988). There are two models suggesting two different yet complementary ways in which PA may protect against affective reactivity to pain. The dynamic model of affect (DMA) poses that the uncertainty of a stressful event places demands on cognitive resources, thereby reducing the capacity to differentiate between PA and NA (Zautra, Potter, & Reich, 1997). Due to this increased interdependence between PA and NA, higher PA at the time of the stressor could buffer the increase of NA in response to stress or pain (Zautra, Smith, Affleck, & Tennen, 2001). Accordingly, a few intensive longitudinal studies in individuals with arthritis and fibromyalgia have found that increases in pain are less strongly associated with NA in the presence of higher PA (Strand et al., 2006; Zautra, Johnson, & Davis, 2005; Zautra & Smith, 2001). These studies, however, were limited to the examination of concurrent associations and therefore did not provide insight into whether PA actually predicts an increase in NA from one moment to the next.

A different yet complementary role of PA in the context of stress has been proposed by the broaden-and-build model (BBM; Fredrickson, 1998). According to the BBM, positive emotions facilitate the acquisition of coping resources by broadening attention and promoting goal-directed action (Fredrickson, 2001). Individuals who generally experience higher levels of PA may therefore feel better equipped to cope with a headache attack and respond to headache with less NA. Thus, while the DMA assumes a protective role for *state* PA, the BBM assumes a similar role for *trait* PA. Although the BBM was not specifically developed to explain stress responses in the context of pain, Zautra et al. (2005) did find that average (i.e., trait) PA moderated the associations between weekly pain and NA in women with fibromyalgia and osteoarthritis. This finding, however, awaits replication in other chronic pain conditions, including chronic migraine.

While PA may draw attention to positive experiences during a headache attack, the way in which people tend to relate to negative experiences (e.g., pain, negative thoughts) also appears to be of importance. There is increasing evidence that mindfulness, both as a practice and a trait, is a resource that helps people manage chronic pain (Day, Jensen, Ehde, & Thorn, 2014; Hilton et al., 2017). A component of mindfulness that seems particularly relevant with respect to affective reactivity to pain is a decentered orientation to negative experience. This decentered orientation involves allowing unpleasant bodily sensations, thoughts, and emotions to be present without judging or reacting to them (e.g., by not engaging in catastrophic or ruminative thinking; Bishop et al., 2004), which may reduce the affective response to pain. Accordingly, several studies have found that the mindfulness facets "nonjudging" and "nonreactivity," as measured with the Five-Facet Mindfulness Questionnaire (FFMQ; Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006), are associated with lower negative mood in the context of chronic pain (Lee et al., 2017; Poulin et al., 2016; Veehof, Ten Klooster, Taal, Westerhof, & Bohlmeijer, 2011). Nevertheless, these studies did not examine the role of nonjudging and nonreactivity in the moment-to-moment associations between pain and NA in daily life, which limits ecological validity of findings.

The primary aim of this study was to examine the role of state and trait PA in the dynamic moment-to-moment associations between pain and NA in individuals with chronic migraine. Its secondary aim was to examine the buffering role of trait mindfulness (i.e., nonjudging and nonreactivity). The experience sampling method (ESM; Csikszentmihalyi & Larson, 1987; deVries, 1992) was used to obtain ecologically valid assessments of pain (i.e., the intensity of headache) and affect in daily life, as well as to examine both concurrent and prospective (i.e., time lagged) relationships between these variables. We hypothesized that increases in pain are less strongly associated with NA (at the same and the next moment in time) when individuals experience higher levels of PA at the moment of pain. Furthermore, we expected lower affective reactivity to pain in individuals with higher average levels of PA and mindfulness (i.e., nonjudging and nonreactivity).

Method

Participants

Patients with chronic migraine were recruited via (1) two neurology outpatient clinics, (2) the Dutch Society for Headache Patients, and (3) local newspapers. Interested patients were called by the researcher to provide further information and screening. Patients were eligible if they were 18 years or older and currently fulfilled International Classification of Headache Disorders third edition criteria for chronic migraine (Headache Classification Committee of the International Headache Society, 2013). Exclusion criteria were diagnosis of a secondary headache disorder (i.e., headache attributed to a structural lesion), with exception of medication-overuse headache; pregnancy in the past year; complete withdrawal from analgesics in the past 3 months; changes in prophylactic or psychological treatment in the past 2 months; severe mental illness; severe memory deficits; poor Dutch language fluency; and not in the possession of a smartphone with Internet connection.

In total, 247 individuals expressed interest in the study, of whom 159 were interested in participation after receiving further information. These patients were screened for eligibility; 71 patients were found eligible. The most common reasons for noneligibility were having fewer than 15 headache days or less than 8 migraine days per month ($n = 64$) and recent changes in pharmacological or psychological treatment that may influence the study results ($n = 18$). Finally, 67 patients provided informed consent. Six patients dropped out during the study; reasons for dropout included illness ($n = 2$), too many technical issues with the smartphone diary ($n = 2$), and finding the study protocol too burdensome ($n = 2$).

The final sample consisted of 61 participants. The mean age of participants was 41.25 years ($SD = 13.24$), and the large majority (95.1%) was female. Three quarters (75.5%) of participants had a partner. Educational level was high (master's or bachelor's degree) in 45.9% of participants, middle (high school diploma or associate's degree) in 44.3%, and low (elementary school) in 9.8%. About one third (45.9%) of participants was either full-time or part-time (self-)employed, 29.5% received disability benefits, and 24.6% had another main activity (e.g., studying).

Procedure

The ESM (Csikszentmihalyi & Larson, 1987; deVries, 1992) was used to collect diary assessments of momentary pain intensity, PA, and NA nine times a day for 7 consecutive days. An end-of-day diary was used to assess relevant contextual variables (e.g., stressful events). Prior to the ESM period, participants completed an online baseline questionnaire assessing demographic characteristics and trait mindfulness. During a telephonic briefing session with the researcher (YC), participants were instructed about the procedure and completed a practice diary.

ESM diaries were completed via a web-based application (Online Digital Assistance; Sorbi, Mak, Houtveen, Kleiboer, & van Doornen, 2007) that operated on participants' own smartphone. At each assessment point, participants received a text message with a link to the diary questionnaire, which they were requested to fill out within the next 30 min. Paper-and-pencil diaries were available in case of technical problems (e.g., no Internet connection). The ESM diaries were sent during waking hours at random moments within 90-min time frames. End-of-day diaries were sent at a fixed time point after the last ESM diary. To promote compliance with the protocol, participants received a financial reward of €50 if they completed at least 80% of the diaries. Participants were excluded from analyses if they completed less than 30% of the diaries. All participants gave written informed consent. The medical ethical committees of the University Medical Center Groningen and the Martini Hospital Groningen approved of the study protocol (NL49506.042).

Measures

ESM diary items were based on items used in previous experience sampling studies and items of existing questionnaires. They were pilot tested in five individuals with chronic migraine to check face validity. Items were only included in analyses if they showed sufficient within-person variation over time. Within-person variation was inspected using individual scatterplots, standard deviations, and by computing a variable representing the percentage of individuals with the same scores on more than 80% of observations (Lebo & Nesselroade, 1978). All ESM items were answered on a 7-point Likert scale ranging from 0 (*not at all*) to 6 (*very much*), which is a commonly used scale in experience sampling research (Hektner, Schmidt, & Csikszentmihalyi, 2007).

Pain intensity: At each ESM assessment, momentary pain intensity was rated in response to the item "At this moment, I'm having a headache." This item is similar to the momentary pain intensity item of the Multidimensional Pain Inventory (Kerns, Turk, & Rudy, 1985), which is also answered on a 7-point scale and has been previously used in headache samples (Hooten, Sandroni, Mantilla, & Townsend, 2010; Magnusson & Becker, 2003).

State PA and NA: At each ESM assessment, participants responded to positive and negative mood adjectives. The following adjectives assessed PA: "content," "enthusiastic," "relaxed," "cheerful" and "strong," and "energetic." Negative affect was assessed with the items "sad," "gloomy," "irritable," "tense," "worried," "lonely," and "anxious." Items were based on items used in two previous ESM/daily diary studies (Houtveen & Sorbi, 2013; Krieke et al., 2016), which were found to be suitable for capturing moment-to-moment fluctuations in mood.

The NA items "I feel lonely" and "I feel anxious" were not included in analyses because they showed insufficient within-person variation. That is, more than 50% of participants reported the same score on these items on more than 80% of observations (Lebo & Nesselroade, 1978). Principal component factor analysis with oblique rotation of the within-person deviations indicated that the mood adjectives "content," "enthusiastic," "relaxed," "cheerful," and "strong" loaded onto one factor representing PA (α = .88) and "sad," "gloomy," "irritable," "tense," and "worried" onto a factor representing NA (α = .80). Hence, we used these items to obtain a mean score for (state) PA and NA at each assessment. The item "energetic" did not load on either of these factors, suggesting that this item measures a different construct. We therefore decided to exclude this item from analysis. Trait PA was represented by the average of an individual's PA scores across all assessments.

Acute medication use: Medication use was assessed in the ESM diary with the item "since the last beep, I used medication for my headaches," answered with "yes" or "no." During the briefing session, participants were instructed that this item only concerned acute headache medication (e.g., painkillers, Triptans).

End-of-day diary.

Sleep quality and stressful events. Sleep quality of the previous night was assessed at the end of the day with the item "I slept well last night" on a scale of 0 (*not at all*) to 6 (*very much*). The severity of negative events during the day was rated on the same answering scale in response to the item "Today, a negative event occurred."

Baseline questionnaire.

Demographic characteristics. The baseline questionnaire included self-report questions on age, gender, education, and employment status.

Mindfulness. At the baseline assessment, two subscales of the FFMQ (Baer et al., 2006; Veehof et al., 2011) were used to assess two facets of mindfulness: nonjudging and nonreactivity. These specific subscales were chosen because they measure aspects of how a person relates to experiences such as unpleasant bodily sensations, thoughts, or emotions. The "nonjudging" subscale measures the extent to which one is judgmental toward experience and contains items such as "I criticize myself for having irrational or inappropriate emotions." The nonreactivity subscale measures the extent to which one tends to react on experiences and includes items such as "I watch my feelings without getting lost in them." All items were answered on a 5-point Likert scale ranging from 1 (*never or very rarely true*) to 5 (*very often or always true*; Baer et al., 2006). Mean scores were calculated for each subscale; items of the nonjudging subscale were reverse coded so that higher scores represent a more nonjudgmental stance toward experience. Cronbach's alpha for the FFMQ in this sample was .89 for nonjudging and .86 for nonreactivity.

Depressive symptoms. Baseline levels of depressive symptoms were assessed with the Patient Health Questionnaire–9 (PHQ-9; Kroenke, Spitzer, & Williams, 2001). The PHQ-9 is a nine-item measure that assesses the presence of *DSM–IV* criteria for depression in the past 2 weeks on a scale of 0 (*not at all*) to 3 (*nearly every day*). The PHQ-9 has been found to be a valid and reliable measure of depression severity (Hammash et al., 2013; Kroenke et al., 2001; Milette, Hudson, Baron, Thombs, & the Canadian Scleroderma Research Group, 2010). Cronbach's alpha for the PHQ-9 in this sample was .61.

Statistical Analyses

Since the ESM data had a hierarchical two-level structure (i.e., observations nested within individuals), data were analyzed with multilevel modeling using the XTMIXED command in Stata 14 (StataCorp, 2015). In all models, the dependent variable was NA at time t. A time variable based on the consecutive day number and beep number was entered as a predictor to control for the influence of time (Bolger & Laurenceau, 2013). Contextual variables (i.e., perceived severity of negative events during the day, sleep quality in the previous night, and acute medication use since the last beep) and severity of depressive symptoms (baseline PHQ-9) were entered as covariates.

In the concurrent models, level 1 ("observation level") predictors of interest were pain intensity (PI) at time t and PA at time t. Level 2 ("person level") predictors of interest were the person mean of PA, nonjudging, and nonreactivity. The moderating effect of state and trait PA was tested by including interaction terms between PI at time t and momentary PA at time t, as well as the cross-level interaction between PI at time t and the *person mean* of PA in the model. The protective role of mindfulness was examined in a separate model by including the cross-level interaction between nonjudging and PI at time t and the interaction between nonreactivity and PI at time t.

In the time-lagged models, Level 1 predictors of interest were PI and PA at time t − 1. In addition, NA at time t − 1 was entered as a predictor to control for the level of NA at the previous time point. Level 2 predictors were the same as in the concurrent models. The moderating effect of state PA, average PA, nonjudging, and nonreactivity was examined by modeling the following interaction terms: $PA^{t-1} \times PI^{t-1}$, Average PA $\times PI^{t-1}$, Nonjudging $\times PI^{t-1}$, and Nonreactivity $\times PI^{t-1}$. Again, the effect of state and average PA and the effect of mindfulness were examined in two separate models. In the time-lagged models, only within-day associations were modeled. That is, a missing value was inserted between the last time point of one day and the first time point of the next day so that the evening to morning association was not included in the models (Höhn et al., 2013; Kramer et al., 2014).

Time-varying predictors were first grand-mean centered and then person-mean centered to separate within-subject effects from between-subjects effects (Bolger & Laurenceau, 2013). All models included a random intercept. Random slopes for the time-varying predictors were included if they improved model fit (as indicated by lower Akaike information criterion [AIC] and Bayesian information criterion [BIC] values). Models with different covariance structures were compared; the best-fitting model was selected based on AIC and BIC criteria. As different model settings resulted in slight differences in significance of the results, and to correct for multiple testing, the significance value for testing our predictors of interest was set at .01.

Results

Descriptives

We collected 3,349 ESM observations in total. Participants completed on average 56 out of 63 (89%) assessments. The number of completed assessments ranged from 23 to 63 (37–100%). Hence, no participants were excluded from the analyses for having completed less than 30% of the data.

Table 1 presents means and standard deviations for the variables of interest. All ESM items were scored on a scale of 0 (i.e., not at all present) to 6 (i.e., very much present). On average, participants rated NA with 1.28 ($SD_{\text{between-persons}}$ = .96), PA with 2.90 ($SD_{\text{between-persons}}$ = .88), and PI with 2.11 ($SD_{\text{between-persons}}$ = 1.31). NA, PA, and PI showed considerable variation across measurements within individuals, as shown by the mean squared successive difference (MSSD) scores. The distribution of pain intensity scores across observations was 0 (28.7%), 1 (18.0%), 2 (13.2%), 3 (13.4%), 4 (12.5%), 5 (8.9%), and 6 (5.4%; not in a table). Thus, headache was present on 71.3% of measurement occasions.

Total scores for the FFMQ subscales nonjudging (M = 3.66, SD = .83) and nonreactivity (M = 3.10, SD = .84) were comparable to those previously reported in nonmeditating students (de Bruin, Topper, Muskens, Bögels, & Kamphuis, 2012) and patients with fibromyalgia (Veehof et al., 2011). Significant intercorrelations among the between-person level were found between nonjudging and depressive symptoms (r = −.40, p < .01) and between average PA and depressive symptoms (r = −.29, p = .03). The associations between average PA and nonjudging (r = .16, p = .22), between average PA and nonreactivity (r = .09, p = .50), between nonjudging and nonreactivity (r = .02, p = .87), and between nonreactivity and depressive symptoms (r = −0.01, p = .96) were all nonsignificant.

Concurrent Associations

Parameter estimates (fixed effects) of the multilevel models examining the concurrent associations between pain and NA are presented in Table 2. A negative effect for "time" indicated that there was a small but significant decrease in NA over time. A higher perceived severity of negative events during the day, acute

Table 1
Mean Scores of ESM Measures Across All Assessments and of Baseline Mindfulness

Variable	*N*	*n*	Mean	Range	Between-person standard deviation	Within-person standard deviation	MSSD
Negative affect	61	3349	1.28	0–6	.96	.80	.66
Positive affect	61	3349	2.90	0–6	.88	.96	.80
Pain intensity	61	3349	2.11	0–6	1.31	1.39	1.67
Nonjudging (FFMQ)	61	—	3.66	1–5	.83	—	
Nonreactivity (FFMQ)	61	—	3.10	1–5	.84	—	

Note. MSSD = mean squared successive difference; FFMQ = Five Facet Mindfulness Questionnaire.

Table 2
Fixed Effects of Multilevel Models Predicting Same Moment Negative Affect

Variable	Baseline model		Control variables		PA		Mindfulness	
	Estimate (*SE*)	*p*	Estimate (*SE*)	*p*	Estimate (*SE*)	*p*	Estimate (*SE*)	*p*
Fixed effects								
Intercept	1.45 (.13)	<.01	1.36 (.18)	<.01	2.30 (.39)	<.01	1.30 (.71)	.07
Time	–.01 (<.01)	<.01	<–.01 (<.01)	<.01	<–.01 (<.01)	<.01	<–.01 (<.01)	.01
Negative event			.14 (.02)	<.01	.07 (.02)	<.01	.13 (.02)	<.01
Medication use (yes)			–.44 (.06)	<.01	–.04 (.04)	.28	–.10 (.04)	.02
Sleep			–.04 (.02)	.03	.01 (.01)	.32	–.02 (.01)	.10
PHQ-9			.16 (.05)	<.01	.13 (.04)	<.01	.15 (.05)	<.01
PI					.17 (.05)	<.01	.40 (.12)	<.01
PA					–.43 (.04)	<.01		
Average PA					–.46 (.11)	<.01		
PI × PA					–.02 (.01)	<.01		
PI × Average PA					–.04 (.02)	.04		
Nonjudging							–.13 (.14)	.37
Nonreactivity							.06 (.13)	.65
PI × Nonjudging							–.10 (.02)	<.01
PI × Nonreactivity							.06 (.02)	.02
Model fit								
AIC	8,113.49		7,436.24		5,556.65		6,760.24	
BIC	8,144.07		7,509.44		5,672.55		6,863.94	
Sample size								
N subjects	61		61		61		61	
N observations	3,349		3,294		3,294		3,294	

Note. Level 1 predictors: time, negative event, medication use, sleep, PI, PA. Level 2 predictors: PHQ-9, average PA, nonjudging, nonreactivity. PA = positive affect; PHQ-9 = Patient Health Questionnaire–9; PI = pain intensity; AIC = Akaike information criterion; BIC = Bayesian information criterion.

medication use since the last time point, and higher levels of depressive symptoms at baseline were associated with higher NA. Sleep was not significantly associated with NA.

PA. Higher momentary PI and lower momentary PA were significantly associated with higher concurrent NA. Also, people with lower average (i.e., person-mean) PA reported on average higher NA. In line with the buffering hypothesis of the DMA (Zautra et al., 1997), momentary PA inversely predicted the strength of the concurrent association between PI and NA, such that as momentary PA increased with one unit, these associations weakened with on average .02. This effect was slightly larger when controlling for the interaction effect between PI and baseline depressive symptoms ($B = -.03$, $SE = .01$, $p < .01$). Average PA did not significantly moderate the within-person concurrent association between PI and NA, which indicates that the strength of these associations was not weaker for individuals with higher average PA. Thus, the results did not support our hypothesis of a buffering effect for average PA.

Mindfulness. Neither the main effect of the mindfulness facet "nonjudging" nor the main effect of "nonreactivity" on NA was significant. Only nonjudging significantly interacted with the effect of PI on concurrent NA. That is, nonjudging inversely predicted the strength of the association between PI and NA. With each unit increase in nonjudging, these associations weakened with .10. The PI × Nonjudging interaction was somewhat weaker but still significant when controlling for the interaction between PI and baseline depressive symptoms ($B = -.07$, $SE = .03$, $p < .01$).

Post hoc sensitivity analyses. The previous analyses were repeated for only those moments when headache was present (i.e., PI > 0), to test whether our moderators of interest had a similar effect on the concurrent associations between varying levels of pain intensity and NA in the presence of headache. Both the interaction effect between momentary PA and PI ($B = -.01$, $SE = .01$, $p = .27$) and the interaction effect between average PA and PI ($B = -.03$, $SE = .02$, $p = .12$) were smaller and no longer significant when including only moments with PI > 0. The interaction between nonjudging and PI was slightly larger and still significant ($B = -.11$, $SE = .03$, $p < .01$), while the interaction between nonreactivity and PI was of the same size and still not significant ($B = .06$, $SE = .03$, $p = .05$).

One of the reasons why the buffering effect of PA disappeared when only examining moments with headache could be that PA primarily buffers the effect of presence of headache (PI > = 1) versus having no headache (PI = 0) on NA. Indeed, when testing a model with a dummy variable for pain (0 = no pain present, 1 = pain present), the interaction effect between the pain dummy and momentary PA was larger and significant: −.13 ($SE = .03$, $p < .01$). Also, the interaction between the pain dummy and average PA was somewhat larger than when examining pain as a continuous variable but not significant: −.08 ($SE = .05$, $p = .08$). On the other hand, the interaction between the pain dummy and the mindfulness facets was much smaller than when examining pain as a continuous variable. The interaction effect between the pain dummy and nonjudging and nonreactivity was .01 ($SE = .06$, $p = .82$) and .01 ($SE = .05$, $p = .86$), respectively.

Time-Lagged Associations

Parameter estimates (fixed effects) of the multilevel models examining the time-lagged associations between pain and NA are presented in Table 3. Again, NA was significantly associated with time, the severity of negative events during the day, medication

Table 3
Time-Lagged Multilevel Models Predicting Next Moment Negative Affect

Variable	Baseline model Estimate (*SE*)	*p*	Control variables Estimate (*SE*)	*p*	PA Estimate (*SE*)	*p*	Mindfulness Estimate (*SE*)	*p*
Fixed effects								
Intercept	1.32 (.12)	<.01	1.17 (.16)	<.01	2.89 (.38)	<.01	1.76 (.67)	.01
Time	<–.01 (<.01)	.01	<–.01 (<.01)	<.01	<–.01 (<.01)	<.01	<–.01 (<.01)	.02
NA^{t-1}	.45 (.03)	<.01	.42 (.03)	<.01	.30 (.03)	<.01	.37 (.03)	<.01
Negative event			.08 (.01)	<.01	.08 (.01)	<.01	.08 (.01)	<.01
Medication use (yes)			–.33 (.05)	<.01	–.26 (.05)	<.01	–.27 (.05)	<.01
Sleep			–.02 (.01)	.03	–.01 (.01)	.15	–.02 (.01)	.04
PHQ-9			.16 (.04)	<.01	.11 (.04)	<.01	.13 (.04)	<.01
PI^{t-1}					.12 (.04)	<.01	.11 (.06)	.07
PA^{t-1}					–.11 (.02)	<.01		
Average PA					–.45 (.11)	<.01		
$PI^{t-1} \times PA^{t-1}$					–.02 (.01)	.05		
PI^{t-1} × Average PA					–.03 (.01)	.01		
Nonjudging							–.21 (.13)	.11
Nonreactivity							.06 (.12)	.60
PI^{t-1} × Nonjudging							–.03 (.01)	.01
PI^{t-1} × Nonreactivity							.02 (.01)	.04
Model fit								
AIC	5,550.91		5,328.48		5,255.12		5,298.59	
BIC	5,592.20		5,399.13		5,361.09		5,398.68	
Sample size								
N subjects	61		61		61		61	
N observations	2,695		2,663		2,663		2,663	

Note. Level 1 predictors: time, negative event, medication use, sleep, PI^{t-1}, PA^{t-1}. Level 2 predictors: PHQ-9, average PA, nonjudging, nonreactivity. PA = positive affect; PHQ-9 = Patient Health Questionnaire–9; PI = pain intensity; AIC = Akaike information criterion; BIC = Bayesian information criterion.

use since the last time point, and the level of depressive symptoms at baseline. In addition, current NA (t) predicted NA at the next moment in time (t + 1).

Positive affect. Higher (momentary) PI and lower (momentary) PA at the current time point (t) were significantly associated with higher momentary NA at the next moment in time (t + 1; see Table 3). Individuals with higher average PA reported on average higher NA. Lagged values of momentary PA did not significantly moderate the associations between lagged values of PI and next-moment NA (–.02, SE = .01, p = .05). Thus, momentary PA appears not to alter the strength of the associations between PI and next-moment NA, which contradicts the buffering hypothesis of the DMA (Zautra et al., 1997). The interaction effect between average PA and PI on next-moment NA was also nonsignificant (p = .01). This suggests that the strength of the within-person association between PI and next-moment NA did not depend on an individual's level of average PA.

Mindfulness. The nonsignificant main effect of baseline levels of nonjudging and nonreactivity on average NA was the same as in the concurrent model. The interaction effect between nonjudging and PI was now nonsignificant (p = .01). Thus, the strength of the within-person association between PI and next-moment NA did not depend on an individual's level of nonjudging. Similar to the concurrent model, the interaction between nonreactivity and PI was not significant.

Post hoc sensitivity analyses. The buffering effect of lagged momentary PA on the associations between lagged values of PI and next-moment NA was somewhat smaller and still not significant when only examining moments on which headache was present (PI > 0; $B = -.01$, SE = .01, p = .16). The interaction effect between average PA and lagged values of PI was somewhat larger and still significant ($B = -.05$, SE = .02, $p < .01$). Both the interaction between nonjudging and PI ($B = -.03$, SE = .02, p = .07) and the interaction between nonreactivity and PI (B = .03, SE = .01, p = .04) were of similar size but not significant.

When testing models with a dummy variable for pain (0 = no pain present, 1 = pain present), the interaction effect between the pain dummy and momentary PA on next-moment NA was larger than when examining a continuous pain variable and significant: $B = -.11$, SE = .04, $p < .01$. The interaction between the pain dummy and average PA was somewhat larger but not significant: $B = -.05$, SE = .04, p = .26. Finally, the interaction effect between the pain dummy and mindfulness facets on next-moment NA was −.05 (SE = .04, p = .25) for nonjudging and .03 (SE = .04, p = .43) for nonreactivity, both not significant.

Discussion

The primary aim of this study was to test two complementary models regarding the role of state versus trait (i.e., average) PA in the dynamic association between pain and NA. State PA was found to moderate the concurrent but not the time-lagged association between pain intensity and NA, providing partial support for the DMA (Zautra et al., 1997). On the other hand, average PA moderated neither the concurrent nor the time-lagged associations between pain intensity and NA, which seems to contradict the BBM (Fredrickson, 1998). Second, we investigated the role of the mindfulness facets "nonjudging" and "nonreactivity." Individuals with higher levels of nonjudging were found to display weaker concurrent associations between pain and NA, while this effect was not significant for the time-lagged associations. Nonreactivity did not moderate the pain–NA association.

Our findings correspond with earlier studies examining affect dynamics in the context of arthritis and fibromyalgia, which have also found a moderating role of state PA in the concurrent associations between pain intensity and NA (Strand et al., 2006; Zautra et al., 2005; Zautra & Smith, 2001). Together, these findings support the proposition of the DMA (Zautra et al., 1997) that PA and NA become more interdependent in the context of pain. The current study extended earlier findings by also examining the time-lagged associations between pain intensity and NA. Notably, state PA did not significantly moderate these time-lagged associations ($p = .05$), which suggests that the buffering effect of PA is too small to significantly reduce affective reactivity a few hours later. However, it is also plausible that other factors (e.g., negative cognitions, coping strategies) have a more prominent influence on the effect of pain on next-moment NA.

The finding that average PA did not moderate the concurrent or time-lagged associations between pain intensity and NA is in line with findings of an earlier study in two different samples of patients with arthritis and fibromyalgia (Zautra & Smith, 2001). In both samples, average PA did not moderate the pain–NA associations, while within-person changes in PA did moderate these associations. However, another study in a mixed arthritis and fibromyalgia sample did find that individuals with higher average PA showed weaker increases in NA during high pain weeks (Zautra et al., 2005). While the BBM suggests that individuals with higher average PA are more resilient during stressful events, these inconsistent findings seem to raise doubt as to whether this can be generalized to the specific context of a pain episode. Especially in case of chronic migraine, it is likely that pain is so overwhelming and incapacitating that many people will be unable to mobilize their coping resources (e.g., seek distraction, ask for help).

To our knowledge, our study was the first to examine whether trait mindfulness moderates the within-day dynamic associations between pain and NA. The finding that nonjudging inversely predicted the strength of the concurrent associations between PI and NA is in line with earlier studies that have found that higher nonjudging is related to lower negative mood in chronic pain (Elvery, Jensen, Ehde, & Day, 2017; Lee et al., 2017; Poulin et al., 2016; Veehof et al., 2011). Our finding suggests that a possible mechanism through which nonjudging contributes to lower negative mood is by reducing affective reactivity to increases in pain. However, our nonsignificant finding for the role of nonjudging in a time-lagged model suggests that this effect is not large enough to buffer the impact of pain on mood a few hours later. An unexpected finding was that individuals with higher nonreactivity showed stronger rather than weaker associations between pain and NA, although this moderating effect was not significant. Findings for the association between nonreactivity and mood have not been consistent across studies (Elvery et al., 2017; Heeren et al., 2015; Lee et al., 2017; Poulin et al., 2016; Veehof et al., 2011). In our sample, nonreactivity was unrelated to depressive symptom scores and nonjudging at baseline. These findings suggest a problem with the construct validity of the nonreactivity subscale in our chronic pain sample.

Because we were interested in the effect of any change in pain intensity on NA, we included the full range of headache ranging from no headache to severe headache. Interestingly, results of post hoc sensitivity analyses suggested that some of our moderators mainly buffered the effect of a change in no headache versus headache, while others seemed to buffer the effect of changes in pain intensity during a headache attack. For instance, the moderating effect of momentary PA was smaller and no longer significant when examining the association between pain intensity and NA in the presence of headache, while it was much larger and significant when examining headache as a dichotomous variable (headache vs. no headache), both in the concurrent and lagged models. In contrast, nonjudging had a concurrent buffering effect when examining the full spectrum of pain intensity but not when examining no headache versus headache. This finding may be unique to chronic migraine, as this condition is characterized by migraine attacks as well as days with nonmigraine headache (Headache Classification Committee of the International Headache Society, 2013). Future studies may get a more detailed picture of the effect of our moderators during these different types of headache by using a longer sampling period and recording migraine characteristics (e.g., nausea, photophobia) during the day.

This study had strengths as well as limitations. An important strength of this study was the used ESM that provides insight into affective reactivity to pain experience in daily life. Besides the enhanced ecological validity of this design (Myin-Germeys et al., 2009), the intensive longitudinal nature of ESM allowed us to examine both concurrent and temporal associations between pain and NA. A limitation was that the large majority of the sample was female, potentially because of our recruitment sources (i.e., patient society, local newspapers) and because males are typically less likely to participate in diary studies (Krieke et al., 2016). Findings are therefore not fully generalizable to males with chronic migraine. Further, to reduce burden on participants, only two facets of mindfulness were assessed. The effect of other mindfulness facets could therefore not be tested. Also, mindfulness was measured at baseline, while average PA was assessed with daily measures, which limits comparability of these effects. Finally, our sample was not large enough to examine all moderators of interest in one model. Future studies should include larger samples to examine the relative contribution of PA and mindfulness as buffering factors.

To our knowledge, this study was the first to examine affective reactivity to pain in individuals with chronic migraine. Chronic migraine can be a highly stressful condition due to its fluctuating nature (Viana et al., 2016) and high interference with daily activities (Lantéri-Minet, Duru, Mudge, & Cottrell, 2011). Our results indeed show that chronic migraine patients may have higher levels of NA when they experience pain but that there are also factors that buffer this affective reactivity. These factors provide promising targets for interventions aimed at improving mood in patients with chronic migraine. Current cognitive–behavioral interventions (e.g., Cognitive behavioural therapy, acceptance and mindfulness based cognitive therapy) typically include strategies that have been found to enhance PA and nonjudging, for example, scheduling pleasurable activities, positive reappraisal, and present-moment awareness (Finan & Garland, 2015). Future studies should examine whether enhancing PA during pain episodes and promoting a nonjudgmental attitude toward experience through such interventions indeed reduces affective reactivity to chronic migraine pain.

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Received August 26, 2017
Revision received July 16, 2018
Accepted August 13, 2018 ■