



Introversiion, Extraversiion, and Worsening of Chronic Pain Impact during Social Isolation: A Mediation Analysis

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Abstract

COVID-19 social distancing mandates increased social isolation, resulting in changes in pain severity and interference among individuals with chronic pain. Differences in personality (e.g., introversion/extraversion) may modulate responses to social isolation. We examined the influence of introversion on reported social distancing-related increases in pain interference and assessed for mediators of this relationship. Individuals with chronic pain ($n = 150$) completed validated questionnaires 4–8 weeks after implementation of social distancing mandates. Introversion/extraversion was measured using a subscale of the Myers-Briggs Type Indicator and changes in pain and psychosocial variables were calculated by comparing participants' recalled and current scores. Association between introversion/extraversion and other variables were assessed using linear regression. A parallel mediation was used to examine mediators of the association between introversion and change in pain interference. Higher introversion was associated with a decrease in pain interference after social distancing ($Rho = -.194$, $p = .017$). Parallel mediation analysis revealed that the relationship between introversion/extraversion and change in pain interference was mediated by changes in sleep disturbance and depression, such that higher introversion was associated with less isolation-induced sleep disruption and depression, and thereby less worsening of pain interference. These findings suggest that personality factors such as introversion/extraversion should be considered when personalizing treatment of chronic pain.

Keywords Introversion · COVID-19 · Chronic pain · Social isolation · Pain interference

Introduction

The coronavirus 2 (SARS-CoV-2; COVID-19) has profoundly impacted physical and mental health across the globe (Consonni et al., 2021; Geoscheme, 2021; Rajkumar, 2020; Torales et al., 2020). Social distancing measures implemented to reduce the transmission of COVID-19 ranged from stay-at-home orders and closure of non-essential businesses to appeals for voluntary self-quarantining and reduction of social contact. These abrupt and profound

changes in everyday life resulted in prominent reductions in social connections, contributing to heightened social isolation and loneliness (Bu et al., 2020; Lee et al., 2020; Tull et al., 2020). Our previous report showed that pandemic-related social isolation was generally associated with greater pain severity and interference (Hruschak et al., 2021). Notably, the degree of pain worsening under these conditions was quite variable among individuals with chronic pain, with some individuals experiencing a worsening, while other experienced no change and, in some cases, even improvements in pain.

The biopsychosocial model provides a theoretical foundation for how biological, psychological, and social factors interact to influence the experience of pain (Fillingim, 2017), including certain personality traits which may contribute to variance in the pain experience (Conrad et al., 2013; Crofford, 2015; Gustin et al., 2016). The dimension of introversion/extraversion exists as a continuum amongst individuals, and, by its nature, importantly interacts with social conditions. Previous work suggests that introverts are

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less impacted by situations of heightened social isolation relative to extraverts (Wei, 2020; Wijngaards et al., 2020), raising the possibility that introversion may serve as a buffer against the negative consequences of social isolation during periods of pandemic-related social distancing mandates.

Psychological factors may contribute to both the maintenance and exacerbation of pain (Fischer et al., 2012; Gatchel, 2004). Individuals with chronic pain commonly have comorbid depression (Edwards et al., 2016a, 2016b) and report significantly greater depressive symptoms than those without chronic pain (Burke et al., 2015). In addition, depression may serve as a risk factor for both the development and maintenance of chronic pain (Fillingim et al., 2013; Lerman et al., 2015; Linton et al., 2011; Pincus et al., 2002). Similarly, sleep disturbance is more frequent among individuals with chronic pain (Finan et al., 2013; Smith & Haythornthwaite, 2004), compared to both healthy controls (Theadom et al., 2007) and the general population (Okifuji & Hare, 2011; Sivertsen et al., 2009), with poorer sleep associated with greater pain (Finan et al., 2013). Both depression and sleep disturbance have been associated with an increase in pain in chronic pain populations (Aloush et al., 2021; Rogers et al., 2021).

The current study primarily aimed to better understand the differential effects of social isolation on individuals with chronic pain and to specifically investigate the influence of introversion/extraversion on self-reported perceived changes in pain interference during COVID-19-related social isolation. The primary hypothesis was that, in comparison with greater introversion, greater extraversion would be associated with more of a reported increase in pain under conditions of social distancing. The secondary aim of this study was to explore the relationships between introversion and self-reported perceived changes in psychosocial variables (i.e., loneliness, depression, sleep disturbance, and stress) and to examine whether these variables mediated the relationship between introversion and change in pain.

Materials and Methods

Study Design

This observational cross-sectional study was approved by the Partners Human Research Committee (PHRX)/Institutional Review Board (IRB), and initial findings are reported in Hruschak et al. (2021). Participants were recruited online through Rally, a Partners Healthcare online platform connecting the public to research studies they may be eligible to participate in, and by inviting patients from our previous chronic pain cohorts, including patients with fibromyalgia, low back pain, and/or post-surgical pain (mastectomy, TKA, C-section, thoracotomy,

spine surgery). Interested respondents were emailed a link to REDCap, a secure data entry system, to complete the eligibility survey.

Eligibility criteria included being a current resident of Massachusetts, ≥ 18 years of age, having self-reported pain present for 3 months or more, and English proficiency. The survey was only open to residents of Massachusetts to best control for discrepancies between state-ordered social distancing mandates at the time of survey distribution. All electronic surveys were completed over a 4-week period (04/28/2020–05/22/2020), 8–12 weeks after state-ordered social distancing mandates were introduced, and sample size was based on response within the timeframe and available funding. Surveys took approximately 30–45 min to complete, and participants were remunerated with a \$20 gift code upon completion.

Measures

Participants completed validated questionnaires and free form questions regarding their sociodemographic information, psychosocial characteristics, pain severity and interference, and other clinical information. For more details on participants' responses to questionnaires, including additional sociodemographic information, please refer to Hruschak et al. (2021). To examine perceived changes since social distancing, participants completed two versions of some psychosocial and pain questionnaires. First, participants answered the questionnaire with each question beginning with "Before social distancing..." followed by the original validated question. After recording recalled scores from before social distancing, participants then answered the questions with the instructions "Since social distancing..." at the beginning of each question.

Assessment of Introversion/Extraversion

The 10-item introversion/extraversion subscale of the *Myers-Briggs type indicator (MBTI)* was used to assess introversion (range: 0–10), with higher scores indicating a more introverted personality type (Gary Allread & Marras, 2006; McCrae & Costa Jr, 1989). The MBTI has been found to have construct validity, and is composed of four independent scales that are qualitatively distinct allowing for use of this single scale as a continuous measure (McCrae & Costa Jr, 1989). As a measure of the relatively stable trait of introversion/extraversion, this subscale was assessed once, without reference to a specific timepoint (e.g., before or after social distancing). The MBTI introversion/extraversion subscale demonstrated adequate reliability in our sample (Cronbach's $\alpha = 0.842$) (Appendix A).

Pain Outcomes

Pain severity (range: 0–10) and pain interference (range: 0–70) were assessed using the 11-item *brief pain inventory (BPI)*, which has high construct validity and test–retest reliability in chronic pain populations (Tan et al., 2004). BPI pain severity (Cronbach's $\alpha = 0.734\text{--}0.890$) and pain interference (Cronbach's $\alpha = 0.908\text{--}0.912$) demonstrated good reliability in our sample for both recalled and current scores. For pain severity, items were rated on a scale of 0 (no pain) to 10 (worst pain imaginable), and for pain interference, items were rated on a scale of 0 (my pain did not interfere) to 10 (my pain completely interfered) (Appendix A).

Psychosocial Questionnaires

The 3-item *UCLA loneliness scale version 3* (range: 3–9) was used to assess loneliness. Each item was rated on a scale of 1 (hardly ever) to 3 (often). The UCLA has demonstrated reliability, internal consistency, and test–retest reliability, with higher scores signifying greater feelings of loneliness (Hughes et al., 2004; Russell, 1996). In our sample, the UCLA had good reliability (Cronbach's $\alpha = 0.766\text{--}0.871$) (Appendix A). The *perceived stress scale (PSS)* was used to assess how unpredictable, uncontrollable, or overloaded participants find their lives, with greater scores indicating higher levels of perceived stress (range: 0–40) (Cohen et al., 1994). The PSS demonstrated good reliability within our sample (Cronbach's $\alpha = 0.703\text{--}0.775$) (Appendix A). Validated short form instruments from the *patient-reported outcome measurement information system (PROMIS)* were used to measure anxiety (range: 7–35), depression (range: 8–40), and sleep disturbance (range: 8–40) (Cella et al., 2010; Choi et al., 2010). Reliabilities for current and recalled PROMIS anxiety (Cronbach's $\alpha = 0.932\text{--}0.952$), depression (Cronbach's $\alpha = 0.944\text{--}0.948$), and sleep disturbance (Cronbach's $\alpha = 0.843\text{--}0.858$) were all acceptable (Appendix A). All PROMIS questions were rated on a 5-point scale, with higher scores indicated greater symptom severity. The *pain catastrophizing scale (PCS)* was used to examine pain-related catastrophic thinking, with higher scores indicating greater catastrophizing (range: 0–52). Items on the PCS were rated on a scale from 0 (not at all) to 4 (all the time). The PCS has been validated in pain populations within both pain and controls (Sullivan et al., 1995; Van Damme et al., 2002) and demonstrated good reliability for current and recalled scores in our sample (Cronbach's $\alpha = 0.949\text{--}0.959$) (Appendix A).

Statistical Methods

Basic descriptive statistics were used to report demographic, clinical, and psychosocial characteristics of participants.

Perceived changes in variables from pre- to post-social distancing conditions were calculated by subtracting ratings for recalled state (i.e., before social distancing) from current state (i.e., since social distancing), such that positive scores indicated a perceived increase in that variable since social distancing and negative scores indicated a perceived decrease. Nonparametric tests (Spearman correlations for continuous variables and Mann–Whitney *U* test for categorical variables) were used to examine the association between introversion with demographic variables and perceived changes in pain and psychosocial variables since social distancing. Introversion/extraversion was kept on a continuous scale for correlational and mediation analyses to give greater statistical power. To allow group comparisons of changes in pain and psychosocial outcomes, 3 MBTI groups were defined: extraverted (MBTI: 0–3), balanced (MBTI: 4–6), and introverted (MBTI: 7–10), and paired *t*-tests used to assess for change in pain interference within each group.

Parallel multiple mediation was used to test the hypothesis that the relationship between introversion and perceived change in pain was mediated by perceived changes in psychosocial variables that were significantly related to introversion (i.e., change in loneliness, change in sleep disturbance, and change in depression). In parallel mediation, these mediators and covariates are held constant while examining the indirect effect of a specific mediator on the relationship between the independent (X) and dependent (Y) variables (Hayes, 2017). Covariates were selected based on their significant association with introversion within our sample. Mediation analyses and post hoc pairwise comparisons were conducted in IBM-SPSS v27 using the Preacher and Hayes PROCESS macro, which utilizes bootstrapping to generate asymmetric confidence intervals (CIs) for the indirect effect of the mediator (M) on the dependent variable (Y) and does not rely on normal curve assumptions (Hayes, 2017).

Results

Study Timeline and Demographic Information

As reported previously (Hruschak et al., 2021), in this IRB-approved study, 204 participants expressed interest in participating and were screened for eligibility, with 150 eligible respondents completing the online survey. The cohort was majority female ($n = 125$, 83%) and predominantly Caucasian ($n = 126$, 85%). The mean age was 41 years, with 83% reporting some post-high school education. (Table 1) Approximately 57% of patients reported chronic back pain, 25% reported fibromyalgia, 11% indicated chronic postsurgical pain, and 58.7% of patients indicated other sources of chronic pain. Most patients reported 2 pain types (58.7%),

Table 1 Relationship between participant characteristics and introversion

	<i>N</i> (total)	<i>N</i> (%) or mean \pm SD	Correlation (Rho) or <i>p</i> group difference (<i>U</i>) ^a	<i>p</i>
Age (years)	150	40.6 \pm 15.7	-.200	.014
Gender ^{a,b}	150		1099.5 ^a	.233
Female		125 (83.3%)		
Male		21 (14.0%)		
Other		4 (2.7%)		
Education (years)	150		< .001	.997
High school diploma		11 (7.3%)		
Associate degree or trade/tech school		15 (10.0%)		
Bachelor's degree		65 (43.3%)		
Graduate degree		59 (39.9%)		
Change in pain severity (range: 0–10)	147	0.79 \pm 1.4	-.144	.083
Change in pain interference (range: 0–70)	149	4.45 \pm 13.4	-.205	.012
Change in loneliness (range: 3–9)	149	1.23 \pm 2.0	-.279	< .001
Change in perceived stress (range: 0–40)	150	1.95 \pm 2.8	-.248	.002
Change in anxiety (range: 7–35)	149	4.64 \pm 4.7	-.092	.265
Change in depression (range: 8–40)	150	4.12 \pm 5.0	-.164	.045
Change in sleep disturbance (range: 4–20)	150	1.75 \pm 4.1	-.163	.046
Change in catastrophizing (range: 0–52)	150	4.44 \pm 8.4	-.125	.128

Range of values for psychosocial measures represents the possible range of the original instruments. Change scores are calculated by subtracting current scores from recalled scores, such that a positive score indicates an increase, and a negative score indicates a decrease

^a*U*, Mann–Whitney *U* (Test Statistic)

^bOnly respondents identifying as either male or female were included in the non-parametric analysis testing the association between introversion and gender

with 30% reporting 3 pain types, and only 11.3% reporting 1 pain type. While most participants reported more than one pain type, only 13% reported taking opioid medications for their pain condition(s).

Association of Introversion and Demographic Variables

The relationships between introversion and demographic factors are reported in Table 1. Younger age was significantly associated with greater introversion (Rho = -.203, *p* = .013). There was no significant difference in introversion scores between males and females (Mann–Whitney *U* = 1097.5, *p* = .228), and there was no significant relationship between introversion and education (Rho = .002, *p* = .980).

Association of Introversion with Perceived Changes in Pain

Levels of introversion/extraversion varied substantially among participants. There was a significant negative correlation between introversion/extraversion and perceived change in pain interference (Rho = -.205, *p* = .012), such that greater introversion was negatively associated with

perceived increases pain interference since social distancing. (Table 1, Fig. 1A) While there was a similar negative correlation between introversion and perceived increase in pain severity, this association did not reach significance (Rho = -.144, *p* = .083).

In this cohort, 60 participants' scores reflected higher extraversion (MBTI: 0–3), 30 participants were more balanced (MBTI: 4–6), and 59 participants' scores reflected higher introversion (MBTI: 7–10). (Table 2) Fig. 1B depicts self-reported perceived change in pain interference, with paired t-tests assessing significant change within each group. Participants who indicated higher extraversion reported a significant increase in pain interference since social distancing compared to recalled scores before social distancing (*t* = 4.99, *p* < .001). Participants who were more balanced and those with higher introversion scores did not report a significant increase in pain interference (Table 2).

Association of Introversion/Extraversion with Perceived Changes in Psychological Factors

Introversion was inversely associated with perceived increases in loneliness since social distancing (Rho = -.248, *p* = .002, Table 1). Higher introversion scores were also inversely related to perceived increases in sleep disturbance

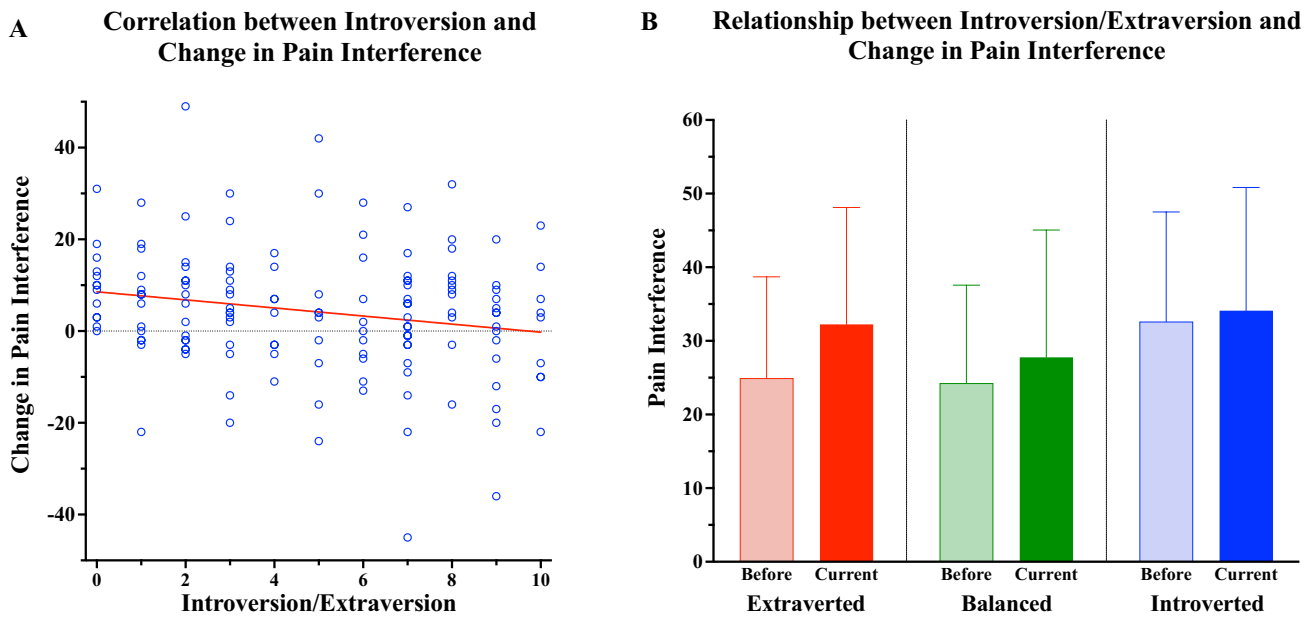


Fig. 1 The relationship between introversion/extraversion and change in pain interference. **a** Correlation between introversion and change in pain interference. Greater introversion was inversely correlated with change in pain interference ($Rho = -0.205, p = 0.012$). **b** The group of participants that indicated higher extraversion (MBTI: 0–3,

red) reported a significant increase in pain interference ($t = 4.99, p < .001$). Individuals with more balanced extraversion/introversion (MBTI: 4–6, green) and higher introversion (MBTI: 7–10, blue) did not have a significant increase in pain interference since social distancing ($t = 1.42, p = 0.167$ and $t = 0.93, p = 0.358$, respectively)

Table 2 Paired samples T-test comparing recalled pain interference before social distancing to current pain interference within introversion groups

MBTI group	<i>n</i>	Mean ^a (95% CI)	SD	SE	<i>t</i>	<i>p</i>
High extraversion (0–3)	60	7.55 (4.52, 10.58)	11.72	1.51	4.99	<.001
Balanced (4–6)	30	3.68 (–1.63, 8.99)	14.22	2.60	1.42	.167
High introversion (7–10)	59	1.69 (–1.96, 5.34)	14.02	1.83	0.93	.358

MBTI Myers-Briggs type indicator, SD standard deviation, SE standard error, CI confidence interval (lower, upper)

^aMean difference between current and recalled pain interference scores, with positive scores indicating an increase in pain interference since social distancing

($Rho = -.163, p = .046$), depression ($Rho = -.164, p = .045$), and perceived stress ($Rho = -.248, p = .002$). Introversion scores were not significantly associated with perceived changes in anxiety or catastrophizing, (Table 1).

Parallel Mediation Analysis

To explore changes in psychosocial factors that occurred during social distancing, which might explain the relationship between introversion/extraversion and perceived change in pain, a parallel mediation model was constructed. Because introversion was significantly related to perceived change in pain interference, but not pain severity, we focused the mediation analysis on the relationship between introversion and perceived change in pain

interference (Fig. 2). Based on their significant association with introversion/extraversion, changes in loneliness, depression, sleep disturbance, and perceived stress were all included as potential mediators in a parallel mediation model, with age included as a covariate, to understand if they mediated the relationship between introversion and changes in pain interference (Fig. 2). The overall model including introversion and all the potential mediators explained 44.5% of the variance in change in pain interference [$F(6,141) = 18.825, p \leq .001$]. After including the indirect effect of all four mediators, the direct effect ($c = -0.764, p = .032$) of introversion on change in pain interference (Fig. 2A) was no longer significant ($c' = 0.141, p = .631$) (Fig. 2B). A significant indirect effect of introversion on change in pain interference was

Fig. 2 a Conceptual model of the relationship between introversion/extraversion and change in pain interference during social isolation. **b** Candidate mediators, including change in loneliness, depression, sleep disturbance, and perceived stress, which were significantly associated with introversion, were entered as potential parallel mediators of this relationship. Change in sleep disturbance and depression were significant mediators of the relationship between introversion and change in pain interference. *Significant at $p < .05$, **Significant at $p < .01$, ***Significant at $p < .001$

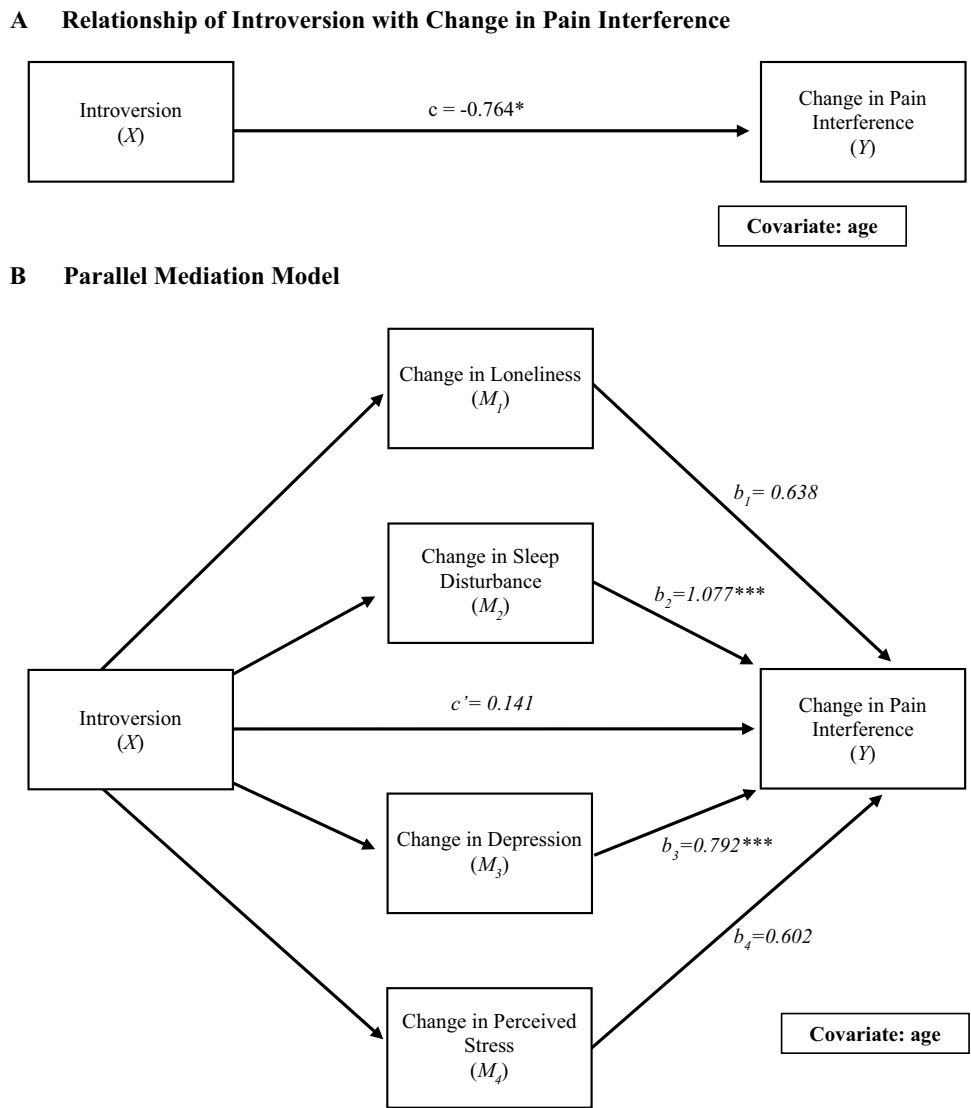


Table 3 Indirect effects of changes in loneliness, depression, sleep disturbance, and perceived stress

Mediators	Indirect effects			
	B	SE	95% LCI	95% UCI
Change in loneliness	-0.120	0.103	-0.363	0.042
Change in depression	0.318	0.136	0.611	-0.082
Change in sleep disturbance	-0.325	0.142	-0.638	-0.088
Change in perceived stress	-0.142	0.104	-0.363	0.050

LCI lower confidence interval, UCI upper confidence interval

observed through both change in depression and change in sleep disturbance (Fig. 2, Table 3). However, there was not a significant indirect effect through change in loneliness or change in perceived stress. This suggests that the association between introversion and change in pain interference

was partially accounted for by changes in depression and sleep disturbance.

Discussion

We previously reported that COVID-19-related social isolation negatively impacted the pain symptoms of patients with chronic pain, but that the extent of this negative impact was variable amongst individuals (Hruschak et al., 2021). Here, we explored the personality dimension of introversion/extraversion to assess whether it might account for some of the variability in perceived change in pain interference reported by individuals after approximately 2 months of social distancing. We observed an interesting relationship between an individual’s degree of introversion/extraversion and their self-reported change in pain. Specifically, more extraverted individuals reported

significantly greater perceived worsening of pain interference since social distancing, while more introverted individuals reported little to no change, sometimes even a decrease, in perceived pain interference. At the same time, higher extraversion (i.e., lower introversion) scores were significantly associated with a greater perceived increase in loneliness, depression, sleep disturbance, and stress. A parallel mediation analysis including these changes in psychosocial variables revealed that perceived changes in depression and sleep disturbance significantly mediated the relationship between the introversion/extraversion and perceived change in pain interference. These findings suggest that individuals with more extraverted personalities may be at particular risk for negative impacts of social distancing on pain, potentially related to concomitant increases in depressive symptoms and sleep disturbance, while those with more introverted personalities may be somewhat less impacted, or may even improve, under conditions of social distancing. Of note, more introverted individuals generally reported higher recalled levels of pain interference (i.e., high baseline levels of pain interference before social distancing). One interpretation of these data is that the externally imposed conditions of social isolation seemingly brought more extraverted individuals up to the same level the pain interference that introverted individuals normally experience, while more introverted individuals were not as impacted, and did not experience a further increase in pain interference.

Investigating how the personality trait of introversion/extraversion impacted pandemic-induced social isolation during the early phases of COVID-19 afforded a rare snapshot of the intersection of psychological and social influence on pain processing, as social conditions are typically quite difficult to control, thus making their systematic study quite challenging under normal conditions. Both personality and social influences are among the many factors contextualized within the biopsychosocial model of pain, which offers a framework for understanding how biological, psychological, and social factors influence the experience of pain (Fillingham, 2017; Maixner et al., 2011). Previous cross-sectional and longitudinal research has demonstrated an important relationship between isolation and both acute and chronic pain (Allen et al., 2020; Elran-Barak & Mozeikov, 2020; Hanssen et al., 2014; Karayannis et al., 2019; Smith et al., 2019; Wolf & Davis, 2014). Furthermore, research has supported the idea of a “pain personality”, noting that certain personality characteristics are more pronounced among chronic pain populations, including lower self-directedness and higher harm avoidance (Conrad et al., 2007; Gencay-Can & Can, 2012; Gustin et al., 2016; Malmgren-Olsson & Bergdahl, 2006), greater neuroticism (Conrad et al., 2007), and feeling more emotionally overwhelmed (Conrad et al., 2013). Personality traits such as introversion have previously

been shown to modulate the experience of pain (Conrad et al., 2013; Crofford, 2015; Gustin et al., 2016). Under normal conditions, more introverted individuals report overall worse psychological health, greater chronic pain, and have a greater likelihood of developing chronic physical disorders compared to more extraverted individuals (Crofford, 2015; Seto et al., 2019; Staab et al., 2014; Wade et al., 1992). One hypothesized mechanism for this disparity is the ease with which extraverted individuals employ active coping mechanisms, particularly engaging in social interactions, and thus possessing larger social networks than introverts, which may serve to buffer stress (Dubayova et al., 2009; Harris et al., 2017; Srivastava et al., 2008). Accordingly, more extraverted individuals report less loneliness and may generally have less difficulty adjusting to changes in day-to-day life compared to more introverted individuals under normal conditions (Albuquerque et al., 2012; Bauer & Liang, 2003).

The interplay of introversion/extraversion and social factors (e.g., isolation from social distancing) is yet another layer of complexity, which may substantially add to the variability observed between individuals. In response to social distancing, we found that higher introversion was associated with significantly less perceived increase in pain interference, loneliness, depression, sleep disturbance, and stress. One possible explanation for these findings is that more introverted individuals were less impacted by heightened social isolation, perhaps because it was less of a departure from their status quo, and related to their preference for less stimulating environments (Eysenck, 1947; Hans Jurgen Eysenck, 1991) and tendency to operate with fewer social interactions prior to social distancing. (Harris et al., 2017; Srivastava et al., 2008) In fact, we did observe relatively more introverted individuals who reported substantially *improved* pain outcomes since social distancing as well. (Fig. 1A) This is consistent with the idea that more limited social contact may be more comfortable for these individuals.

Previous work has shown that extraverted individuals have reported greater concern that COVID-19 would disrupt daily life and cause them to be lonely (Aschwanden et al., 2020). Correspondingly, a study on social connectedness since the pandemic showed that the most extraverted individuals reported larger decreases in social connectedness since social distancing (Wei, 2020). In addition, extraversion has been associated with less engagement in social distancing, as well as less future intention to social distance (Blagov, 2020; Muto et al., 2020), which may be another important contributor to the variability of isolation-related impacts. In contrast, more introverted individuals reported a sense of relief in the face of the decrease in pressure to leave their homes and socialize, whereas those who are more extraverted found this more distressing (Asselmann et al., 2020). However, another US-based study observed

that higher introversion was also associated with *higher* levels of depression, as well as anxiety and loneliness, during the pandemic. It has also been suggested that introversion moderated the relationship between adherence of stringent protective COVID-19 measures and resulting depressive symptoms, such that introverts fared better in countries with more stringent protective measures (Wijngaards et al., 2020). The sample of pain patients in the current study were residing in Massachusetts, which was enforcing relatively stringent and consistent social distancing mandates at the time of data collection, and where adherence and uptake of measure was anecdotally quite high, perhaps owing to the fact that one of the first known US clusters occurred in the Boston metro area.

Participants in this study reported perceived changes in several psychosocial variables, which seemed to parallel perceived changes in pain and many of which have previously been shown to modulate the pain experience. Depression is one of the most commonly assessed psychological factors showing comorbidity with chronic pain (Edwards et al., 2016a, 2016b), and may serve as an important risk factor for the development and maintenance of chronic pain conditions (Fillingim et al., 2013; Lerman et al., 2015; Linton et al., 2011; Pincus et al., 2002) and tends to be more severe in individuals with chronic pain (Burke et al., 2015). During COVID-19, depressive symptoms have reportedly increased (Wilke et al., 2021), especially for individuals with chronic pain (Garrido-Cumbrera et al., 2021), consistent with our findings in the current cohort. In July 2020, 80% of adults with chronic pain reported significant depression (Yu et al., 2021). These rates are higher than those in the general population during COVID-19 (21–37%) (Dawson & Golijani-Moghaddam, 2020; McCracken et al., 2020; Pakenham et al., 2020) and higher than in chronic pain samples pre-COVID-19 (55–60%) (Rayner et al., 2016). Depressive symptoms have been associated with greater increases in chronic pain during COVID-19 in other samples as well (Aloush et al., 2021). The findings of the current study add insight that this relationship between depression and greater pain interference appears stronger among individuals with greater levels of extraversion under conditions of social distancing.

Sleep disturbances are frequently comorbid with chronic pain (Theadom et al., 2007), being more prevalent in chronic pain populations than in healthy controls (Theadom et al., 2007) or in the general population (Okifuji & Hare, 2011; Sivertsen et al., 2009). Pain interference and sleep disturbance are often closely associated in studies of chronic pain (Finan et al., 2013; Smith & Haythornthwaite, 2004). This relationship, while reciprocal, appears to be somewhat directional, in that evidence suggests that improving sleep may improve pain, while improving pain does not consistently improve sleep (Andersen et al., 2018; Vitiello et al.,

2014). This directionality is consistent with our observation of sleep disturbance as mediator of change in pain interference. While several factors may explain the rises in the interruption of sleep during the pandemic (Altena et al., 2020) at least one previous study documents an association of decreased social interaction with worsened sleep quality (Thieme et al., 2004), in agreement with our proposed mediation model, where social isolation leads to worsened sleep disturbance in extraverted individuals, and worsened sleep partially mediates the relationship between extraversion and pain interference.

Greater loneliness has also been associated with both worse acute pain and disability (Hanssen et al., 2014), as well as chronic pain (Allen et al., 2020; Elran-Barak & Mozeikov, 2020; Smith et al., 2019). Among individuals with chronic pain, loneliness correlates with greater daily pain (Wolf & Davis, 2014). Social distancing during COVID-19 has resulted in decreased emotional and social support from peers, both of which are coping mechanisms for many individuals with chronic pain (Wijngaards et al., 2020). Furthermore, loneliness during COVID has been associated with a deterioration in self-reported health (Elran-Barak & Mozeikov, 2020). In agreement with this, we also observed a relationship between increased social-distancing-imposed loneliness and pain. However, loneliness did not emerge as a significant mediator in this parallel mediation model, possibly due to its covariation with sleep disturbance and depression, which were significant mediators.

Telehealth has become a prominent mode employed to manage chronic pain during social distancing, and may continue as an important tool to deliver care to vulnerable patients (Mariano et al., 2021; Puntillo et al., 2020). Interestingly, a subset of studies suggests that introverted individuals have more positive attitudes towards teletherapy (Knechtel & Erickson, 2020) and are better able to express their feelings via remote therapy than extraverts (Irvine et al., 2020). One study found that introverted individuals were quite adept at communicating in an online setting, in that they had significantly higher ASR/TSR ratios (Affective Self Reference/Total-Self Reference) during telephone counselling than during face-to-face sessions, whilst the reverse was true for extraverted individuals (Irvine et al., 2020). In addition, highly introverted individuals expressed a more positive attitude toward online therapy than moderately introverted or extraverted individuals (Knechtel & Erickson, 2020).

Individuals with pain, regardless of their level of introversion/extraversion, may therefore benefit from pain telehealth services. More introverted patients may benefit because they are more likely to prefer the virtual format of psychological treatment for pain, as opposed to engaging in face-to-face interactions. However, during times of social distancing, it may be of relatively greater importance to extroverted

individuals to have access to online individual or group therapy. Individuals who do not have reliable internet, or technology to make these kinds of activities possible, might be at higher risk. Another implication of these findings may be recognizing the importance of treating depression and sleep disturbances in extraverted individuals with chronic pain during times of social isolation, as these psychological symptoms may further exacerbate their pain experience.

Limitations

Several important limitations must be considered in interpreting the findings of our study. First, this study is cross-sectional, and thus, causal and temporal claims cannot be made. The mediation analysis only begins to put a structure on understanding how some of these factors influence each other, and almost certainly there is a bidirectional influence of personality on pain, and pain on personality. Second, there is a potential for recall bias. We asked participants to recall their pain severity and interference, loneliness, sleep disturbance, depression, and perceived stress before the social distancing conditions, and therefore, recall bias may have been at play, either falsely elevating or decreasing the estimation of actual change in factors. However, given the conditions and the salience of people's situation imposed by the pandemic, it seems likely that people were more vigilant, attentive, and self-reflective during this time, and were more accurately attuned to their own state and changes in it. Future studies should explore the longitudinal association between personality, pain, and psychological factors. Third, given the relatively short timeframe in which this study had to be planned, approved, and executed, and the online nature of the recruitment, the sample is not broadly representative. Specifically, the gender was highly skewed towards women, and race was also predominantly Caucasian, unfortunately limiting the generalization of findings to racial and ethnic minorities and men. Future work should aim to recruit a more demographically diverse sample. Fourth, although we observed that more introverted individuals reported less of a perceived increase in pain, loneliness, sleep disturbance, and depression, their recalled scores on these items were higher, opening the possibility that there was a ceiling effect (i.e., they could not get much worse). Counter to this idea, however, some individuals did report perceived improvement in pain. Finally, many of the original, validated questionnaires [i.e., the BPI (pain severity and interference) and the PROMIS measures (depression, anxiety, and sleep disturbance)] use specific language that asks patients to answer questions based on how they have felt within the past seven days. By adding "before social distancing", we were asking participants to recall how they felt prior to social distancing (i.e., ≥ 2 months prior

to taking the survey), and by adding "since social distancing" as a qualifier, we were asking them to put themselves in the context of the timeframe social distancing was implemented in Massachusetts. However, altering the original, validated questionnaire items may have affected the validity of the tools used... Further research is needed to understand how qualifiers such as those used in this study affect participant's responses to items compare to the original validated questionnaires.

Conclusion

Chronic pain patients experienced varying degrees of worsening of pain interference with social distancing, which may be partially explained by their individual degree of introversion/extraversion. In particular, more extraverted patients appeared to be at greater risk, experiencing more of a perceived increase in sleep disturbance and depression which was associated with an increase in perceived pain interference. A greater degree of introversion, on the other hand, seemed to serve as a protective factor against worsening of pain under conditions of social isolation.

Appendix A: Reliability of Measures

	Recalled state (Before social distancing)		Current state (During social dis- tancing)	
	α	Number of items	α	Number of items
Introversion (MBTI) ^a	–	–	0.842	10
Pain severity (BPI)	0.734	3	0.837	3
Pain interference (BPI)	0.908	7	0.912	7
Loneliness (UCLA)	0.871	3	0.766	3
Perceived stress (PSS)	0.775	4	0.703	4
Anxiety (PROMIS-SF)	0.932	7	0.952	7
Depression (PROMIS-SF)	0.948	8	0.944	8
Sleep DISTURBANCE (PROMIS-SF)	0.843	4	0.858	4
Catastrophizing (PCS)	0.949	13	0.959	13

MBTI Myers-Briggs type indicator, *BPI* brief pain inventory, *UCLA* University of California, Los Angeles, *PSS* perceived stress scale, *PROMIS* patient-reported outcomes measurement information system-short form, *PCS* pain catastrophizing scale

^aIntroversion is considered to be a stable trait across time, so participants provided current answers only; α , Cronbach's Alpha

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Declarations

Conflict of interest Authors K. Mikayla Flowers, Carin A. Colebaugh, Valerie Hruschak, Desiree R. Azizoddin, Samantha M. Meints, Robert N. Jamison, Jenna M. Wilson, Robert R. Edwards, and Kristin L. Schreiber declare that they have no conflict of interest.

Informed Consent All participants provided electronic informed consent via REDCap, a secure data entry system prior to beginning surveys.

Human and Animal Rights This study has been approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

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