Perceived injustice in chronic pain: an examination through the lens of predictive processing

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Practice points

- The current framework emphasizes the individual with pain as an active participant in pain-related appraisal; top-down effects of pain-related belief structures (e.g., injustice related to pain) may shape expectancies and future cognitive, behavioral and affective responses to pain.
- Individuals with high injustice beliefs may show differences in their appraisal of pain, physical activity and social engagement, above and beyond effects of chronic pain itself.
- Much like pain catastrophizing, injustice beliefs represent a maladaptive pattern of cognitive appraisal that may prove to be salient target for improving pain-related coping.
- Existing cognitive-behavioral therapy interventions for chronic pain have traditionally emphasized more 'reactive' approaches to cognition (e.g., recognition and reappraisal of existing cognitions), which may be more challenging for deeply or rigidly held beliefs about inequality or unfairness related to pain.
- Principles of psychological flexibility and improved attentional control (e.g., through mindfulness meditation or acceptance-based interventions) may confer the ability to readjust expectancies or de-emphasize the impact of injustice beliefs.
- Adoption of the predictive-processing model may allow for improvement in measurement of therapeutic process, as well as inform design of future interventions.

Chronic pain conditions have been shown to be exacerbated by psychological factors, and a better understanding of these factors can inform clinical practice and improve the efficacy of interventions. The current paper investigates perceived injustice, a novel psychosocial construct, within a framework influenced by the tenets of predictive processing. The proposed conceptual model derived from tenets of predictive processing yields a single hierarchical self-reconfiguring system driven by prediction, which accounts for a wide range of human experiences such as perception, behavior, learning and emotion. This conceptualization can inform the development and implementation of more targeted therapeutic interventions for chronic pain.

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Chronic pain affects about 100 million US adults and costs the nation US\$635 billion annually in medical costs and lost productivity [1]. Chronic pain has a wide range of deleterious consequences for physical function, psychosocial function and overall health [2,3]. Research demonstrates that psychological factors, including expectations and cognitive appraisals, have significant implications for mood, behavior and overall health, and play important roles as moderators and mechanisms of the pain experience [4–6].

Perception is a key component of psychological responses to pain (e.g., behavior), and injustice perception is an emerging construct that has been proposed as a key factor in chronic pain-related outcomes. Injustice appraisals related to pain negatively affect physical and psychological outcomes among individuals with an acute injury or a chronic pain condition [7–11]. Pain-related injustice perception has been conceptualized as a cognitive appraisal reflecting the severity and irreparability of pain- or injury-related loss (e.g., 'I just want my life back'), and

externalizing blame and unfairness ('I am suffering because of someone else's negligence') [8]. Like earlier models of locus of control in chronic pain (e.g., [12]), injustice perception may engender feelings of helplessness due to beliefs about the uncontrollable nature of an injustice or the predominant role of others in perpetuating a health-related issue, but also incorporate a strong aspect of social comparison that may foster social conflict and greater distress (e.g., the nature of a stressor is not only negative but also unjust in comparison to the experiences of others). Perceptions of injustice may arise from a variety of circumstances but have been studied more prominently in cases of litigation [7] and prior injuries (e.g., whiplash injuries), resulting in significant pain and physical impairment [13]. Follow-up studies in other cohorts have demonstrated that perceptions of injustice have a wide range of deleterious consequences. For example, Sullivan *et al.* found that perceived injustice was associated with greater self-reported pain intensity and disability, more severe depressive symptomatology and reduced likelihood to return to work 1 year after multidisciplinary rehabilitation among individuals with musculoskeletal pain [14] and pain intensity, perceived functional impairment and psychological distress [7,10]. Finally, violations of equity can give rise to perceptions of injustice even when the events seem random [11].

Understanding the mechanisms linking perceived injustice to health outcomes is an important goal. Previous studies have identified maladaptive psychological processes including emotional distress (e.g., depressive symptoms and anger), as well as maladaptive behavioral responses to pain [14,15], as concomitant challenges for individuals with high injustice beliefs about their pain condition. However, there remains a continued need to understand antecedents and mechanisms of effect related to this phenomenon, which have often appeared only as an implicit aspect of prior studies. In one of the few studies examining perceptual differences underlying injustice appraisal, Trost *et al.* demonstrated that individuals with chronic pain who report greater levels of perceived injustice show differences in appraisals of pain, physical task difficulty and intensity of negative emotional stimuli [16].

Unfortunately, there remains a need to identify a unifying construct that explains why individuals with high injustice beliefs may show perceptual differences in their appraisal of pain, physical activity and social stimuli. In the current paper, we propose a model of predictive cognition that may connect antecedent personal events to current appraisal processes and explore how these processes may contribute to worse pain-related adjustment. This paper will review the current literature on injustice beliefs through the lens of a predictive processing (PP) framework. This framework may elucidate new ways to explain how psychological factors, most notably cognitive appraisals, influence pain perception and coping. Additionally, we will address clinical implications of this model in chronic pain.

Predictive processing

PP is a theoretical framework used in computational neuroscience, defined as a process of 'incoming sensory data [that] is constantly met with a cascade of top-down prediction, whose job is to predict the incoming signal across multiple temporal and spatial scales' [17].

Historically, many neuroscience-based perceptual models have considered the brain to be a passive entity awaiting sensory input and reliably perceiving reality. In contrast, proponents of PP claim that the brain is actively making predictions to meet incoming sensory stimuli and these predictions dramatically shape perception [17–20]. PP models emphasize the importance of hierarchical systems, which develop, refine and deploy probabilistic models [21,22]. This model of information processing implies flexible integration of top-down and bottom-up processing and context-based learning that may explain the robust and highly complex nature of perceptual and behavioral learning [19]. This type of information processing allows for construction of Bayesian prediction, which we define here as estimation of the probability of an event given prior knowledge of conditions that are assumed to be related to the event [23]. These predictions occur in an active process in which the system self-reconfigures according to sensory and perceptual input, which drives future predictions [19]. A key tenet of the PP model concerns revisions of predictions based on incoming sensory data. Predictions of future events rely on identification and minimization of discrepancies between expected outcomes and perceived outcomes. Particularly in novel situations where there is limited prior experience, preliminary predictive models may demonstrate a high degree of error (i.e., discrepancy between predicted and perceived states), but may rapidly evolve based on perceptual inputs that minimize errors and increase the accuracy of future predictions. In essence, there is a continual refinement of predictions based on incoming sensory and perceptual data that, optimally, will yield better future prediction. This refinement process may occur both through adaptation of existing models (i.e., through adaptation of new sensory and perceptual information), but may also be behaviorally mediated (e.g., through behavioral efforts to confirm or update information relevant to predicted models).

Within the PP framework, the term ‘predictions’ (and, similarly, other similar terms such as beliefs or expectations) refers to probabilistic representations. In defining these terms in the PP model, a central consideration is the key role of inferences regarding the cause of sensory input may play in processing of current sensory information [20]. The beliefs an individual holds may dramatically influence the predictions he or she makes and may bias the nature of incoming sensory data. A wide range of psychological phenomena and biases can be conceptualized within the current framework. Research suggests the nocebo effect and placebo analgesia could be a result of the top-down expectations modulating bottom-up sensory signals in a hierarchical Bayesian framework (i.e., holding particularly positive or negative expectancies about treatment may bias perceptual data concerning the treatment during or after it is administered) [18,24,25]. Other research has found that the beliefs people hold regarding their treatment also affect the strength of placebo response in pain [26]. Finally, a variety of cognitive biases may be understood using an expectation-based framework, including the Hawthorne effect, Stereotype threat and confirmation bias [25]. This body of literature highlights the central role of expectations in determining the precise nature of phenomenological experiences. According to Clark, the same process determines not just the flow of perception, appraisals and emotion but also the flow of action [19]. This finding would seemingly suggest, and is echoed by clinical (particularly cognitive-behavioral) models, that perceptual input may also be altered by behavioral responses. We will discuss the interplay of cognitive, perceptual and behavioral factors within the PP framework later in this paper. Given the persistent nature of chronic pain and the possibly constant nature of pain-specific adaptation, greater operationalization and application of this cognitive system to existing clinical and empirical models may be of great utility.

PP: implications for chronic pain

A key implication of the PP model is that predictions/expectations are integral contribution processes in generating perceptions. Therefore, inaccuracy or regular violations of higher-level predictions may lead to perceptual or cognitive biases, particularly in cases of prolonged adaptation or in cases where beliefs demonstrate a high degree of personal relevance or importance (e.g., confirmation bias). The beliefs and expectations related to pain are diverse; sensory-focused beliefs may focus on the timing, location and intensity of the pain felt in one region of the body, while future-oriented beliefs may center on the cause or long-term prognosis of these sensations. Both types of beliefs are important determinants of behavior. Individuals with a pain condition may avoid certain movements due to a belief that it will initiate or exacerbate pain, but may also show differences in their long-term willingness to do certain activities based on the perceived cause of the pain (i.e., viewing pain as a sign of continued bodily harm vs an aberrant nervous system signal that does not reflect harmfulness of activity) [27]. In chronic pain populations, expectations about symptoms and progression of injuries are salient factors which influence the condition, as stronger maladaptive beliefs about the nature of one’s chronic pain symptoms may lead to poorer clinical outcomes [15,28–30].

From a neurophysiological standpoint, prior research has built a convincing base of evidence suggesting that behavioral decisions integrate negative affective circuitry (e.g., neural pathways related to aversive states like pain) and positive affective circuitry that may be activated by anticipation of an appetitive or rewarding stimulus [31]. We propose that our proposed PP model is germane to this phenomenon when goal-directed behavior in chronic pain is considered (see [Figure 1](#)). Aspects of the individual’s interoceptive state, which include primary motivators (hunger, thirst), pain or aspects of the environment (perception of a potentially threatening or rewarding stimulus), initiate the decision-making process. As a potential need or opportunity becomes salient, a goal selection process is initiated that weighs the needs of the individual (i.e., amelioration of an aversive state or attainment of a valued external stimulus) with the probability of rewarding and painful consequences of each potential behavior. Calculation of probability is based on current context, as well as prior experience. As in Bayesian models, prior experiences heavily inform the probability of each perceived outcome; in the case of the perceiver, this may increase the perceived probability of success or failure of goal attainment, or perceived costs of expended effort (e.g., did prior behaviors cause increased pain?) [32]. In this way, the probability of rewards or punishments is a key determinant of behavior [33–35]; as the optimal opportunity to minimize pain and maximize reward is identified, the individual chooses an action. After completion of the action, the actual reward and punishment are compared with the predicted reward and punishment, and the direction and magnitude of the discrepancy between these aspects will have significant implications for affective states and future behavior. The direction of the discrepancy may dictate the valence of an emotional reaction (e.g., a better-than-expected outcome may yield a positive emotional response such as delight or satisfaction, while a worse-than-expected outcome may elicit anger or disappointment), and the magnitude of the discrepancy may impact the intensity of this emotional response. These emotional states, too,

Figure 1. A proposed model of predictive processing for chronic pain and related outcomes.

may impact encoding of memories and affect future goal-based decision-making [36]. This information is then incorporated into the existing expectancy structures (belief system) and the process begins again. In this model, expectancies are both determinants of and subject to behavioral efforts; in essence, refinement of probabilistic predictions proposed by the PP model occurs as a result of integration of cognitive–perceptual and behavioral processes.

Under most circumstances, identified discrepancies between predicted and actual outcomes can be assimilated into the existing belief structure. However, some discrepancies may be so pronounced that they are fundamentally contradictory to existing beliefs and thus cannot be incorporated into the current schemata of the individual. This process may occur due to psychological resistance to assimilating new information (e.g., denial, dissonance). This exception may also occur due to the presence of new information that contradicts or undermines confidence in existing beliefs. For example, a fundamental belief in the justice or fairness of the world may be compromised by the sudden and unexpected onset of chronic pain. In the earliest studies of injustice perception in chronic pain, this construct was developed in whiplash populations, which are notable for an obvious inciting event (e.g., motor vehicle accidents) and, often, an external figure that may be to blame for the injury. When individuals experience a highly salient change in their own wellbeing as a result of others, this may initiate a cascade of thoughts and emotions not only to adaptation to new physical symptoms but to more abstract violations of deeply held beliefs (e.g., that the universe is fair and just). Violation of these deeply held beliefs of justice may initiate feelings of injustice that not only contribute to immediate distress but may also infiltrate existing expectancy structures and manifest in future behavior and appraisals.

Injustice perceptions inherently presume a discrepancy between expected and actual outcomes, which may lead to feelings of anger, frustration or other forms of emotional distress. This phenomenon also appears to manifest in terms of some biases in cognitive processing. For example, individuals with chronic pain who report greater levels of injustice beliefs associated with their pain perceive physical movement tasks as more difficult and painful, and tend to perceive more intense negative emotions (sadness and anger) in experimental facial cues [16]. It should be noted that experimental research in this area is still in a relatively nascent stage and more evidence is needed to clearly establish a link between injustice beliefs and various forms of cognitive appraisal. However, it appears that individuals with stronger injustice beliefs may be vulnerable to more frequent and intense negative appraisals in potentially painful situations.

The cognitive bias that may be exhibited by individuals with strong injustice beliefs related to their pain may have a number of downstream consequences. First, they may develop broader patterns of expectancies related to their pain condition that compromise wellbeing and meaningful function. Given that the experience of pain itself may vary from day to day in terms of timing or intensity of pain, an overarching negative bias related to pain may manifest in terms of traditional cognitive biases that have been highlighted as negative prognostic factors in chronic pain, such as catastrophizing or other forms of fatalistic thinking. Furthermore, these negative expectancies may extend to rehabilitation efforts and thereby compromise willingness or ability to adhere to treatment, which

may be painful or challenging, thereby reducing the likelihood of optimal treatment outcomes. Research showed that expectancies mediate the relationship between perceived injustice and return to work in a whiplash cohort, and highlight beliefs in the permanence of injury- or pain-related losses may be permanent as a key implicating factor [15]. Importantly, in the context of chronic pain, unsuccessful or 'failed' rehabilitative efforts may reinforce the pattern of negative expectancies already in place.

Other areas of research suggest that chronic pain outcomes can be impacted by addressing individuals' expectations of their pain condition. Research has shown whiplash injuries following motor vehicle accidents are very rare in countries where the general population is unaware of the anticipated shape of this injury. However, where the injury is well-publicized even minor traffic accidents can result in symptoms of whiplash [37]. While these studies were unable to capture specifics in the intensity and damage of the accident these results, and other factors such as the material composition of the vehicle and seat-belt use [38] also appear to play a salient role, they nevertheless suggest that expectations regarding the nature of the malady in turn affect perception. A study aimed at manipulating the beliefs of the population through a media campaign regarding the symptoms of chronic back pain found sustained and significant reduction in the occurrence and severity of chronic back pain [39]. After the campaign, the effects were not sustained, which suggest the enduring nature of those baseline beliefs about 'proper' treatment of back pain in the community, including some of the medical community, as well as the need for continued intervention in order to potentially prolong the effects of an ameliorative or preventative intervention at the public health level. Thus, negative beliefs about the nature of recurrent pain and its origin may both have significant implications for the perceived intensity of pain and its consequences. Therefore, addressing expectancies may be an important target of intervention within these populations.

There are also potential modifiers of the PP model that warrant consideration. For example, expectancies may develop differentially according to specific characteristics of certain pain conditions (e.g., latency or immediacy of pain flares after physical exertion or other factors may be different in cases of immediate nerve impingement versus more delayed-onset soreness or pain that may manifest, which may affect the ability of the individual to determine their cause). Similarly, there may be demographically based differences that moderate the processes described in the PP model. For example, prior experience (which may well vary according to age, gender, racial or ethnic background, or socioeconomic status) may contribute to differences in pain perception and pain responses due both to broader prior experiences (e.g., previous instances of nonpain-related injustice or inequity) and to personal experiences in pain treatment (e.g., individuals may be treated differently by their medical providers in terms of age or racial/ethnic status). Although it is beyond the scope of this paper to explore these factors in greater detail, they may be highly relevant factors to consider in future research.

Notably, tenets of the PP model may inform other pain psychology concepts such as fear avoidance, catastrophizing and depression. Fear-avoidant behaviors may arise from anxiety of distressing sensations (e.g., pain), and prolonged avoidance of these sensations may further reinforce this anxiety/fear and the appraisal of these situations. For depression, the individual may perceive that their efforts would not be 'worth' the reward (as is in cases of anhedonia, in which individuals commonly anticipate that they will enjoy an activity less than usual), and which may be susceptible to self-reinforcement due to altered information processing (perhaps due to increased emotional distress when engaged in the activity) or to differences in behavior (performing the activity in less-optimal ways, thereby changing the outcome of behavioral efforts). These all share a potential circular self-reinforcing cycle of cognition and behavior in which the perceiver actively imposes their beliefs on the situation, which may incrementally bias the information drawn from the current environment.

How might these insights shape the future of pain management?

The proposed model may have clinical implications for treatment in individuals who report strong pain-related injustice beliefs. In this model, expectation and motivation are key components of pain-related coping. For individuals who report strong injustice beliefs related to pain (or, similarly, appraise their pain as a personally catastrophic event), these expectations may filter down to immediate struggles with pain-related emotional dysregulation or poorer coping. Those with higher emotional distress may be less willing or able to adopt more adaptive coping responses to pain that may be uncomfortable (e.g., reducing pain medication use, maintaining or increasing exercise or other physical activity behaviors), thereby compromising future function. The matter of how to address these maladaptive beliefs has been explored for a number of years using various psychotherapeutic models (e.g., cognitive-behavioral therapy (CBT), mindfulness or acceptance-based approaches). However, to date there have been no studies that have specifically examined the relationship between injustice appraisal and psychotherapy

outcomes, either as a mechanism or moderator of effect. We offer some possible avenues for future research in this regard.

In CBT, the psychological intervention for chronic pain that is both most ubiquitous and has the largest base of evidence across pain conditions [40], maladaptive cognitions are addressed using a ‘scientific’ approach adopted by the patient in which distorted or unhelpful thoughts are challenged and reappraised with real-life evidence (e.g., through behavioral experiments, consensus gathering) as a means of ameliorating emotional distress and improving behavioral responses. CBT approaches allude to ‘core beliefs’ that are fundamental to automatic thoughts that may arise situationally; for individuals who maintain a core belief that the self is worthless (e.g., low self-esteem, high self-loathing) or helpless (e.g., external locus of control, low self-efficacy), this belief may generalize to various situations and, as a consequence, automatic thought content may reflect this belief more frequently. Notably, changing content of core beliefs has been identified as a particularly challenging aspect of CBT [41], especially for some people, but may be possible using techniques that undermine confidence in these core beliefs or make them more flexible or situational, thereby reducing their pervasiveness [41]. We propose that injustice perception, which may stem from beliefs about fairness that individuals may view as very personally meaningful and ego-syntonic, may be resistant to CBT approaches as a result. It may be easier to restructure thoughts that are otherwise aversive and do not come into conflict with strongly held beliefs about the world (e.g., that pain will not ruin one’s life, that one’s body is not being damaged simply because pain is present). In contrast, individuals with strong injustice beliefs may resist the idea that this thought content should be challenged or reinterpreted, which may alter both the palatability of this treatment approach and the degree to which it is effectively utilized in patients. In other words, rational control over cognitive content may be particularly difficult in cases where an individual may be particularly biased toward negative interpretations due to a rigid underlying belief.

In contrast, some aspects of ‘third wave’ psychotherapies, such as mindfulness-based stress reduction or acceptance and commitment therapy (ACT), may be more germane to the PP model. Most notably, these approaches emphasize tenets of nonjudgment and anchoring in the present moment (i.e., ‘mindfulness’) that may show unique protective effects against self-reinforcing, maladaptive cognitive systems like injustice appraisals (as they are defined by the PP model) [42–45]. Unlike CBT, ACT and mindfulness-based interventions do not emphasize thought content as the primary cognitive target. Instead, these interventions emphasize changing one’s reactions to thoughts as they occur, optimally leading the individual to ‘defuse’ the self from the thought and reducing its impact on current psychological function. For patients who (perhaps accurately) conclude that their pain was caused by an outside entity and may be considered unjust, defusion from these thoughts may nevertheless lessen the impact of these beliefs.

It should be noted that we are not suggesting that rational cognitive change, as posed by CBT, is ineffective in all individuals who appraise their pain as an unjust experience. Indeed, cognitive restructuring is a robust component of CBT interventions broadly [46] and is a core component of CBT interventions for pain specifically [47]. Furthermore, ACT approaches are highly compatible with CBT principles, and more recent definitions of ACT have been reformulated as contextual CBT, integrating both traditional CBT strategies and expansion of acceptance/mindfulness-based practices (e.g., [42]). Rather, it may be that for at least a subset of individuals, it may be inaccurate to suppose that they have sufficient cognitive self-regulatory control to change these cognitive and perceptual biases. By teaching individuals to anchor their experiences in the present moment (e.g., through meditation or attentional training), it may serve to disrupt the self-reinforcing nature of negative cognitions whose content individuals do not feel willing or able to challenge directly. Recent conceptualizations of third-wave psychotherapies have also highlighted psychological flexibility, defined as the ability to effectively modify behavioral pursuits in a way that is consistent with one’s own personal values [48], as a potentially key mediator of effect in chronic pain [49]. In the context of the PP model, psychological flexibility, in conjunction with improved attentional control yielded from mindfulness practice, may confer the ability to readjust expectancies in such a way that reduces the impact of injustice beliefs.

Our discussion of optimal treatments for injustice beliefs about pain, compared with other forms of maladaptive cognition common in chronic pain, echoes a longstanding and relatively understudied issue in the literature about the importance of identifying consistent moderators of psychological treatment. Notably, a recent systematic review of ACT for chronic pain identified relatively few consistent findings in terms of moderators of treatment, due to both variable quality of prior studies and a limited base of consistent examination and reporting of these effects in prior research [50]. Given the inconsistent nature of their findings, these authors asserted that development of theory-based moderators is an important next step in understanding the variability in engagement and response

to various treatments. We propose that injustice perception may serve as a signal that patients may benefit from interventions that combine changing of cognitive content with strategies that help patients separate themselves from cognitive content that they cannot easily challenge. However, there remains a strong need to develop additional empirical validation and support of the theoretical concepts proposed here, both in terms of the experimental and clinical implications of PP and psychological aspects of chronic pain.

Conclusion

This review proposed a conceptual framework for understanding the dynamics of expectancies, perceptions, emotions and behavioral processes in chronic pain. The PP model defines individuals as active participants in their perception, constantly predicting and refining predictive models based on incoming feedback. Individuals may alter future expectancies or behavioral patterns as a means of reducing disparities between expected and actual outcomes, and perceptual input may be biased by existing expectancy structures. This model is consistent with models of approach and avoidance behavior in chronic pain, which weighs anticipated costs and rewards of a behavior associated with pain, and may provide a suitable framework to explain recurrent maladaptive patterns of appraisal and behavior (e.g., catastrophizing, avoidance, anhedonia) that commonly co-occur with pain. Importantly, we applied the PP model to perceived injustice, which appears to be an important and emerging construct in chronic pain adaptation and may be a target for psychological intervention in this population. Injustice appraisals related to pain may arise from perceived disparity between the expected and actual state of an individual's health, the cause of pain or the overall status of one's life as it relates to pain, and may bias the individual towards future expectancies of additional injustice, pain or suffering. Unfortunately, these appraisals may reinforce themselves through greater emotional distress, behavioral avoidance, social conflict or poorer treatment response, thereby increasing the likelihood of perceptual input that supports predictions based on these negative expectancies.

To date, the intervention literature regarding injustice perception is scarce. Some existing evidence suggests that community- or nationally based education initiatives may serve as useful approaches to altering the expectancies related to chronic pain, though these studies suggest that continued educational efforts may be necessary to prolong their protective effects. Psychotherapeutic treatments that focus on identification and restructuring of maladaptive cognitive content (e.g., CBT) may be helpful in some individuals, but may be less palatable or more difficult to implement in individuals with strong injustice beliefs. In the context of PP, therapeutic processes like cognitive flexibility and improved attentional control may promote the ability to readjust expectancies to reduce the impact of injustice perceptions without requiring individuals to identify their broader views on injustice as maladaptive and in need of change. In this way, the proposed model may yield incremental improvements to both existing treatment approaches, as well as information about key differences between individuals (e.g., injustice beliefs) that may highlight differential suitability for various psychological interventions. However, the clinical implications suggested by the PP model require validation in future research, as do conclusions about relative palatability or efficacy of distinct psychotherapies for individuals with varying levels of injustice appraisal related to their pain conditions. Nevertheless, adoption of future models that define individuals with pain as active participants in their own perceptual experiences and examine the integration of active top-down processes with the traditional bottom-up perceptual integration of pain may foster both better empirical definitions and more promising clinical interventions to treat chronic pain.

Future perspective

The current review sought to connect a relatively novel construct in chronic pain (perceived injustice) with a burgeoning concept in computational neuroscience: PP. The PP model has implications for how the development of maladaptive patterns of cognitive appraisal and behavior may occur, but also may offer new insights in the context of effective treatment of chronic pain from a psychological standpoint. Furthermore, given evidence that incoming information may be biased by beliefs held by the individual, this model highlights two distinct avenues to therapeutic change: changing higher-order beliefs about pain, mood and function (e.g., through psychoeducation or cognitively focused interventions) while addressing more immediate aspects of perceptual input (e.g., behavioral activation, social reintegration, exposure-based treatments). We propose that this conceptual model may be worthwhile to incorporate into future theoretical models of clinical intervention, as it may be germane to both cognitive-behavioral models (e.g., as they relate to catastrophic or fearful appraisal of pain) and more recent therapeutic models of psychological flexibility, mindfulness and acceptance.

In addition to the continued study of active expectation and perceptual bias in injustice appraisal, the antecedents of these perceptual and cognitive biases are also important topics for future research. For individuals who have been repeatedly victimized (e.g., due to personal traumas, or through broader patterns of socioeconomic, racial or ethnic, or other demographically based disparities), a bias toward perceiving pain as unjust or irreparable may develop. This observation is supported to some degree by the ubiquity of prior research in injustice appraisal in whiplash injuries (where a perpetrator of injustice or harm may be readily identifiable). Similar patterns of appraisal may also emerge in cases where an individual perceives that their pain is caused by suboptimal medical care (e.g., a failed surgical or medical intervention) or a lack of support from family members, friends or coworkers. In some cases, these perceived sources of personal injustice may prove to be suitable targets for treatment (e.g., improving communication with family members or treatment providers, treating grief or loss after a failed surgery). In other cases, however, these perceptions may require extreme care when they are addressed in treatment, particularly with regard to longstanding disparities that may affect individuals in domains exceeding their experiences with chronic pain. For example, Black and African-American individuals with chronic pain have shown poorer pain-related outcomes compared with other ethnic groups, which appear to be attributable at least in part to disparities in pain treatment [51,52]. Although there is little research examining the role of racial or ethnic status in injustice appraisal, prior racially based injustice experiences may contribute to worsened pain and disability among African-Americans with chronic pain [53]. Identification of these antecedents may help us to better understand and treat individuals with strong injustice beliefs or other cognitive appraisal patterns that worsen pain-related distress or disability. However, the optimal method of addressing instances of injustice perception in patients is still very much an open question, and one that may involve treating both individuals who have experienced prior injustices as well as adopting preventative approaches that may prevent the development of these injustices in the first place.

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References

Papers of special note have been highlighted as: ● of interest; ●● of considerable interest

1. Simon LS. Relieving pain in America: a blueprint for transforming prevention, care, education, and research. *J. Pain Palliat. Care Pharmacother.* 26(2), 197–198 (2012).
 2. Linton SJ, Shaw WS. Impact of psychological factors in the experience of pain. *Phys. Ther.* 91(5), 700–711 (2011).
 3. Turk DC, Okifuji A. Psychological factors in chronic pain: evolution and revolution. *J. Consult. Clin. Psychol.* 70(3), 678 (2002).
 4. Dolan RJ. Emotion, cognition, and behavior. *Science* 298(5596), 1191–1194 (2002).
 5. Schwarz N. Emotion, cognition, and decision making. *Cogn. Emot.* 14(4), 433–440 (2000).
 6. Sullivan MJ, Rodgers WM, Kirsch I. Catastrophizing, depression and expectancies for pain and emotional distress. *Pain* 91(1), 147–154 (2001).
 7. Monden KR, Trost Z, Scott W, Bogart KR, Driver S. The unfairness of it all: exploring the role of injustice appraisals in rehabilitation outcomes. *Rehabil. Psychol.* 61(1), 44 (2016).
 8. Sullivan MJ, Scott W, Trost Z. Perceived injustice: a risk factor for problematic pain outcomes. *Clin. J. Pain.* 28(6), 484–488 (2012).
 9. Sullivan MJ, Yakobov E, Scott W, Tait R. Perceived injustice and adverse recovery outcomes. *Psychol. Inj. Law* 7(4), 325–334 (2014).
 10. Trost Z, Agtarap S, Scott W *et al.* Perceived injustice after traumatic injury: associations with pain, psychological distress, and quality of life outcomes 12 months after injury. *Rehabil. Psychol.* 60(3), 213 (2015).
 11. Yakobov E, Scott W, Stanish W, Dunbar M, Richardson G, Sullivan M. The role of perceived injustice in the prediction of pain and function after total knee arthroplasty. *Pain* 155(10), 2040–2046 (2014).
 12. Crisson JE, Keefe FJ. The relationship of locus of control to pain coping strategies and psychological distress in chronic pain patients. *Pain* 35(2), 147–154 (1988).
 13. Sullivan MJ, Adams H, Horan S, Maher D, Boland D, Gross R. The role of perceived injustice in the experience of chronic pain and disability: scale development and validation. *J. Occup. Rehabil.* 18(3), 249–261 (2008).
- **Seminal study establishing construct of perceived injustice in a whiplash population.**

14. Sullivan MJ, Davidson N, Garfinkel B, Siriapaipant N, Scott W. Perceived injustice is associated with heightened pain behavior and disability in individuals with whiplash injuries. *Psychol. Inj. Law* 2(3–4), 238–247 (2009).
15. Carriere J, Thibault P, Adams H, Milioto M, Ditto B, Sullivan M. Expectancies mediate the relationship between perceived injustice and return to work following whiplash injury: a 1-year prospective study. *Eur. J. Pain* 21(7), 1234–1242 (2017).
- **It is the first to examine expectancies as a mediator of the effects of injustice appraisals on rehabilitative outcomes.**
16. Trost Z, Van Ryckeghem D, Scott W, Guck A, Vervoort T. The effect of perceived injustice on appraisals of physical activity: an examination of the mediating role of attention bias to pain in a chronic low back pain sample. *J. Pain* 17(11), 1207–1216 (2016).
- **To date, it provides the only experimental study of the relationship between pain-related perceptual factors and perceived injustice.**
17. Clark A. Embodied prediction. In: *Open Mind*. Metzinger T, Windt J (Eds). MIND Group, Frankfurt am Main, Germany (2015).
- **This publication provides an in-depth conceptualization and applications of the Predictive Processing model.**
18. Büchel C, Geuter S, Sprenger C, Eippert F. Placebo analgesia: a predictive coding perspective. *Neuron* 81(6), 1223–1239 (2014).
19. Clark A. *Surfing Uncertainty: Prediction, Action, and the Embodied Mind*. Oxford University Press, Oxford, UK (2015).
20. Edwards MJ, Adams RA, Brown H, Pareés I, Friston KJ. A Bayesian account of ‘hysteria’. *Brain* 135(11), 3495–3512 (2012).
21. Friston KJ, Stephan KE, Montague R, Dolan RJ. Computational psychiatry: the brain as a phantastic organ. *Lancet Psychiatry* 1(2), 148–158 (2014).
22. Jacobs RA, Kruschke JK. Bayesian learning theory applied to human cognition. *Wiley Interdiscip. Rev. Cogn. Sci.* 2(1), 8–21 (2011).
23. Wiese W, Metzinger T. Vanilla PP for philosophers: a primer on predictive processing. In: *Philosophy and Predictive Processing*. Metzinger T, Wiese W (Eds). MIND Group, Frankfurt am Main, Germany (2017).
- **Introduction to predictive processing for readers outside of the field of computational neuroscience.**
24. Finniss DG, Kaptchuk TJ, Miller F, Benedetti F. Biological, clinical, and ethical advances of placebo effects. *Lancet* 375(9715), 686–695 (2010).
25. Schwarz KA, Pfister R, Büchel C. Rethinking explicit expectations: connecting placebos, social cognition, and contextual perception. *Trends Cogn. Sci.* 20(6), 469–480 (2016).
26. Watkinson A, Chapman SC, Horne R. Beliefs about pharmaceutical medicines and natural remedies explain individual variation in placebo analgesia. *J. Pain* 18(8), 908–922 (2017).
27. Jensen MP, Romano JM, Turner JA, Good AB, Wald LH. Patient beliefs predict patient functioning: further support for a cognitive-behavioural model of chronic pain. *Pain* 81(1), 95–104 (1999).
28. Wertli MM, Burgstaller JM, Weiser S, Steurer J, Kofmehl R, Held U. Influence of catastrophizing on treatment outcome in patients with nonspecific low back pain: a systematic review. *Spine* 39(3), 263–273 (2014).
29. Sullivan MJ, Stanish W, Waite H, Sullivan M, Tripp DA. Catastrophizing, pain, and disability in patients with soft-tissue injuries. *Pain* 77(3), 253–260 (1998).
30. Keefe FJ, Brown GK, Wallston KA, Caldwell DS. Coping with rheumatoid arthritis pain: catastrophizing as a maladaptive strategy. *Pain* 37(1), 51–56 (1989).
31. Navratilova E, Porreca F. Reward and motivation in pain and pain relief. *Nat. Neurosci.* 17(10), 1304–1312 (2014).
32. Vlaeyen JW, Linton SJ. Fear-avoidance model of chronic musculoskeletal pain: 12 years on. *Pain* 153(6), 1144–1147 (2012).
33. Wideman TH, Asmundson GG, Smeets RJM *et al.* Re-thinking the fear avoidance model: toward a multi-dimensional framework of pain-related disability. *Pain* 154(11), 2262 (2013).
34. Vlaeyen JW, Linton SJ. Fear-avoidance and its consequences in chronic musculoskeletal pain: a state of the art. *Pain* 85(3), 317–332 (2000).
35. Crombez G, Eccleston C, Van Damme S, Vlaeyen JW, Karoly P. Fear-avoidance model of chronic pain: the next generation. *Clin. J. Pain* 28(6), 475–483 (2012).
36. Levine LJ, Edelstein RS. Emotion and memory narrowing: a review and goal-relevance approach. *Cogn. Emot.* 23(5), 833–875 (2009).
37. Ferrari R. Whiplash – review of a commonly misunderstood injury. *Am. J. Med.* 112(2), 162–163 (2002).
38. Siegmund GP. Whiplash injury: vehicle, seat, occupant and tissue responses. *J. Whiplash Relat. Disord.* 3(2), 21–35 (2004).
39. Buchbinder R, Jolley D. Effects of a media campaign on back beliefs is sustained 3 years after its cessation. *Spine* 30(11), 1323–1330 (2005).
40. Day MA, Thorn BE, Burns JW. The continuing evolution of biopsychosocial interventions for chronic pain. *J. Cogn. Psychother.* 26(2), 114–129 (2012).
41. James IA, Barton S. Changing core beliefs with the continuum technique. *Behav. Cogn. Psychother.* 32(4), 431–442 (2004).
42. McCracken LM, Morley S. The psychological flexibility model: a basis for integration and progress in psychological approaches to chronic pain management. *J. Pain* 15(3), 221–234 (2014).

43. McCracken LM, Vowles KE. Acceptance and commitment therapy and mindfulness for chronic pain: model, process, and progress. *Am. Psychol.* 69(2), 178 (2014).
- **An overview of the rationale for third-wave psychotherapies, emphasizing the importance of psychological flexibility.**
44. Sturgeon JA. Psychological therapies for the management of chronic pain. *Psychol. Res. Behav. Manag.* 7, 115–124 (2014).
45. Yu L, McCracken LM. Model and processes of acceptance and commitment therapy (ACT) for chronic pain including a closer look at the self. *Curr. Pain Headache Rep.* 20(2), 12 (2016).
46. Hofmann SG, Asnaani A, Vonk IJ, Sawyer AT, Fang A. The efficacy of cognitive behavioral therapy: a review of meta-analyses. *Cognit. Ther. Res.* 36(5), 427–440 (2012).
47. Ehde DM, Dillworth TM, Turner JA. Cognitive-behavioral therapy for individuals with chronic pain: efficacy, innovations, and directions for research. *Am. Psychol.* 69(2), 153 (2014).
48. Hayes SC, Luoma JB, Bond FW, Masuda A, Lillis J. Acceptance and commitment therapy: model, processes and outcomes. *Behav. Res. Ther.* 44(1), 1–25 (2006).
49. Scott W, Hann KE, McCracken LM. A Comprehensive examination of changes in psychological flexibility following acceptance and commitment therapy for chronic pain. *J. Contemp. Psychother.* 46(3), 139–148 (2016).
50. Gilpin HR, Keyes A, Stahl DR, Greig R, McCracken LM. Predictors of treatment outcome in contextual cognitive and behavioural therapies for chronic pain: a systematic review. *J. Pain* 18(10), 1153–1164 (2017).
51. Anderson KO, Green CR, Payne R. Racial and ethnic disparities in pain: causes and consequences of unequal care. *J. Pain* 10(12), 1187–1204 (2009).
52. Green CR, Anderson KO, Baker TA *et al.* The unequal burden of pain: confronting racial and ethnic disparities in pain. *Pain Med.* 4(3), 277–294 (2003).
53. Burgess DJ, Grill J, Noorbaloochi S *et al.* The effect of perceived racial discrimination on bodily pain among older African American men. *Pain Med.* 10(8), 1341–1352 (2009).