CellPress

Opinion

The Anatomy of Suffering: Understanding the Relationship between Nociceptive and Empathic Pain

Jamil Zaki,[1,*] Tor D. Wager,[2,6] Tania Singer,[3,6] Christian Keysers,[4,5,6] and Valeria Gazzola[4,5,6]

Pain features centrally in numerous illnesses and generates enormous public health costs. Despite its ubiquity, the psychological and neurophysiological nature of pain remains controversial. Here, we survey one controversy in particular: the relation between nociceptive pain, which is somatic in origin, and empathic pain, which arises from observing others in pain. First, we review evidence for neural overlap between nociceptive and empathic pain and what this overlap implies about underlying mental representations. Then, we propose a framework for understanding the nature of the psychological and neurophysiological correspondence across these types of 'pain'. This framework suggests new directions for research that can better identify shared and dissociable representations underlying different types of distress, and can inform theories about the nature of pain.

Nociceptive and Empathic Pain

Imagine accidentally hitting your hand with a hammer. This experience would induce a spectrum of physical and psychological events: tissue damage, visceral discomfort, shifts in attention, arousal, negative affect, and a desire to avoid repeating the experience. These events contribute to the broad phenomenon of 'pain', and, more specifically to **nociceptive pain** (see Glossary), which originates in peripheral nociceptive fibers (see Box 1 for detailed definitions). Although pain helps individuals to avoid future harm, it also impairs wellbeing and generates an enormous public health burden [1].

Now imagine observing a friend hit themselves with a hammer. This experience typically generates **empathic pain**, a phenomenon that, despite differences in origin, shares features with nociceptive pain. Here, we explore the relation between nociceptive and empathic pain. What does it mean to label both of these experiences as 'pain?' And, how grounded are these labels in shared neurophysiological representation?

The Debate

Decades of evidence in humans and animals suggest at least some overlap between nociceptive and empathic pain [2,3]. Witnessing others in pain can create or intensify behavioral signs of nociceptive pain [4–6], and individuals with congenital insensitivity to nociceptive pain exhibit blunted responses to empathic pain [7]. Neuroscientists have further demonstrated that brain structures, such as anterior insula (AI) and parts of the cingulate cortex (CC), commonly respond when humans experience nociceptive and empathic pain [8–15] (Figure 1A). In some cases,

Trends

Neuroimaging evidence has suggested both overlapping and nonoverlapping representations across nociceptive and empathic pain, leading to debates as to whether empathic experience should be considered a type of pain or a distinct experience.

Here, we advocate dispensing with binary definitions of pain versus nonpain, and instead considering the constellation of phenomena that comprise pain.

This approach, in conjunction with cumulative efforts testing the specificity and generalizability of brain measures across labs, can help us move beyond debates about which experiences are or are not pain, and towards a more comprehensive understanding of aversive experiences and their constituent representations.

[1]Department of Psychology, Stanford University, Stanford, CA, USA
[2]Department of Psychology & Neuroscience, University of Colorado at Boulder, Boulder, CO, USA
[3]Department of Social Neuroscience, Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany
[4]Netherlands Institute for Neuroscience, Royal Netherlands Academy of Arts and Sciences, Amsterdam, The Netherlands
[5]Department of Psychology, University of Amsterdam, Amsterdam, The Netherlands
[6]These authors contributed equally.

*Correspondence: jzaki@stanford.edu (J. Zaki).

Box 1. Definitions of Pain

The International Association for the Study of Pain (IASP) defines pain as 'An unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage' [89]. This includes not only effects of noxious physical stimulation, but also other experiences that 'hurt'. After witnessing a friend hit herself with a hammer, for instance, you might feel a 'crushing' sensation in your own hand, or discomfort in your stomach. Such empathic pain includes bodily sensations described in terms of tissue damage, meeting the IASP criteria for pain.

The IASP definition of pain contrasts with its narrower definition of nociceptive pain: 'pain that arises from actual or threatened damage to non-neural tissue and is due to the activation of nociceptors.' This definition privileges etiology and excludes empathic pain, which is not triggered by nociceptors in the person experiencing empathy.

Definitions by nature are operational: they serve the study of a phenomenon in a particular context. If scientists investigate a phenomenon such as pain at multiple levels (e.g., nociceptors, cortical neurons, patterns of BOLD activity, psychological experience, behavior, and pathology), operational definitions useful at one level may lose their relevance at another, potentially impeding vital efforts to link these levels. At some levels, such as the response of certain neurons in the cingulate cortex, nociceptive and empathic pain might trigger identical responses [78]. At the psychological level, both might feel aversive, trigger strong motivations and be described in terms of tissue damage. Yet, at the level of peripheral nociceptors, they will seem fundamentally different. Scientists specializing in each of these three levels may then disagree about whether empathic pain is a form of 'true' pain. These scientists would disagree not about data, but rather about definitions.

Instead of a universal definition of pain to settle resulting arguments, here we argue for an agnostic approach: investigating particular pain-related dimensions at various levels of analysis, and mapping similarities and dissimilarities between empathic and nociceptive experiences with respect to each dimension. This could allow scientists to more precisely shed light on how nociceptive and empathic experiences relate, as well as how practitioners can effectively intervene to reduce the burden of pain. This approach further allows for a common ground from which each investigator can decide whether they believe empathic experiences constitute 'pain', based on relevant data.

Glossary

Component: a subset of a brain pattern inferred to track a specific dimension of psychological experience (e.g., attention shifts or location coding).
Constructionism: an approach to psychology and neuroscience positing that complex states (e.g., emotions) can be best understood not as irreducible entities, but rather as combinations of psychological 'ingredients'.
Empathic pain: pain that arises from observing actual or threatened tissue damage in another person.
Marker: a pattern or component that displays sensitivity and specificity to one psychological state, allowing for reverse inference about that state based on the activation of that pattern.
Nociceptive pain: pain that arises from actual or threatened damage to non-neural tissue and is due to the activation of nociceptors.
Pattern: the set of voxels activated (and their accompanying intensity) by a stimulus or task.
Sensitivity: the probability of engaging a neural marker given that a particular mental state is present.
Separate modifiability: a state under which activity in two patterns or components is modulated by differing tasks; for example, activity in pattern A tracks psychological variable X but not variable Y, and activity in pattern B tracks psychological variable Y but not variable X.
Specificity: the probability of not engaging a neural marker when a particular mental state is not present.

empathic experiences also activate somatosensory cortex [9] and facilitate motor programs associated with nociceptive pain [16]. Brain responses to others' pain in AI and CC correlate with subjective experiences of pain empathy [2,17,18] and willingness to shoulder costs to reduce others' pain [3,19]. Finally, brain responses to empathic pain diminish after placebo analgesia pain [20,21].

These findings signal important relations between nociceptive and empathic pain, but do not necessarily imply that they rely on the same psychological representations. For instance, AI and CC respond to nonpain states, including arousal and attention [22–28]. Manipulations that affect nociception, such as placebo analgesia, likewise influence not only pain, but also stress and anxiety [29]. Critics suggest that conclusions about the overlap between empathic and nociceptive pain rely heavily on spurious reverse inference (*cf*. [30]; Box 2), and that social and nociceptive experiences might not in fact share pain-specific processes [31].

Often, questions about pain states are posed as a binary: empathic pain either 'counts' as pain or does not. We believe that understanding the nature of empathy and pain requires moving away from this simple distinction and instead: (i) decomposing pain into its **component** 'ingredients'; (ii) identifying brain **markers** of these ingredients; and (iii) using those markers to identify exactly which ingredients empathic and nociceptive pain share. This approach transforms the binary question of whether both empathic and nociceptive experiences constitute pain into a graded question: how far from one another do these experiences fall in the multidimensional space of pain ingredients?

Multidimensional Pain

Pain includes a complex suite of processes. Consider the moment in which you hit yourself with a hammer. This event triggers a multidimensional experience, including, but not restricted to, processing: (i) the location of pain (in your hand, not foot); (ii) its intensity (strong); (iii) qualities (crushing, aching); (iv) generalized discomfort; the negative (v) valence and (vi) high arousal characterizing your emotional response; (vii) redirection of attention to your hand; (viii) motivation

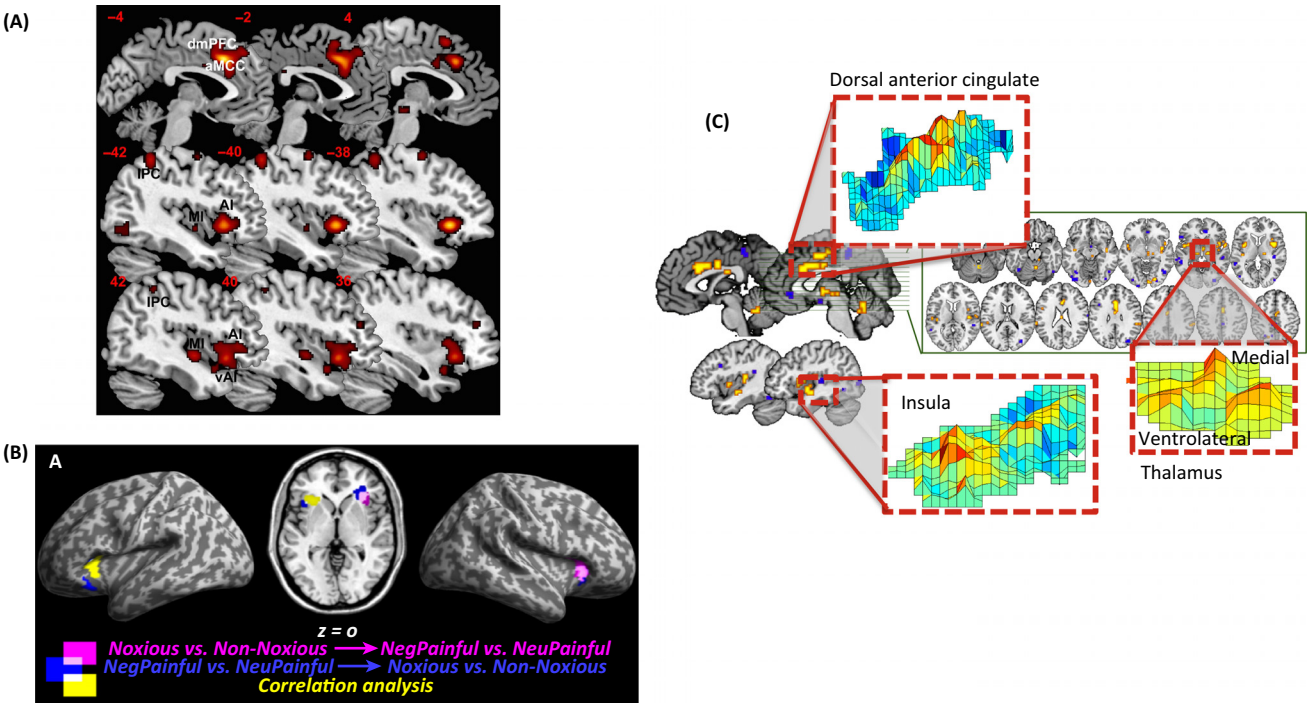


Figure 1. Brain Patterns Suggesting Overlap, versus Nonoverlap, between Nociceptive and Empathic Pain. (A) Overlapping activations between nociceptive and empathic pain in a meta-analysis of 32 studies. (B) Overlap between multivariate patterns related to nociceptive pain (noxious versus non-noxious stimuli) and empathic pain (pictures of others in pain versus neutral pictures). (C) The 'Neurologic Pain Signature' (NPS), a multivariate pattern that is sensitive to nociceptive pain but not other aversive emotional experiences. Reproduced from [10] (A), [8] (B), and [50] (C).

to reduce pain: (ix) motor plans to do so (e.g., rubbing the affected area); and (x) learning to avoid future pain by wielding tools more carefully. Decades of research on nociceptive pain demonstrate that some of these dimensions covary more than others, and that it is useful to organize them into three broad groups: sensory-discriminative, affective, and cognitive dimensions [32,33]. For instance, pharmacological and psychological manipulations, such as hypnosis [34], mood induction [35–37], or opioid drugs [38], alter the affective qualities of pain more than its sensory qualities, or vice versa.

Most components of pain, when considered individually, are nonspecific, in that they occur both during pain and during nonpain experiences. For instance, arousal and attention have a role not only in pain, but also pleasure, anger, and stress [39]. Likewise, location coding occurs during processing of both painful and nonpainful stimulation. Thus, nociceptive pain represents not a single psychological feature, but rather a set of features coming together in a particular configuration. This reflects a **constructionist** approach, which posits that phenomena such as emotion or value reflect combinations of more basic psychological ingredients [40–42].

This framework provides a powerful lens for using neuroscience to understand the overlap between pain types. Consider our example of hitting yourself with a hammer. This experience would produce a complex **pattern** of activity across many brain areas, which can further be broken down into components, or pieces of this pattern. Does activity in each component constitute a marker of pain? Not necessarily. Crucial here is the pattern or **sensitivity** and **specificity** of the component to pain. If a pattern is sensitive and specific to a psychological state, then it qualifies as a marker of a psychological state, because its engagement warrants

Box 2. Pattern Classification and Inference

When scientists use neuroimaging to examining overlap and dissociations between nociceptive and empathic, they must draw inferences about the psychological meaning of brain activity. Such inference is often problematic, especially when brain regions of interest respond to many states [90,91]. In such cases, two phenomena (e.g., empathic and nociceptive pain) could produce overlap in those regions, but nonetheless reflect fundamentally different psychological processes (Figure I).

In an effort to overcome this limitation, scientists now commonly examine brain activity across multiregion patterns of voxels, and associate those patterns with variance in stimuli and reported experience [92]. This technique has helped to adjudicate differences and similarities between nociceptive and empathic pain. However, researchers should take two important considerations into account. First, activity patterns need not represent all aspects of a phenomenon in which researchers are interested. For instance, nociceptive and empathic pain might share a multivoxel activity pattern, but this pattern might reflect nonspecific features of arousal and attention, rather than the pain-specific experience (Figure II). As such, the tuning curve approach we advocate here can help to assess the meaning of activity within a region and multivoxel patterns across regions.

Second, scientists should consider the way in which they extract multivoxel patterns. In assessing pain, one approach is to extract patterns that track the intensity of a localized nociceptive stimulus (e.g., heat to the hand), and test whether these patterns also track manipulations of empathic pain. This approach will identify combinations of voxels that most robustly differentiate levels of pain in the training set (here, nociceptive pain) and, as such, tests a strong assumption that empathic pain modulates brain activity associated with encoding the intensity of specific pain stimuli. Under our multidimensional framework, failure to document such an overlap does not imply that these pain types share no crucial features, but rather that what they do share is not captured by that specific training set. One alternative would be for researchers to develop multivoxel methods that are trained on examples of both forms of pain, and test this pattern on new examples of both pain types. This would address the broader question of whether empathic and nociceptive pain share any key dimensions. Further research could test the responsivity of these shared patterns to pain-specific or nonspecific manipulations, thus precisely characterizing the nature of psychological overlap across these states.

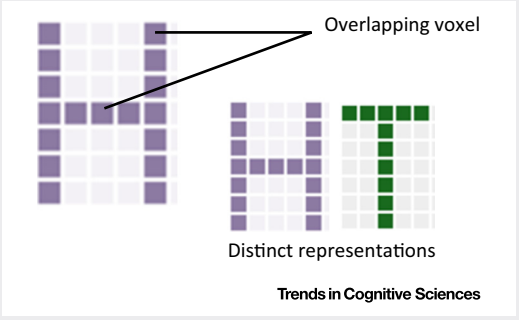


Figure I. Visual Representation of how Overlapping Activity in a Cell or Voxel across Nociceptive and Empathic Pain Could nonetheless Reflect Dissociable Activity Patterns.

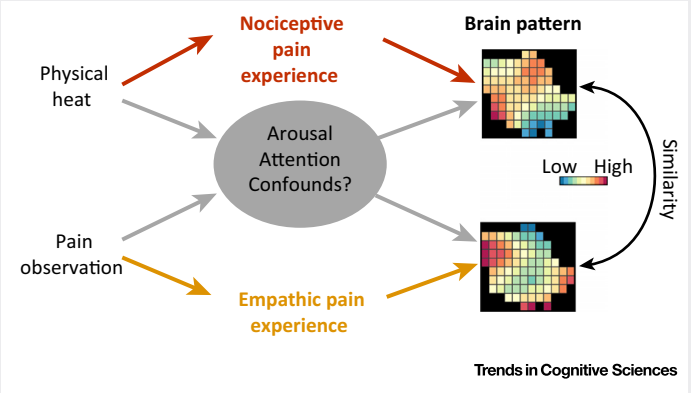


Figure II. Visual Representation of Potential Confounds when Using Multivoxel Patterns to Assess Similarity across Nociceptive and Empathic Pain.

'reverse inference' about the presence of that state: presence of that marker strongly implies the presence of that psychological experience.

Most patterns and components that accompany pain do not meet this criterion. Voxels in sensory cortex, for instance, might respond to you hitting your finger, thus exhibiting sensitivity to pain, but also to nonpainful tactile experiences, thus not exhibiting specificity. Likewise, activation in the frontal eye fields might respond to you hitting yourself, but also to any attentional shift towards unexpected events [43]. In our model, pain constitutes the unique combination of these ingredients, and markers of pain should respond only when those ingredients come together.

Psychological 'Tuning Curves' for Pain-Related Experience

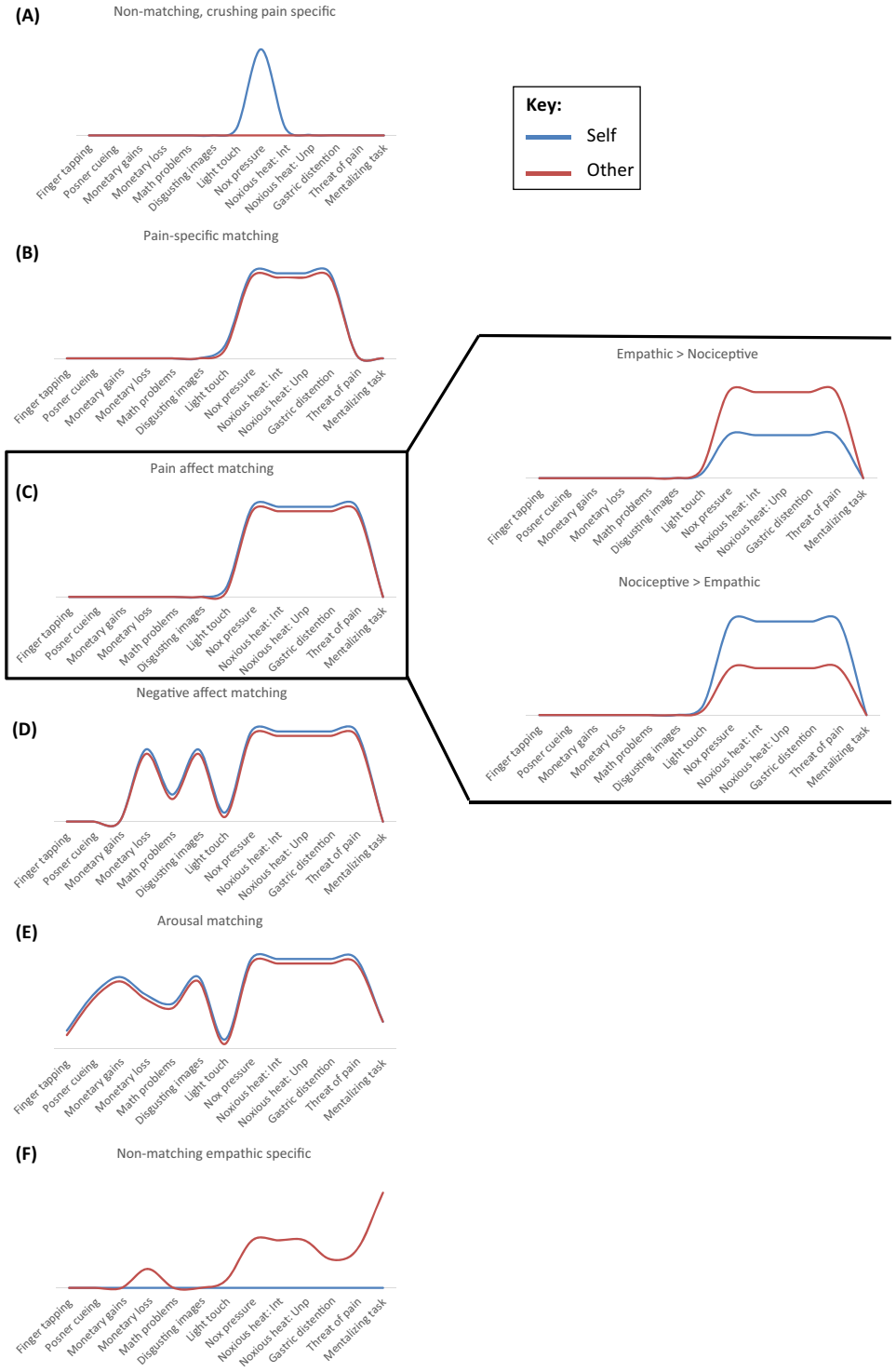
One way of assessing the psychological meaning of brain activity is through examination of tuning curves, or plots depicting the psychological 'landscape' characterizing the responsivity of a brain pattern. This approach originates in measures of single neurons [44], but can easily be broadened to assess fMRI activity within and across brain regions [45,46].

To assess the tuning curves in the domain of pain, scientists should isolate brain patterns that respond to pain, and test the response of those patterns to a systematic set of control conditions that share specific ingredients with pain. Figure 2 suggests some such control tasks, and illustrates tuning curves describing how a hypothetical brain pattern might respond to these tasks.

Some tuning curves are pain specific, in that they only respond when pain ingredients co-occur. For instance, the tuning curve in Figure 2A is narrowly focused on painful pressure, and the curve in Figure 2B additionally responds to other nociceptive pain types, but not to nonpain events (Figure 2B). Patterns that exhibit such tuning curves are both sensitive and specific to nociceptive pain and, thus, can be considered markers of this state. Of course, any form of reverse inference, including one based on a tuning curve approach, is necessarily probabilistic. However, identifying markers based on their sensitivity and specificity to many tasks and stimuli allows for inferences that are more precise than examining brain responses to only pain, or pain and only one control condition.

Other markers might exhibit broader, less-specific tuning curves. Consider a marker of pain affect, or the visceral discomfort brought on by painful stimuli. This marker might respond to noxious pressure and heat, and also exhibit some responsiveness to other 'painful' stimuli, such as threat of pain (Figure 2C), but not to other negative affective stimuli, such as disgusting images. A broader marker might respond to negatively valenced affective stimuli, including disgusting images and monetary loss (Figure 2D). Finally, an even broader marker for arousal might respond to these states, and also to math problems, winning money, and other states that engage the sympathetic nervous system (Figure 2E).

This framework provides a substrate for precisely assessing what nociceptive pain shares with empathic pain (marked 'other' in Figure 2). If markers specific to nociceptive pain in first-person experiences are also engaged by third-person pain (Figure 2B), these states likely share a pain-specific configuration of ingredients. If viewing others in pain engages patterns that are activated during first-hand experience of other 'painful' physical and emotional events (e.g., pain threat) but not nonpainful experiences, such as disgust [47], that would support the inference that nociceptive and empathic states share ingredients that characterize 'pain affect' (Figure 2C). Alternatively, if markers shared by empathic and nociceptive pain also respond to nonpainful stimuli, such as aversive images or math problems [48], which all have high level or arousal in common, we might conclude that empathic and nociceptive pain share only less-specific representations of negative emotion or arousal (Figure 2D).



Trends in Cognitive Sciences

Figure 2. Inference Based on Tuning Curves. Each panel represents the response (along the y-axis) of hypothetical 'markers' to various stimuli (x-axis) experienced directly (blue) or vicariously (red). The responsivity is tested against different forms of pain, as well tasks and stimuli meant to elicit nonspecific dimensions of pain, such as location and intensity coding, negative affect, and motor programs. Markers A–E all respond to noxious pressure, but not light touch, applied to the self. If

Only a few studies have examined 'tuning curves' associated with empathic pain using analysis of multivoxel patterns, and these have produced somewhat discrepant findings (Box 2). For example, AI and CC patterns identified in [8] responded not only to nociceptive and empathic pain, but also to negative emotional pictures, consistent with a broad response to negative affect (Figure 1B). Newer work focusing on regions of interest in AI and CC has painted a more complex picture, identifying patterns with several types of response profile [49]. In some regions, such as the right AI, response patterns are specific to both the type of affect (domain) and the target (whether experience is direct or empathic). This area showed separate patterns for nociceptive pain, empathic pain, disgust, empathic disgust, fairness, and empathic fairness, consistent with cases illustrated in Figure 2A,F. Other regions, such as the left AI and CC, appear to respond to all of the types of events listed above roughly equally, consistent with a representation of negative affect, as illustrated in Figure 2D.

By contrast, other recent work identifies a multivariate 'neurologic signature' that tracks the intensity of heat, pressure, and shock pain applied to the arm [50], but does not respond to negative images [51] or social rejection cues [52] (Figure 1C). These findings demonstrate **separate modifiability** [53] and imply that brain patterns responsive to nociceptive and empathic pain might reflect distinct psychological representations. This work also provides a method for assessing what proportion of representations across these states are shared or unshared.

The discrepancies across these approaches could reflect several differences in design and analysis. First, markers that show an overlap between pain types are drawn from studies that compare high versus low pain in both empathic and nociceptive conditions, whereas patterns found to be specific to nociceptive pain and not social experiences (and vice versa) emerge using markers trained to predict graded ratings of participants' experience. More importantly, these studies also varied with respect to how they directed participants' attention. Studies that point towards nociceptive-specific representations typically direct participants to make ratings of pain intensity, possibly driving attention towards the sensory component of the pain experience. Thus, activity in the neurologic pain signature correlates with increases in the intensity of nociceptive pain, but not other aversive experiences [50–52]. By contrast, studies identifying overlap between pain types typically ask participants to report on the affective unpleasantness of pain [8,49], likely driving their attention towards pain affect.

These data highlight the complexity of drawing inferences about markers of pain based on any one study. Demonstrations of separate modifiability suggest independence between nociceptive and empathic pain, but do not imply that these pain types are entirely or always independent. Instead, separate modifiability here might reflect only some dimensions of pain experience, such as coding of intensity ratings of pain delivered to one's extremities [50].

only those two conditions had been tested, this marker might have been thought to represent pain. However, testing them in a variety of other conditions sometimes results in pain nonspecific profiles. Overlap between tuning in self and other conditions further reveals whether the marker co-represents states of others and self. Note: 'Noxious heat: Int' = intensity ratings over noxious heat, and 'Noxious heat: Unp' = unpleasantness ratings made over noxious heat. (A) This marker responds with high specificity to nociceptive pressure, but not to any empathic experiences. (B) This marker responds narrowly to painful pressure and other forms of nociceptive pain (such as heat or gastric distension) in both self and other, suggesting overlap between these states in coding pain intensity and modality. (C) This marker responds to many types of nociceptive and empathic pain, and to other unpleasant experiences, such as threat of pain in the absence of direct nociception. The amplitude of responses to self and other can vary independently of the response 'landscape' of a marker, with some markers showing stronger responses when stimuli are applied to the self (right column, top) or to others (right column, bottom). (D) This marker exhibits sensitivity to negative affective experiences, including not only pain and threat of pain, but also disgusting images and monetary loss. (E) This marker exhibits sensitivity to both personal and vicarious experience of many arousing states and, thus, captures overlap between these phenomena that is not pain specific. (F) This marker responds uniquely to empathic pain states, but not nociceptive pain.

Although this intensity-focused marker uniquely tracks nociceptive pain, markers of other pain dimensions, such as pain affect, might reveal responses shared with empathic pain (although, in some cases, these rating types tightly correlate with each other; *cf*. [54]). Future work should directly examine the effects of attention set on markers for empathic and nociceptive pain, as well as their overlap.

In general, scientists should leverage the 'tuning curve' concept to examine responses of nociceptive and empathic neural markers to a broader set of phenomena. Doing so will be a long-term endeavor, requiring many studies across multiple labs to compare neural markers that respond to numerous pain-related states delivered to the self and to others. This dovetails with the increasingly cumulative nature of cognitive neuroscience, under which reverse inference about psychological processes based on brain activity requires the synthesis of many studies to estimate the specificity and sensitivity of neural markers [55]. In an affective analog to the 'cognitive ontologies' [56], such a cumulative approach will allow scientists to better decompose pain and understand the relations between self- and other-oriented pain states.

Methodological Suggestions

Thus far, we have suggested a conceptual approach for charting the overlap between empathic and nociceptive pain. We now turn to methodological suggestions through which to apply this approach.

Train Classifiers on Multidimensional Pain Experiences

Existing paradigms typically compare empathic pain to nociceptive stimuli delivered to participants' extremities (such as heat pain to the arm). Patterns trained on intensity judgments for such stimuli likely home in on brain patterns that encode pain in a modality- and location-specific way, with a narrow tuning curve similar to that visualized in Figure 2A. If empathic and nociceptive pain instead overlap at an intermediate level, for instance in representations of pain affect (Figure 2C), neural patterns trained on intensity judgments might miss this shared pain experience. Comparing empathic pain to other forms of nociceptive pain that produce more diffuse intensity and location coding, such as gut or rectal distention [57,58], or comparing patterns tracking people's affective discomfort in response to pain, might show more overlap with empathetic pain [59,60].

Explore Factors that Modulate Overlap

Several factors, including attention, motivation, context, and individual differences, powerfully shape the experience of both nociceptive [61–64] and empathic pain [2,14,19,65–70]. For instance, observers who pay close attention to, or share group membership with, social targets exhibit intensified brain activity in response to empathic pain [19,71], whereas situational factors, such as intergroup barriers [12,68,72,73], and individual factors, such as psychopathy [14] and alexithymia [74], diminish or even eliminate these responses. Likewise, empathy training induces functional changes in AI and CC activity during empathic pain, which track increases in self-reported empathy [75]. Contextual and individual differences also interact: for instance, individuals with psychopathy exhibit blunted neural responses to empathic pain, but not when explicitly instructed to empathize [14].

Modulatory factors likely alter not only the intensity of empathic pain, but also the dimensions over which it operates. For instance, observers who are highly motivated to process specific characteristics of another person's pain, such as a parent whose child is injured or, by contrast, an emergency-room doctor attempting to objectively treat that injury, could exhibit differential overlap between empathic and nociceptive pain [9,76]. Future work should merge a tuning curve approach with manipulations of context or individual differences to examine whether these factors indeed modulate the overlap between pain types.

The Need for Neuronal Resolution

The question of whether empathic and nociceptive pain share neural substrates ultimately rests on whether individual neurons co-represent aspects of each pain type. Noninvasive neuroimaging suggests, but cannot demonstrate, such overlap. For instance, an fMRI voxel or pattern might contain separate neuronal populations that respond to each pain type, generating false overlap when activity is averaged across those populations. Furthermore, although AI and CC respond to many stimuli and contexts, these regions nonetheless contain pain-specific, as well as nonspecific neurons [77,78], such that averaging across these cell population yields pain nonspecific signals. Averaging can also falsely imply independence. For instance, an fMRI pattern sensitive to nociceptive, but not empathic pain, could mean that no nociceptive neurons respond to empathic pain, but could also occur if a few neurons do in fact respond to both pain types. Such overlap could be obscured by averaging the activity of such shared neurons with others that respond specifically to nociceptive pain.

Single cell recordings can provide crucial converging information in cases such as these. Consider the case of 'mirror neurons'. Single cell recordings in monkeys and humans showed that many of the voxels that respond to both self and other action indeed contain neurons that co-represent these states [79,80]. These mirror neurons exhibit specificity and sensitivity for particular actions [79,80]. However, this is true for only approximately 10% of neurons, while approximately 90% respond exclusively during self-actions [79,80]. Averaging the 10% of 'true' mirror neurons with the 90% that respond exclusively to self-actions produces activation patterns that translate poorly (although sometimes significantly) from actions of the self to the actions of others [81–83].

Almost no single cell studies have examined empathic pain (but see [78]), but emerging rodent models of empathic pain pave the way for measuring and manipulating cellular activity to shed light on the nature of empathic pain. For instance, deactivating regions involved in pain (e.g., CC) reduces behavioral signs of empathic pain [84]. One key question that these techniques will help answer is whether neurons that respond to both empathic and nociceptive pain, even if they comprise a few nociceptive neurons overall, suffice to generate pain-relevant experience. Techniques such as optogenetics will allow scientists to address this question by directly triggering or suppress activity in these shared neurons [85].

Concluding Remarks

The relation between empathic and nociceptive pain has generated great interest and controversy over recent years. Debates about the status of these states as pain or not connect with thorny issues concerning the psychological and biological nature of pain. Here, we propose replacing binary questions about whether empathic pain 'counts' as pain or not with a multidimensional approach that focuses scientists on finer-grained questions about the particular psychological dimensions that empathic and nociceptive pain share. We hope that this nuanced approach, in combination with a growing set of tools and techniques, will deliver increasingly mechanistic accounts of how personal and vicarious pain relate and interact. The coming years will offer new and exciting insight into the connection between pain types, which can inform our basic understanding of what pain constitutes (see Outstanding Questions). In the long term, this approach might help assess the nature of pain-related symptoms associated with varying states of illness and dysfunction, and determine the best targets for intervention. Finally, this approach lends itself to many other domains. How, for instance, does the memory of nociception, rejection [52,86], shame, embarrassment [87,88], or guilt relate to nociception? A fine-grained understanding of the many dimensions of pain will allow us to situate these and other experiences as they relate to the broad experience of suffering.

Outstanding Questions

Given a set of brain markers representing different dimensions of pain, such as location, intensity, discomfort, and arousal, which of these markers (and which levels of pain specificity) generate overlap between nociceptive and empathic pain?

How might contextual factors (e.g., group membership) and individual differences (e.g., in trait empathy or psychopathy) alter the representational dimensions that nociceptive and empathic pain share?

How will patterns of overlap between pain types revealed by neuroimaging map onto similar evidence gleaned from neurophysiological recordings and manipulations in nonhuman animals?

How do the markers associated with different tuning curves map onto clinical disorders, and how does that structure our understanding of the associated experiential symptomatology?

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