Topical Review

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Embodied pain—negotiating the boundaries of possible action

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1. Introduction

Pain is a protective strategy, which emerges from on-going interaction between body and world. However, pain is often thought of as a unitary output—an end product experienced as an intrusion upon an often unsuspecting perceiver.[55] We know a lot about how nociception relates to pain, informed by both biological and psychological influences,[30,68,96] how pain intrudes into awareness,[5,26,29,34] and how it relates to clinical variables, such as suffering and disability.[35] However, despite significant advances, the mechanisms of pain intrusion remain elusive.[62] In this article, we stress a functional view of pain as more than experience, as defensive action operating in the context of uncertain threat.

Although traditional characterisations of perception as a product of sensory information have been critiqued,[19,41,52] including in pain,[87,94] there is now a well-advanced contemporary view that all perception is embodied and embedded.[41,46,65,77,84,86] Here, *embodied* is defined by action, the premise that cognition extends beyond the brain so that an ever-changing body is at the core of how our experiences are shaped; this may be the unconscious workings of our immune system or the collaborative efforts made to avoid movement. *Embedded* refers to the situated interaction between the embodied being and the external environment, in both place (current context) and time (evolutionary context).

From this view, all experience is inferential,[78] dynamic,[22,54] and related to action in the world.[2,21,24] Thus, to describe the experience of pain, we must understand it within its evolved, learned, and ultimately threat-defined context.[33,99] Theories of embodied experience are well advanced elsewhere, most notably in cybernetics,[4,23,79] evolutionary biology,[39,73,80] and consciousness.[81,82] Its provenance can be traced to structural psychology,[91] phenomenology,[47,52,61] and perception.[41,75] However, embodied domains have avoided pain, considering it either too simple[32] or paradoxically too difficult.[6]

Our embodied view, in many ways, complements the existing literature,[18,27,36,42,93,95] supporting the growing understanding of pain as an experience inferred from uncertain information.[3,17,83,98] However, it critically looks to extend this work beyond a passive information processing model that has come to dominate.[48] Here, we emphasise the body, not separate from the brain nor the world, but part of the facility that actively shapes our experience of pain. This perspective defines pain in terms of action: an experience that, as part of a protective strategy, attempts to defend one's *self* in the presence of inferred threat.

We start with a consideration of the core features of embodied pain. Next, we review the few studies that have been attempted on embodied perception and pain. Finally, we discuss how this approach can be applied usefully to pain, exploring both the research and clinical implications of embodied pain.

2. Inferring experience in an uncertain world

In proposing a view of pain as embodied and embedded, we draw upon 3 principles from the broader literature on embodied experience: inference, liminality, and defence. First, all experience is inferred, and inference functions principally to maintain coherence in complex and inherently uncertain environments—*inference*. Second, all experience is fundamentally defined by the boundaries of possible action—*liminality*. Third, all experience can be disturbed by bodily threat: pain is an action that functions to reduce threat, promoting defence and maintaining the integrity of coherent behaviour—*defence*.

2.1. Inference

We know now that our experiences are inferred[47,87]: we fill in the gaps,[44] selectively attend,[1,31] unconsciously prime,[10,49] and in essence prioritise efficiency over accuracy.[51,92] Perception results from attempts to accommodate information that has deviated from our predictions.[20] It is only through the actions of our body and our predictions of the consequences of these actions that we are able to disambiguate the world.[39] Thus, the reciprocal relationship between action and prediction continually reshapes our experience of pain.

Perception as inference can be characterised computationally[101] and has been explored in pain.[3,17,60] Critically, however, the role of the body is often relegated in these more reductionist models, overshadowed by the dominant view of pain as a phenomenon of the brain.[97] In contrast, experience from an embodied perspective is borne out of the hierarchical, sensorimotor interactions we have with the world.[40,71,72] Importantly, this accounts for the changing ability of the individual to act in their environment and what the environment affords. When pain is included within this sensorimotor interaction, it can be considered an action that deliberately alters the way in which we are able to interact with our environment and so in turn, changes what the environment affords.

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2.2. Liminality

Experience can be thought of as a strategy generated from the need to continually adjust our actions when our predictions emerge as inadequate, that is, a mismatch that does not provide a coherent basis for action.[23,50] The need for homeostatic coherence above all else drives experience.[9,25,79] Pain along with other bodily experiences (eg, fatigue, itch, temperature, pressure, and disequilibrium) that intrude upon awareness indicate that boundaries have been reached and action must be taken—they are liminal experiences.

2.3. Defence

Much of the active inference we describe occurs outside of awareness. Like a stream following a well-worn channel defined by natural banks that guide and constrain, so felt experience flows largely uninterrupted, embodied by physical constraints and embedded within social constraints. To stray outside of these bounds produces specific alerts that function to modify our actions or alter our predictions. Each physical sense has a specific threat tied to specific defensive actions, which attempt to return the individual to within viable constraints.[28]

In some circumstances, those defensive actions are insufficient, and the result is experienced as disturbing (eg, das unheimliche phenomena in which we experience incoherent perceptions of familiarity), an illusion of relationship, in which objects are uncannily personal.[38] When all defensive actions fail, there emerge whole system delusional experiences, including repression, derealization, and—as the final defence—dissociation.[12,13,57]

3. Embodied pain motivating action

First, we review research on how pain influences nonpain perceptual judgement, and the obverse—*inference*. Second, we consider studies of action constrained when it meets the boundaries imposed by the body in pain, studied as illusions that alter the experience of pain—*liminal*. Third, we consider examples of whole-body disturbances for their accounting of pain, studied as specific experiences of pain-related dissociation, or global experiences of delusion, in a final defence by departure—*defence*.

There is a small body of experimental work on how the experience of pain can alter nonpain perception. For example, we have shown that pain affects judgements of distance when the object distance being judged is threat related,[89] an observation previously made in patients with clinical pain.[100] Similarly, pain can affect judgements of the weight of external objects,[88] and the weight, size, and shape of one's own body.[65,67] Clinically, reports of pain, temperature, stiffness, and imbalance are hard to disentangle, so often appear together,[66] and have yet to be experimentally separated. Without such finesse, attempts to capture embodied experience rightly faces scrutiny and challenge,[37] although studies have replicated the effects of higher-

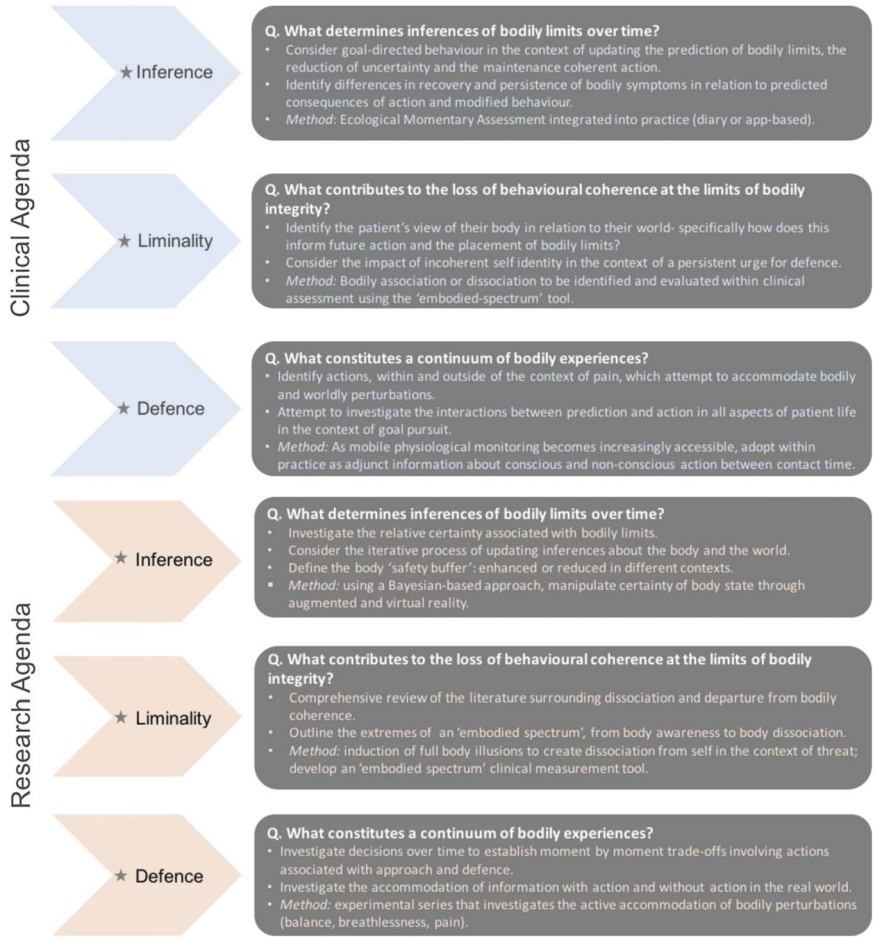

Figure 1. *Embodied pain*: proposed research and clinical agendas.

order cognition and mood on pain.[11,90] There are also studies of counterstimulation offered in competition to pain as distraction.[58] Evidence from direct experimental studies conducted shows pain to be dynamic, flexible, and connected, a reflection of inference in an uncertain world.

Illusionary experience goes beyond altered sensory judgements. "Illusionary" is normally judged as impossible or improbable perception based on a common agreement on the world (eg, if I perceive a limb that every external observer knows me to have lost). Painful missing body parts are a common experience for amputees,[70] although they are rarely reported in isolation from temperature, pressure, weight, size, and itch phenomena. Visual counterstimulation using mirrors or virtual reality can alter not only aspects of size, position, and ownership but also pain.[15,59,74] Some illusions may be harder to identify than others. For example, patients with osteoarthritis demonstrate an altered sensorimotor relationship with the affected limb in addition to the experience of pain.[43,85,86] Evidence from studies of illusionary physical experience can be seen usefully as examples of pain operating as a liminal phenomenon, unstable, and malleable.

Embodied pain involves an elision between perception and action, such that pain without action should be considered unusual, abnormal, or extreme. From this perspective, chronic pain involves persistent action that attempts to reduce threat over time. Inescapable pain, where action is inadequate, may be a signal feature of severe distress (eg, total pain or locked in syndrome).[7] At risk in inescapable pain is the coherence of all behaviour. There are studies of altered bodily coherence in individuals with complex regional pain syndrome I[65] and observations of dissociation from ownership of a limb.[56] But, there are a few experimental studies of what can be considered a final defence by departure, in repression, de-realization, or dissociation. In anthropology, there are qualitative accounts of specific rites of passage[63] and in social psychology of deviant social practice.[8] In the history of medicine, we find rich description of inescapable surgical pain without anaesthesia,[14] and in contemporary medicine, there are similar accounts such as in emergency care or burns care.[64] There is no meta-synthesis of this literature, however, accounts of inescapable pain—of pain denied action—all feature what we call a final defence in a dissociative departure from our body. Although these departures are well studied in clinical neurology, and so have a structure,[53] they have not been studied in pain. Evidence from studies of final defence show that only in extreme circumstances does perception cleave from action.

4. Discussion

Pain as embodied and embedded—inferred, liminal, and functioning for defence—has far reaching research and clinical implications (**Fig. 1**). Our focus should shift from pain as a passive, sensory experience to pain as a dynamic, motor experience. Pain is always about action.[94]

For research, our focus should be on the critical gaps. First, there is a need to explore the changing interactions between experience of the body and associated action (conscious and nonconscious). Studies of proprioception,[45] peripersonal space,[77] and bodily size[66] have offered the best entry points, but a programme of research into other liminal bodily experiences, such as itch, fatigue, disequilibrium, and respiration, are also needed.

The clinical study of treatments aimed at altering experience should consider actions associated with threat. In part, this approach is concerned with gaining detailed accounts of real-life interactions. In acute pain, there are unexplored opportunities in going beyond simple distraction, making use of the inherent uncertainty associated with our bodily experiences, recognising that we act continually to reduce uncertainty. This line of work is already being pursued with the use of bodily illusions.[45,69,74] In chronic pain, interesting are e-health and m-health innovations that now allow for moment-by-moment measurement of functional, physiological, and experiential parameters in the real word. Clinically, treatments framed within a motivational context of how pain interferes with purposeful goal-orientated behaviour (eg, completing a work task) may be improved by studying how threat to bodily coherence is managed.[16,78] In particular, accounting for how action and prediction influence individually defined boundaries. We are beginning to think of therapy as the attempt to redefine a stable coherence of one's identity in line with the context of a persistent urge for defence.[64]

5. Conclusions

We propose that pain is inescapably embodied and embedded; an action that reflects the uncertainty of body and world. "*Embodied pain*" provides a theoretical platform from which novel investigations can aim to understand coherent action in complex, goal-rich environments.

Conflict of interest statement

The authors have no conflicts of interest to declare.

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