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1 Embodied pain—negotiating the boundaries of possible action

2

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23 1. Introduction.

24 Pain is a protective strategy, which emerges from on-going interaction between body
25 and world. Pain is, however, often thought of as a unitary output—an end product
26 experienced as an intrusion upon an often unsuspecting perceiver [56]. We know a lot
27 about how nociception relates to pain, informed by both biological and psychological
28 influences [30,70,98], about how pain intrudes into awareness [5,26,29,34], and how
29 it relates to clinical variables such as suffering and disability [35]. However, despite
30 significant advances, the mechanisms of pain intrusion remain elusive [63]. In this
31 paper we stress a functional view of pain as more than experience; as defensive action
32 operating in the context of uncertain threat.

33

34 Although traditional characterisations of perception as a product of sensory information
35 have been critiqued [19,41,53], including in pain [89,96], there is now a well advanced
36 contemporary view that all perception is embodied and embedded [41,67,79,88]. Here,
37 **embodied** is defined by action, the premise that cognition extends beyond the brain
38 so that an ever-changing body is at the core of how our experiences are shaped; this
39 may be the unconscious workings of our immune system or the collaborative efforts
40 made to avoid movement. **Embedded** refers to the situated interaction between the
41 embodied being and the external environment, in both place (current context) and time
42 (evolutionary context).

43

44 From this view, all experience is inferential [78], dynamic [22,55], and related to action
45 in the world [2,21,24]. Thus, to describe the experience of pain we must understand it
46 within its evolved, learned, and ultimately threat-defined context [33,101]. Theories of
47 embodied experience are well advanced elsewhere, most notably in cybernetics
48 [4,23,81], evolutionary biology [39,75,82] and consciousness [83,84]. Its provenance
49 can be traced to structural psychology [93], phenomenology [47,53,62], and perception

50 [41,77]. However, embodied domains have avoided pain, considering it either too
51 simple [32] or paradoxically too difficult [6].

52

53 Our embodied view, in many ways complements existing literature [18,27,36,42,97]
54 supporting the growing understanding of pain as an experience inferred from uncertain
55 information [3,17,85,100]. However, it critically looks to extend this work beyond a
56 passive, information processing model that has come to dominate [49]. Here, we
57 emphasise the body, not separate from the brain nor the world, but part of the facility
58 that actively shapes our experience of pain. This perspective defines pain in terms of
59 action: an experience which, as part of a protective strategy, attempts to defend one's
60 *self* in the presence of inferred threat.

61

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

66

67 2. Inferring experience in an uncertain world

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

76

77 2.1. *Inference*

78 We know now that our experiences are inferred [47, 89]: we fill in the gaps [44],
79 selectively attend [1,31], unconsciously prime [10,50], and in essence prioritise
80 efficiency over accuracy [52,94]. Perception results from attempts to accommodate
81 information that has deviated from our predictions [20]. It is only through the actions of
82 our body and our predictions of the consequences of these actions that we are able to
83 disambiguate the world [39]. Thus, the reciprocal relationship between action and
84 prediction continually reshapes our experience of pain.

85

86 Perception as inference can be characterised computationally [103], and has been
87 explored in pain [3,17,61]. Critically, however, the role of the body is often relegated in
88 these more reductionist models, overshadowed by the dominant view of pain as a
89 phenomenon of the brain [99]. In contrast, experience from an embodied perspective
90 is borne out of the hierarchical, sensorimotor interactions we have with the world
91 [40,73,74]. Importantly, this accounts for the changing ability of the individual to act in
92 their environment, as well as what the environment affords. When pain is included
93 within this sensorimotor interaction, it can be considered an action that deliberately
94 alters the way in which we are able to interact with our environment and so in turn,
95 changes what the environment affords.

96

97 *2.2. Liminality*

98 Experience can be thought of as a strategy generated from the need to continually
99 adjust our actions when our predictions emerge as inadequate, i.e., a mismatch that
100 does not provide a coherent basis for action [23,51]. The need for homeostatic
101 coherence above all else drives experience [9,25,81]. Pain, along with other bodily
102 experiences (e.g. fatigue, itch, temperature, pressure and disequilibrium) that intrude
103 upon awareness indicate that boundaries have been reached and action must be
104 taken—they are liminal experiences.

105

106 2.3 Defence

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

114

115 In some circumstances those defensive actions are insufficient and the result is
116 experienced as disturbing, e.g., *das unheimliche* phenomena in which we experience
117 incoherent perceptions of familiarity; an illusion of relationship, in which objects are
118 uncannily personal [38]. When all defensive actions fail there emerge whole system
119 delusional experiences, including repression, de-realization, and—as the final
120 defence—dissociation [12,13,58].

121

122 3. Embodied pain motivating action

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

130

131 There is a small body of experimental work on how the experience of pain can alter
132 non-pain perception. For example, we have shown that pain affects judgements of
133 distance when the object-distance being judged is threat-related [91], an observation

134 previously made in patients with clinical pain [102]. Similarly, pain can affect
135 judgements of the weight of external objects [90], and the weight, size, and shape of
136 one's own body [67,69]. Clinically, reports of pain, temperature, stiffness, and
137 imbalance are hard to disentangle, so often appear together [68], and have yet to be
138 experimentally separated. Without such finesse, attempts to capture embodied
139 experience rightly faces scrutiny and challenge [37]; although studies have replicated
140 the effects of higher order cognition and mood on pain [11,92]. There are also studies
141 of counter-stimulation offered in competition to pain as distraction [59]. Evidence from
142 direct experimental studies conducted shows pain to be dynamic, flexible, and
143 connected; a reflection of inference in an uncertain world.

144

145 Illusory experience goes beyond altered sensory judgements. 'Illusory' is
146 normally judged as impossible or improbable perception based on a common
147 agreement on the world; for example, if I perceive a limb that every external observer
148 knows me to have lost. Painful missing body parts are a common experience for
149 amputees [72], although they are rarely reported in isolation from temperature,
150 pressure, weight, size and itch phenomena. Visual counter-stimulation using mirrors
151 or virtual reality can alter aspects of size, position, and ownership, but also pain
152 [15,60,76]. Some illusions may be harder to identify than others. For example, patients
153 with osteoarthritis demonstrate an altered sensorimotor relationship with the affected
154 limb in addition to the experience of pain [43,87,88]. Evidence from studies of
155 illusory physical experience can be seen usefully as examples of pain operating as
156 a liminal phenomenon, unstable and malleable.

157

158 Embodied pain involves an elision between perception and action, such that pain
159 without action should be considered unusual, abnormal, or extreme. From this
160 perspective, chronic pain involves persistent action that attempts to reduce threat over
161 time. Inescapable pain, where action is inadequate, may be a signal feature of severe

162 distress eg., total pain, or locked in syndrome) [7]. At risk in inescapable pain is the
163 coherence of all behaviour. There are studies of altered bodily coherence in individuals
164 with CRPS I [67] and observations of dissociation from ownership of a limb [57]. But
165 there are few experimental studies of what can be considered a final defence by
166 departure, in repression, de-realization, or dissociation. In anthropology there are
167 qualitative accounts of specific rites of passage [65], and in social psychology of
168 deviant social practice [8]. In the history of medicine we find rich description of
169 inescapable surgical pain without anaesthesia [14] and in contemporary medicine
170 there are similar accounts, such as in emergency care, or burns care [66]. There is no
171 meta-synthesis of this literature, however, accounts of inescapable pain—of pain
172 denied action—all feature what we call a final defence in a dissociative departure from
173 our body. Although these departures are well studied in clinical neurology, and so have
174 a structure [54] they have not been studied in pain. Evidence from studies of final
175 defence show that only in extreme circumstances does perception cleave from action.

176

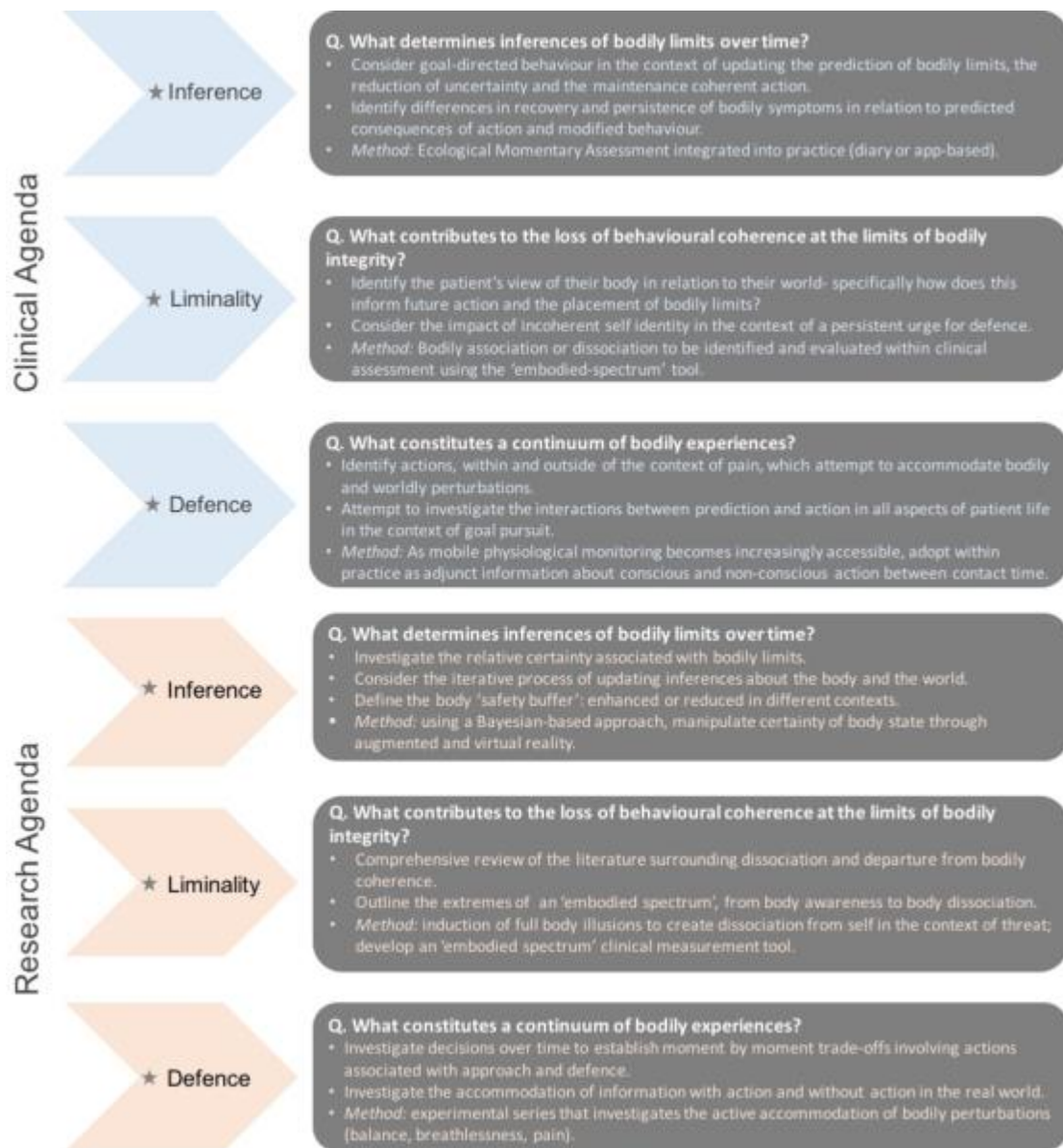
177 4. Discussion

178 Pain as embodied and embedded—inferred, liminal, and functioning for defence—has
179 far reaching research and clinical implications (Fig. 1.). Our focus should shift from
180 pain as a passive, sensory experience to pain as a dynamic, motor experience. Pain
181 is always about action [96].

182

183 For research, our focus should be on the critical gaps. First, there is a need to explore
184 the changing interactions between experience of the body and associated action
185 (conscious and non-conscious). Studies of proprioception [45], peri-personal space
186 [79], and bodily size [68] have offered the best entry points, but a programme of
187 research into other liminal bodily experiences, such as itch, fatigue, disequilibrium, and
188 respiration are also needed.

189



190

191 Fig. 1. *Embodied Pain*: proposed research and clinical agendas.

192

193 The clinical study of treatments aimed at altering experience should consider actions
 194 associated with threat. In part, this approach is concerned with gaining detailed
 195 accounts of real-life interactions. In acute pain, there are unexplored opportunities in
 196 going beyond simple distraction, making use of the inherent uncertainty associated
 197 with our bodily experiences; recognising that we act continually to reduce uncertainty.
 198 This line of work is already being pursued with the use of bodily illusions [45,71,76]. In
 199 chronic pain, interesting are e-health and m-health innovations that now allow for

200 moment-by-moment measurement of functional, physiological and experiential
201 parameters in the real world. Clinically, treatments framed within a motivational context
202 of how pain interferes with purposeful goal-orientated behaviour (e.g, completing a
203 work task) may be improved by studying how threat to bodily coherence is managed
204 [16,80]. In particular, accounting for how action and prediction influence individually
205 defined boundaries. We are beginning to think of therapy as the attempt to redefine a
206 stable coherence of one's identity in line with the context of a persistent urge for
207 defence [66].

208

209 5. Conclusion

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

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