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. Pain is, however, often thought of as a unitary output—an end product experienced as an intrusion upon an often unsuspecting perceiver [56]. We know a lot about how nociception relates to pain, informed by both biological and psychological influences [30,70,98], about 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 [63]. In this paper 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 [19,41,53], including in pain [89,96], there is now a well advanced contemporary view that all perception is embodied and embedded [41,67,79,88]. 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 [22,55], 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 [33,101]. Theories of embodied experience are well advanced elsewhere, most notably in cybernetics [4,23,81], evolutionary biology [39,75,82] and consciousness [83,84]. Its provenance can be traced to structural psychology [93], phenomenology [47,53,62], and perception

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

Our embodied view, in many ways complements existing literature [18,27,36,42,97] supporting the growing understanding of pain as an experience inferred from uncertain information [3,17,85,100]. However, it critically looks to extend this work beyond a passive, information processing model that has come to dominate [49]. 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 which, 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 three 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, 89]: we fill in the gaps [44], selectively attend [1,31], unconsciously prime [10,50], and in essence prioritise efficiency over accuracy [52,94]. 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 [103], and has been explored in pain [3,17,61]. 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 [99]. In contrast, experience from an embodied perspective is borne out of the hierarchical, sensorimotor interactions we have with the world [40,73,74]. Importantly, this accounts for the changing ability of the individual to act in their environment, as well as 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.

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, i.e., a mismatch that does not provide a coherent basis for action [23,51]. The need for homeostatic coherence above all else drives experience [9,25,81]. Pain, along with other bodily experiences (e.g. 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, e.g., 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, de-realization, and—as the final defence—dissociation [12,13,58].

3. Embodied pain motivating action

First we review research on how pain influences non-pain 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 non-pain perception. For example, we have shown that pain affects judgements of distance when the object-distance being judged is threat-related [91], an observation

previously made in patients with clinical pain [102]. Similarly, pain can affect judgements of the weight of external objects [90], and the weight, size, and shape of one's own body [67,69]. Clinically, reports of pain, temperature, stiffness, and imbalance are hard to disentangle, so often appear together [68], 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 order cognition and mood on pain [11,92]. There are also studies of counter-stimulation offered in competition to pain as distraction [59]. 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; for example, if I perceive a limb that every external observer knows me to have lost. Painful missing body parts are a common experience for amputees [72], although they are rarely reported in isolation from temperature, pressure, weight, size and itch phenomena. Visual counter-stimulation using mirrors or virtual reality can alter aspects of size, position, and ownership, but also pain [15,60,76]. 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 [43,87,88]. 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 CRPS I [67] and observations of dissociation from ownership of a limb [57]. But there are 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 [65], 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 [66]. 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 [54] 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 [96].

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 non-conscious). Studies of proprioception [45], peri-personal space [79], and bodily size [68] 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.

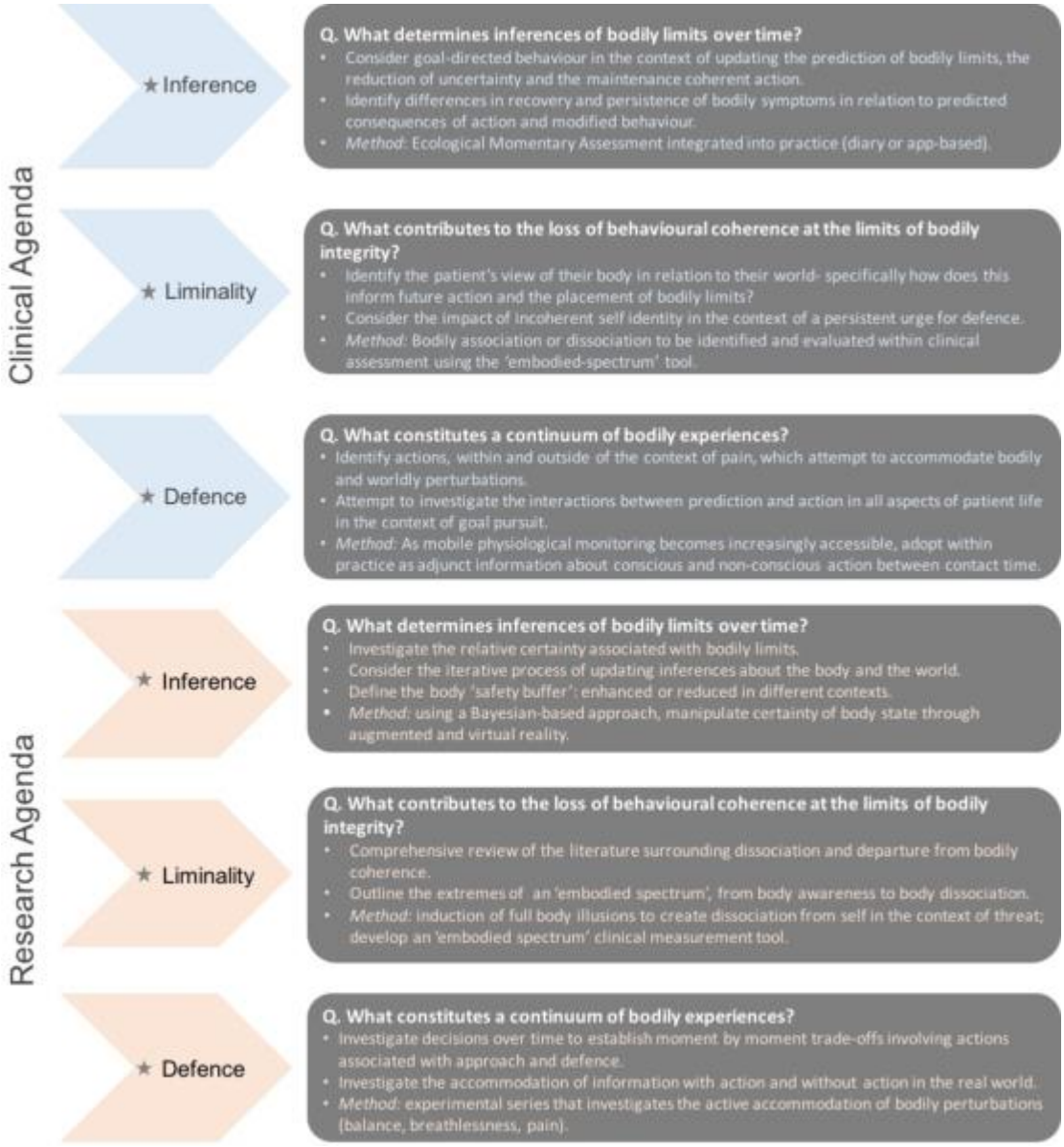

Fig. 1. *Embodied Pain:* proposed research and clinical agendas.

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 [45,71,76]. 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 (e.g, completing a work task) may be improved by studying how threat to bodily coherence is managed [16,80]. 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 [66].

5. Conclusion

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.

References

[1] Allport DA. Attention and control: have we been asking the wrong questions? A critical review of twenty-five years. In: Meyer E, Kornblurn S, editors. Attention and Performance XVI: Synergies in Experimental Psychology, Artificial Intelligence, and Cognitive Neuroscience. Cambridge, MA: MIT Press, 1993. pp. 182–218.

[2] Allport DA. Selection for action: some behavioral and neurophysiological considerations of attention and action. In: Heuer H, Sanders HF, editors. Perspectives on Perception and Action. Hillsdale, NJ: Lawrence Erlbaum Associates, 1987. pp. 395–419.

[3] Anchisi D, Zanon M. A Bayesian perspective on sensory and cognitive integration in pain perception and placebo analgesia. PLoS One 2015;10:1–20.

[4] Ashby WR. An introduction to cybernetics. London: Chapman & Hail Ltd., 1956.

[5] Attridge N, Crombez G, Van Ryckeghem D, Keogh E, Eccleston C. The experience of cognitive intrusion of pain. Pain 2015;156:1978–90.

[6] Aydede M. Is feeling pain the perception of something? J. Philos. 2009;106:531–567.

[7] Bauby J-D. The diving bell and the butterfly. London: Fourth Estate, 1997.

[8] Baumeister RF. The enigmatic appeal of sexual masochism: why people desire pain, bondage, and humiliation sex. J. Soc. Clin. Psychol. 1997;16:133–150.

[9] Bechara A, Damasio AR. The somatic marker hypothesis: a neural theory of economic decision. Games Econ. Behav. 2005;52:336–372.

[10] Beierholm UR, Quartz SR, Shams L. Bayesian priors are encoded independently from likelihoods in human multisensory perception. J. Vis. 2009;9:1–9.

[11] Benedetti F, Pollo A, Lopiano L, Lanotte M, Vighetti S, Rainero I. Conscious expectation and unconscious conditioning in analgesic, motor, and hormonal placebo/nocebo responses. J. Neurosci. 2003;23:4315–4323.

[12] Blackmore SJ. Beyond the body: an investigation of the out-of-the-body experiences. London: Heinemann, 1982.

[13] Blanke O. Out of body experiences and their neural basis. BMJ 2004;329:1414–1415.

[14] Bourke J. The story of pain: from prayer to painkillers. Oxford: Oxford University Press, 2014.

[15] Bowering KJ, O'Connell NE, Tabor A, Catley MJ, Leake HB, Moseley GL, Stanton TR. The effects of graded motor imagery and its components on chronic pain: a systematic review and meta-analysis. J. Pain 2013;14:3–13.

[16] Brandtstadter J, Rothermund K. The life-course dynamics of goal pursuit and goal adjustment: a two-process framework. Dev. Rev. 2002;22:117–150.

[17] Buchel C, Geuter S, Sprenger C, Eippert F. Placebo analgesia: a predictive coding perspective. Neuron 2014;81:1223–1239.

[18] Butler DS, Moseley GL. Explain Pain: revised and updated. 2nd ed. Adelaide, SA: Noigroup Publications, 2013.

[19] Chemero A. An outline of a theory of affordances. Ecol. Psychol. 2003;15:181–195.

[20] Clark. Busting out: predictive brains, embodied minds, and the puzzle of the evidentiary veil. Nous 2016:1–27.

[21] Clark A. An embodied cognitive science? Trends Cogn. Sci. 1999;3:345–351. doi:10.1016/S1364-6613(99)01361-3.

[22] Clark A. Embodied Prediction. In: Metzinger T, Windt JM, editors. Open MIND. Frankfurt am Main: MIND Group, 2015. p. 7. doi:10.15502/9783958570115.

[23] Clark A. Whatever next? Predictive brains, situated agents, and the future of cognitive science. Behav. Brain Sci. 2013;36:181–204.

[24] Clark A, Chalmers D. The extended mind. Analysis 1998;58:7–19.

[25] Craig AD. A new view of pain as a homeostatic emotion. Trends Neurosci. 2003;26:303–307.

[26] Crombez G, Eccleston C, Baeyens F, Eelen P. Disruptive nature of pain: an experimental investigation. Behav. Res. Ther. 1996;34:911–918.

[27] Crombez G, Eccleston C, Van Damme S, Vlaeyen JWS, Karoly P. Fear-avoidance model of chronic pain: the next generation. Clin. J. Pain 2012;28:475–83.

[28] Damasio A, Carvalho GB. The nature of feelings: evolutionary and neurobiological origins. Nat. Rev. Neurosci. 2013;14:143–52.

[29] Van Damme S, Legrain V, Vogt J, Crombez G. Keeping pain in mind: a motivational account of attention to pain. Neurosci. Biobehav. Rev. 2010;34:204–213.

[30] Davis KD. Neuroimaging of pain: what does it tell us? Curr. Opin. Support. Palliat. Care 2011;5:116–121.

[31] Dayan P, Kakade S, Montague PR. Learning and selective attention. Nat. Neurosci. 2000;3:1218–1223.

[32] Dennett DC. Quining qualia. In: Marcel A, Bisiach E, editors. Consciousness in Modern Science. Oxford: Oxford University Press, 1988.

[33] Eccleston C, Crombez G. Worry and chronic pain: a misdirected problem solving model. Pain, 132; 233-236.

[34] Eccleston C, Crombez G. Pain demands attention: a cognitive-affective model of the interruptive function of pain. Psychol Bull 1999;125:356–366.

[35] Eccleston C, Crombez G, Aldrich S, Stannard C. Attention and somatic awareness in chronic pain. Pain 1997;72:209–215.

[36] Engel GL. The need for a new medical model: A challenge for biomedicine. Science. 1977;196:129–136.

[37] Firestone C, Scholl BJ. Cognition does not affect perception: Evaluating the

evidence for “top-down” effects. Behav. Brain Sci. 2015:1–72. Available: doi.org/10.1017/s0140525x15000965.

[38] Freud S. The Uncanny. In: Strachey J, editor. The standard edition of the complete psychological works of Sigmund Freud (Vol 17). London: The Hogarth Press, 1919. pp. 218–256.

[39] Friston K. The free-energy principle: a unified brain theory? Nat. Rev. Neurosci. 2010;11:127–138.

[40] Gallagher S, Bower M. Making enactivism even more embodied. Avant Trends Interdiscip. Stud. 2014;2:232–247.

[41] Gibson JJ. The Theory of Affordances. In: Shaw R, Bransford J, editors. Perceiving, Acting, and Knowing. Towards an Ecological Psychology. Hoboken, NJ: John Wiley & Sons Inc., 1977. pp. 127–142.

[42] Gifford L. Pain, the Tissues and the Nervous System: A conceptual model. Physiotherapy 1998;84:27–36.

[43] Gilpin HR, Moseley GL, Stanton TR, Newport R. Evidence for distorted mental representation of the hand in osteoarthritis. Rheumatology 2014;54:678–682.

[44] Gregory RL. Perceptions as hypotheses. Philos. Trans. R. Soc. B Biol. Sci. 1980;290:181–197.

[45] Harvie DS, Broecker M, Smith RT, Meulders A, Madden VJ, Moseley GL. Bogus visual feedback alters onset of movement-evoked pain in people with neck pain. Psychol. Sci. 2015;26:385–92.

[46] Haugeland J. Mind embodied and embedded. In: Haugeland J, editor. Having Thought: Essays in the Metaphysics of Mind. Cambridge, MA: Harvard University Press, 1998.

[47] Heidegger M. Being and Time. trans. J. Macquarrie and E Robinson, editor Tubingen: Max Niemeyer Verlag, 1962.

[48] Helmholtz H von. Handbuch der physiologischen optik, vol 3. (Trans.). Southall JPC, editor New York, NY: Dover Publications, 1962.

[49] Helmholtz H von. Treatise on physiological optics, vol. II. 1924.

[50] Hohwy J. Attention and conscious perception in the hypothesis testing brain. Front. Psychol. 2012;2:96.

[51] Hohwy J. The predictive mind. Oxford: Oxford University Press, 2013.

[52] Humphrey N. The placebo effect. In: Gregory R, editor. Oxford companion to the mind. Oxford: Oxford University Press, 2005.

[53] Husserl E. Ideas: a general introduction to pure phenomenology. Trans. W. R Boyce Gibson, editor New York: Collier Books, 1931.

[54] Kihlstrom JF. Dissociative Disorders. Annu. Rev. Clin. Psychol. 2005;1:227–253.

[55] Körding KP, Wolpert DM. Bayesian integration in sensorimotor learning. Nature 2004;427:244–247.

[56] Legrain V, Damme S Van, Eccleston C, Davis KD, Seminowicz DA, Crombez G. A neurocognitive model of attention to pain: behavioral and neuroimaging evidence. Pain 2009;144:230–232.

[57] Lewis JS, Schweinhardt P. Perceptions of the painful body: the relationship between body perception disturbance, pain and tactile discrimination in complex regional pain syndrome. Eur. J. Pain 2012;16:1320–1330.

[58] Lopez C, Halje P, Blanke O. Body ownership and embodiment: vestibular and multisensory mechanisms. Neurophysiol. Clin. 2008;38:149–161.

[59] Malloy KM, Milling LS. The effectiveness of virtual reality distraction for pain reduction: a systematic review. Clin. Psychol. Rev. 2010;30:1011–1018.

[60] Mancini F, Longo MR, Kammers MPM, Haggard P. Visual distortion of body size modulates pain perception. Psychol. Sci. 2011;22:325–330.

[61] Mano H, Seymour B. Pain: a distributed brain information network? PLoS Biol. 2015;13:e1002037.

[62] Merleau-Ponty M. Phenomenology of Perception (Trans.). Smith C, editor London: Routledge & Kegan Paul, 1962.

[63] Moayedi M, Davis KD. Theories of pain: from Specificity to Gate Control. J. Neurophysiol. 2013;109:5–12.

[64] Moore A, Derry S, Eccleston C, Kalso E. Expect analgesic failure; pursue analgesic success. Br. Med. J. 2013;346:f2690–f2690.

[65] Morinis A. The ritual experience: pain and the transformation of consciousness in ordeals of initiation. Ethos 1985;13:150–174.

[66] Morse JM, Mitcham C. The experience of agonizing pain and signals of disembodiment. J. Psychosom. Res. 1998;44:667–680.

[67] Moseley GL. Distorted body image in complex regional pain syndrome. Neurology 2005;65:773–778.

[68] Moseley GL, Gallace A, Spence C. Bodily illusions in health and disease: physiological and clinical perspectives and the concept of a cortical “body matrix.” Neurosci. Biobehav. Rev. 2012;36:34–46.

[69] Moseley GL, Parsons TJ, Spence C. Visual distortion of a limb modulates the pain and swelling evoked by movement. Curr. Biol. 2008;18:R1047-8.

[70] Moseley GL, Vlaeyen JWS. Beyond nociception: the imprecision hypothesis of chronic pain. Pain 2015;156:35–38.

[71] Murray CD, Pettifer S, Howard T, Patchick EL, Caillette F, Kulkarni J, Bamford C. The treatment of phantom limb pain using immersive virtual reality: three case studies. Disabil. Rehabil. 2007;29:1465–1469.

[72] Nikolajsen L, Jensen ST. Phantom limb pain. Br. J. Anaesth. 2001;87:107–116.

[73] Noe A. Action in perception. Cambridge, MA: MIT Press, 2004 p.

[74] O’Regan JK, Dagenaar J. Consciousness without inner models: a sensorimotor account of what is going on in our heads. Proc. AISB 2014.

[75] Prescott TJ, Bryson JJ, Seth AK. Introduction. Modelling natural action selection. Philos. Trans. R. Soc. B Biol. Sci. 2007;362:1521–1529.

[76] Preston C, Newport R. Analgesic effects of multisensory illusions in

osteoarthritis. Rheumatology 2011;50:2314–2315.

[77] Proffitt DR. An embodied approach to perception: by what units are visual perceptions scaled? Perspect. Psychol. Sci. 2013;8:474–483.

[78] Rao RPN, Ballard DH. Predictive coding in the visual cortex: a functional interpretation of some extra-classical receptive-field effects. Nat. Neurosci. 1999;2:79–87.

[79] Sambo CF, Iannetti GD. Better safe than sorry? The safety margin surrounding the body is increased by anxiety. J. Neurosci. 2013;33:14225–30.

[80] Schmitz U, Saile H, Nilges P. Coping with chronic pain: flexible goal adjustment as an interactive buffer against pain-related distress. Pain 1996;67:41–51.

[81] Seth AK. The Cybernetic Bayesian Brain. In: Metzinger T, Windt JM, editors. Open MIND. Frankfurt am Main: MIND Group, 2015;35. doi:10.15502/9783958570108.

[82] Seth AK. The ecology of action selection: insights from artificial life. Philos. Trans. R. Soc. Lond. B. Biol. Sci. 2007;362:1545–1558.

[83] Seth AK. Why fish pain cannot and should not be ruled out. Anim. Sentience 2016;3:1–5.

[84] Seth AK, Suzuki K, Critchley HD. An interoceptive predictive coding model of conscious presence. Front. Psychol. 2012;3:1–16.

[85] Seymour B, Dolan RJ. Emotion, Motivation, and Pain. In: McMahon S, Koltzenburg M, Tracey I, Turk DC, editors. Wall and Melzack's Textbook of Pain. Philadelphia, PA: Saunders, Elsevier Ltd, 2013. pp. 248–255.

[86] Shapiro LA. The mind incarnate. Cambridge, MA: MIT Press, 2004.

[87] Stanton TR, Lin CWC, Bray H, Smeets RJEM, Taylor D, Law RYW, Moseley GL. Tactile acuity is disrupted in osteoarthritis but is unrelated to disruptions in motor imagery performance. Rheumatology 2013;52:1509–1519.

[88] Stanton TR, Lin CWC, Smeets RJEM, Taylor D, Law R, Lorimer Moseley G.

Spatially defined disruption of motor imagery performance in people with osteoarthritis. Rheumatology 2012;51:1455–1464.

[89] Sullivan MD. Pain in language. From sentience to Sapience. J. Pain 1995;4:3–14.

[90] Sullivan MJ, Thibault P, Savard A, Catchlove R, Kozey J, Stanish WD. The influence of communication goals and physical demands on different dimensions of pain behavior. Pain 2006;125:270–277.

[91] Tabor A, Catley MJ, Gandevia SC, Thacker M a., Spence C, Moseley GL. The close proximity of threat: altered distance perception in the anticipation of pain. Front. Psychol. 2015;6:1–6.

[92] Tang NKY, Salkovskis PM, Hodges A, Wright KJ, Hanna M, Hester J. Effects of mood on pain responses and pain tolerance: an experimental study in chronic back pain patients. Pain 2008;138:392–401.

[93] Titchener EB. Structural and functional psychology. Philos. Rev. 1899;8:290–299.

[94] Trimmer PC, Marshall JAR, Fromhage L, McNamara JM, Houston AI. Understanding the placebo effect from an evolutionary perspective. Evol. Hum. Behav. 2013;34:8–15.

[95] Varela F, Rosch E, Thompson E. The embodied mind: cognitive science and human experience. Cambridge, MA: MIT Press, 1991.

[96] Wall PD. On the relation of injury to pain. The John J. Bonica Lecture. Pain 1979;6:253–264.

[97] Wall PD. Pain: the science of suffering. New York, NY: Columbia University Press, 2000.

[98] Wiech K, Ploner M, Tracey I. Neurocognitive aspects of pain perception. Trends Cogn. Sci. 2008;12:306–313.

[99] Wiech K, Tracey I. Pain, decisions, and actions: a motivational perspective. Front. Neurosci. 2013;7:1–12.

[100] Wiech K, Vandekerckhove J, Zaman J, Tuerlinckx F, Vlaeyen JWS, Tracey I. Influence of prior information on pain involves biased perceptual decision-making. Curr. Biol. 2014:R679–R681.

[101] Williams AC de C. What can evolutionary theory tell us about chronic pain? Pain 2015;157:1.

[102] Witt JK, Linkenauger SA, Bakdash JZ, Augustyn JS, Cook A, Proffitt DR. The long road of pain: chronic pain increases perceived distance. Exp. Brain Res. 2009;192:145–148.

[103] Yuille AL, Bulthoff HH, Kersten D, Mamassian P. Perception as Bayesian Inference. Annu. Rev. Psychol. 1996;55:271–304.