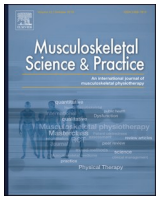
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The role of inference in musculoskeletal pain: an (En)Active Inference Masterclass for clinical reasoning, communication and person-centred care

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A B S T R A C T

Introduction: Persistent musculoskeletal (MSK) pain is often inadequately explained by tissue findings alone. Reassurance may not resolve fear, while the meaning of an activity may influence how it is experienced. Although widely endorsed, the biopsychosocial model is often applied as a checklist not as a guiding philosophy. Active inference, which describes perception, action and learning as prediction-based processes, may help clinicians connect these observations.
Purpose: This Masterclass presents active inference as a conceptual framework and heuristic for person-centred clinical reasoning in MSK pain. Core concepts, including prediction, prediction error, precision and allostasis, are introduced through clinical examples. A five-step clinical reasoning cycle connects the patient's account and priorities with provisional and alternative hypotheses, communication, collaborative movement exploration, and reflection on the patient's response. Evidence for clinical effectiveness, proposed mechanisms and active inference specifically is distinguished throughout.
Implications: Five clinical levers: therapeutic alliance, manual therapy and touch, language, exercise, and context, are presented alongside concrete clinician behaviours, supporting evidence and safeguards against overtreatment, and illustrated through a chronic low back pain vignette. The framework complements differential diagnosis, established approaches such as Cognitive Functional Therapy, and consideration of biological and social contributors. Its additional clinical value remains untested. Falsifiable predictions and priorities for future research are proposed.

1. Introduction

Musculoskeletal (MSK) conditions are a leading global cause of pain and disability (Safiri et al., 2021), and persistent pain is common: in primary care cohorts of people with recent-onset low back pain, about two-thirds still report pain a year later (Itz et al., 2013). Clinicians repeatedly meet three problems that tissue-based explanations handle poorly. First, information and reassurance do not always change a person's worry or the way they move. Second, the meaning and context of an activity can change how it feels: the same bend may feel manageable in the garden, yet alarming in the clinic. Third, communication, movement, the therapeutic relationship and everyday participation influence one another, but are often assessed and treated as separate domains (Cormack et al., 2023).

Two familiar approaches offer partial responses to these problems, which are complex rather than merely complicated (Sturmberg and Martin, 2009). Tissue-based explanations are limited by the observation that degenerative imaging findings are common in people without

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pain (Brinjikji et al., 2015). Tissue-level processes remain relevant (Langevin, 2021), but altered processing of nociceptive information may also contribute, sometimes alongside ongoing nociceptive input (Fitzcharles et al., 2021). The biopsychosocial (BPS) model provides a broader perspective, yet its application has often been 'lost in translation', taking the form of an additive checklist of biological, psychological and social factors rather than an integrated account (Mescouto et al., 2022; Cormack et al., 2023). Enactive approaches seek to address this limitation by understanding these factors as interacting aspects of embodied, situated life and framing care as participation in shared sense-making (Stilwell and Harman, 2019; De Haan, 2020; Coninx and Stilwell, 2023; Vaz et al., 2023; Dierckxsens, 2025).

Active inference is a theory derived from the Free Energy Principle that describes perception, action, learning and emotion in terms of how living systems anticipate and regulate their interactions with the world (Friston, 2010; Parr et al., 2022; Pezzulo et al., 2024). In accessible terms, the theory proposes that the body and nervous system continually anticipate incoming sensations and respond to discrepancies between predicted and incoming sensations by revising predictions or acting to influence sensory experiences. Key terms are defined in Table 1. The theory has developed alongside enactive, ecological and embodied accounts of pain (Ramstead et al., 2020; Kiverstein et al., 2022; Esteves et al., 2022). Its potential clinical contribution is a shared vocabulary for considering relationships among expectations, bodily sensations, movement, context and the therapeutic relationship. Whether it explains these relationships better than existing accounts remains unestablished.

This Masterclass has two complementary purposes. Conceptually, it presents active inference as a proposed account of how communication, therapeutic interaction, movement-related uncertainty and person-centred care might be understood within a predictive, embodied and relational process. This represents a theoretical contribution, whose proposed explanations of processes underlying patients' experiences remain hypotheses to be tested (Section 6). Practically, it considers how these concepts may support the clinician's own reasoning. When applied clinically, terms such as 'prior' and 'precision' denote provisional theoretical interpretations of the person's account and behaviour. They are not directly observed clinical findings and do not replace the person's account of their experience.

Throughout the article, we distinguish evidence for clinical effectiveness, evidence for proposed mechanisms, evidence specific to active inference, and conceptual extrapolation. By the end of the Masterclass, readers should be able to: (1) explain, using a patient example, why reassurance alone may not change pain-related fear or movement; (2) distinguish the person's reported experience from the clinician's theoretical interpretation; (3) develop provisional hypotheses and alternative explanations, and explore these with the person; (4) plan collaborative, tolerable movement experiences and use the person's response to revise care, including decisions about when to stop treatment; and (5) appraise the framework's evidential limitations. Sections 2–6 introduce the conceptual foundations, consider their relevance to persistent pain, explore clinical application, present a single clinical vignette, and examine limitations and priorities for future research.

2. Conceptual foundations

Six concepts provide the foundations for the sections that follow and are presented without mathematics. Four are central to clinical reasoning: generative models and prediction error (Section 2.2), precision (Section 2.3), action and sensory attenuation (Section 2.4), and allostasis (Section 2.5). Two provide additional theoretical background and may be read selectively: the Free Energy Principle (Section 2.1) and Markov blankets (Section 2.6). Each concept is introduced through a clinical example and linked to its application in Section 4. Table 1 provides plain-language definitions, identifies the core terms and includes annotated further reading.

Table 1
Glossary of key terms, with core terms for bedside reasoning marked, and annotated further reading.

Term	Definition
Active inference (core)	Perceptual inference *plus action*. The system not only updates beliefs to explain sensations but also selects actions that change what it senses, sampling the world in ways that reduce uncertainty and keep the organism in safe, workable states.
Affordances (core)	Opportunities for action made available by the environment (including the clinical environment). In care, conditions can afford safety, exploration, and new movement strategies.
Allostasis (core)	Predictive regulation: adjusting physiology and behaviour in advance of expected demands to maintain stability and viability, rather than only reacting after problems arise.
Attractor	A stable region of a dynamic state space that a system tends to fall into and remain within. It is used here as a theoretical description: in persistent pain, threat-weighted patterns (e.g., guarding, hypervigilance, pain expectation) may behave like attractors that are difficult to shift.
Contextual factors (core)	Elements of the encounter that shape expectations, meaning, and trust (e.g., language, clinician confidence, therapeutic alliance, environment, treatment ritual). They may shape outcomes, although trials that deliberately enhanced them in chronic primary MSK pain found little to no effect on pain or function (Saueressig et al., 2024).
Ecological	Perception, and therefore pain, emerges within an environment: the person's expectations and regulation are shaped by the affordances and constraints of their social and physical world.
Embodied	Perception, and therefore pain, is generated by the whole organism (brain, body, and action) through coupled sensorimotor and physiological regulation, not by the brain alone.
Free energy	A quantity that places an upper bound on how surprising sensory input is (also called surprisal), given a system's expectations; under simplifying assumptions it can be approximated by precision-weighted prediction error. In the theory, living systems act and learn in ways that reduce free energy over time.
Generative model (core)	The organised set of expectations with which a body and nervous system are proposed to anticipate the causes of sensations, used here in a deflationary sense. It is a theoretical construct in the clinician's reasoning and cannot be observed directly.
Hands-on care (core)	Clinical care delivered through physical contact, including assessment and therapeutic techniques that involve touch, movement, and guided interaction.
Inference (core)	Working out the most likely cause of what you sense, given what you already expect. Inference is ongoing and evidence-based: it is how the system updates its best guess about what is happening.
Likelihood	The system's learned mapping between causes and sensations — how probable a given sensory pattern is if a particular hidden cause is true. In plain terms: "If the world is like this, what should it feel like?"
Markov blanket	A statistical boundary that separates a system's internal states from external states, with exchange through sensory and active states. Its interpretation is debated (Bruineberg et al., 2022); it is not needed for bedside reasoning.
Niche	The structured subset of the world that an organism reliably inhabits and is adapted to, including typical resources, threats, social structures, and cultural practices. A niche constrains which states are reachable and which behaviours are viable, shaping the organism's expectations (priors) and how it regulates itself.
Perceptual inference (core)	Updating one's best estimate of what is happening by combining prior expectations with incoming sensory evidence. Perception is thus treated as a form of inference: the system "works out" the most likely cause of its sensations.
Policies (action policies)	Possible action plans the system can choose from (e.g., avoid, explore, guard, seek reassurance, relax). In active inference, policies are selected according to which actions are expected to keep the system safe and reduce uncertainty (formally, to minimise expected free energy).

(*continued on next page*)

Table 1 (*continued*)

Term	Definition
Posterior	The system's updated belief after combining prior expectations with new sensory evidence. In plain terms: "What I now think is most likely, given what I expected and what I just sensed."
Precision weighting (core)	The context-dependent weight given to prior expectations relative to incoming signals. In theory, high weighting of threat-related signals may make pain more likely, and credible cues of safety may reduce it; these are hypotheses, and precision cannot be measured in routine clinical assessment.
Prediction error (core)	The mismatch between what is expected and what is sensed. Prediction errors prompt either belief updating ("I was wrong") or action ("change what I sample") to reduce uncertainty. Larger mismatches do not necessarily produce more updating (§4.1).
Predictive processing	The idea that the nervous system, as part of the whole organism, is constantly revising best-guess predictions about sensory input and adjusting them in light of incoming signals. Perception is therefore shaped by expectation as well as sensation.
Priors (core)	Expectations built from previous experience and biology. These can be low-level (sensorimotor predictions) or high-level; a clinician may hypothesise a high-level prior from a statement such as "my back is damaged", but the statement, not the prior, is what is observed.
Sense-making (core)	The process by which a living system actively interprets and responds to its situation in light of what matters for its viability. We use the term primarily in this basic, adaptive sense, extending it to participatory sense-making — meaning generated between people — when describing the therapeutic encounter; we do not use it in a purely cognitive or narrative sense.
Sensory attenuation (core)	The down-weighting of sensations produced by one's own movement, thought to help the body recede from awareness during action. Whether it is altered in persistent MSK pain is uncertain (McNaughton et al., 2022).
Surprise	How unexpected the sensory input is, given the system's current model. Surprise itself is not directly measured; instead, organisms act to minimise expected surprise (and so remain viable).
Viability (viable states)	The set of bodily and behavioural states compatible with continued survival and functioning. Active inference can be understood as keeping the system within this viable region of state space.
World	The full environment and its generative processes: everything outside the organism that could, in principle, influence its sensory inputs, opportunities, threats, and survival.

Note: Definitions are written to be accessible to clinicians while remaining faithful to their technical meaning within predictive-processing, active-inference, and enactive frameworks. Where a term carries a broader or contested usage elsewhere, the sense intended here is the one given above.
Terms marked (core) are needed to follow the clinical sections (Sections 4 and 5); the remaining terms provide theoretical background.
Annotated further reading. Parr et al. (2022): a textbook introducing active inference from intuitive principles to formal models. Pezzulo et al. (2024): a concise review of active inference as a theory of sentient behaviour. Smith et al. (2022): a step-by-step tutorial on building active inference models and fitting them to behavioural data. Kiverstein et al. (2022): the embodied predictive processing theory of pain on which the neuraxis heuristic draws. Seymour and Mancini (2020): hierarchical computational models of pain linking inference, information-seeking and control. Bruineberg et al. (2022): a critical analysis of how Markov blankets are used in this literature.

2.1. *The free energy principle in brief (Background)*

The Free Energy Principle proposes that living systems persist by remaining within a range of viable states, limiting encounters with sensations that are unexpected given the kind of system they are and/or worlds they inhabit. Within this account, systems can respond to discrepancies between predicted and incoming sensations by updating predictions to better reflect the world (perceptual inference and learning) or by acting to bring sensory input into line with predictions (active inference) (Fig. 1). Both are described in terms of minimising variational free energy, a quantity that places an upper bound on surprise in its statistical sense (Friston, 2010). Therefore, successfully reducing variational free energy will lead to a decrease in surprisal.

For clinical reasoning, this perspective invites consideration of whether a person's current ways of managing uncertainty remain helpful. Guarding, avoidance and checking, for example, may offer short-term predictability while limiting opportunities to discover that movement can be tolerable (Pezzulo et al., 2015). This provides one possible interpretation for clinicians to explore with the person, informing the discussion of fear-avoidance in Section 3.3 and exercise in Section 4.5.

2.2. *Generative models and prediction error (Core)*

A generative model is the organised set of expectations with which a system anticipates what is likely to be causing its sensations. Sensations are ambiguous, because different causes can produce similar signals; prediction errors, the discrepancy between predicted and actual signals, are the information from which the system learns and regulates. In active inference, this hierarchy of expectations is not confined to the brain but is described as spanning peripheral, immune, endocrine and autonomic activity, movement, affect, social interaction and narrative meaning (Tabor et al., 2017; Pezzulo et al., 2019; Kiverstein et al., 2022). We use 'generative model' here in a deflationary sense, as a description of how a body anticipates and engages its world rather than a claim that a model is stored in neural tissue (Hutto and Myin, 2013; Gallagher, 2017). Importantly, the clinician never observes a patient's generative model, i.e., it is an inferential process. Clinical example: when a person says "my back is damaged" and hesitates before bending, the clinician may hypothesise and infer a strong expectation of harm; the hypothesis is the clinician's, and in good practice checked with the person (Section 4.1).

2.3. *Precision (Core)*

Not all prediction errors are weighted equally. Precision refers to the confidence assigned to predictions or incoming evidence and, within the framework, influences whether new evidence changes expectations or is discounted. Attention is one proposed route through which precision is weighted. Arousal, threat, inflammation and descending modulation may also influence the weighting of bodily signals, often outside awareness (Edwards et al., 2012; Seymour and Mancini, 2020).

Precision is a theoretical construct and cannot be inferred directly from a clinical examination. Hypervigilance, repeated checking or difficulty interpreting a successful movement as evidence of safety may be consistent with greater weighting of threat-related information, but these observations also admit other explanations (Section 6).

For example, a person who completes a lift without harm but reports 'I got away with it this time' may be discounting the experience rather than revising their expectations. This is a provisional interpretation for the clinician to explore with the person, including what would make the experience meaningful evidence for them (Sections 4.1 and 4.5).

2.4. *From homeostasis to allostasis (Core)*

Homeostasis corrects deviations after they occur; allostasis anticipates demands and adjusts physiology and behaviour in advance (Sterling, 2012; Bettinger and Friston, 2023). Persistent pain can be read, speculatively, as protection that continues after the circumstances that made it useful have changed. Sleep, stress, inflammation, metabolic health, workload, relationships and recovery capacity are therefore proposed to shape the expectations and regulatory responses through which pain is experienced (Bhat et al., 2021; Kiverstein et al., 2022). For example, exploring sleep, financial stress, training load, caring responsibilities or work pressure is already part of biopsychosocial

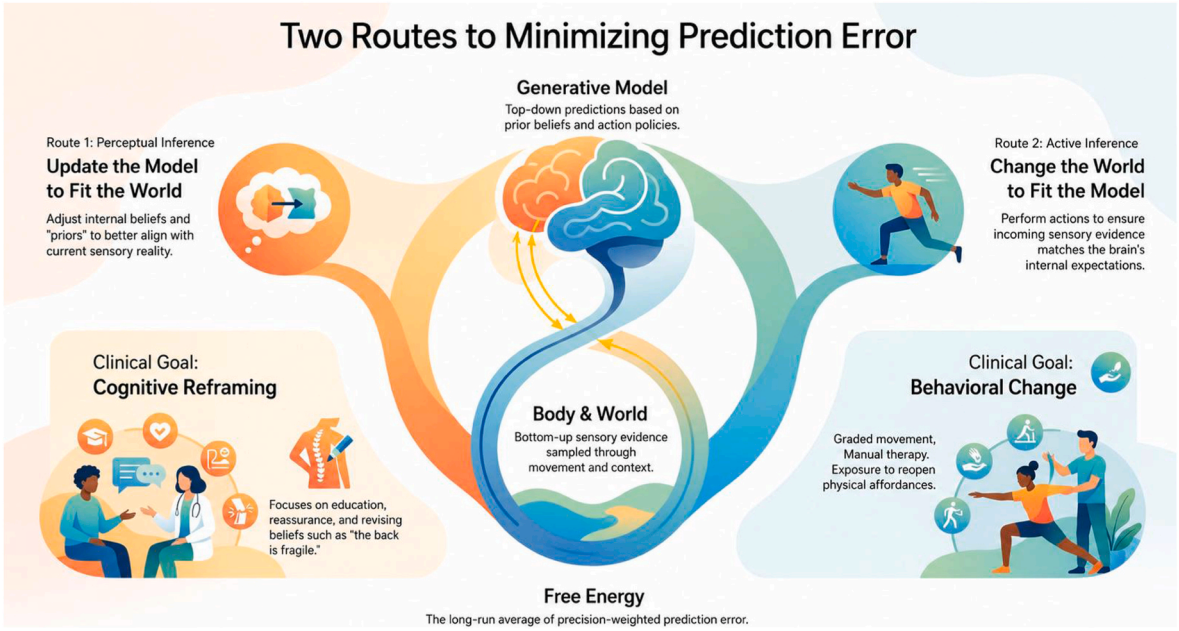


Fig. 1. Two routes to reducing prediction error, as described by active inference: updating expectations (perceptual inference and learning) and acting to change sensory input (active inference). Clinical correlates are illustrative examples, not validated mechanisms.

assessment; active inference adds a rationale for treating these as possible contributors to the problem rather than as background risk factors (Section 4.1).

2.5. Markov blankets (Background)

A Markov blanket is a statistical boundary that separates a system's internal states from external states while allowing exchange through sensory and active states; such boundaries can be nested, from cell to tissue to person to social world (Friston, 2013; Kirchhoff et al., 2018; Palacios et al., 2020). The construct is debated, including whether it describes real boundaries or modelling choices (Bruineberg et al., 2022; Hipólito and van Es, 2022). Its clinical implication is modest and familiar: the nervous system has no direct access to tissue state and must interpret the signals available to it, so pain and nociception are different phenomena (Raja et al., 2020), and interventions may act by changing what is sensed or how it is interpreted.

3. Persistent musculoskeletal pain through an active inference lens

3.1. Pain as inference rather than a direct readout of tissue damage

The International Association for the Study of Pain distinguishes pain from nociception and emphasises that a person's report of pain should be respected (Raja et al., 2020). Active inference offers one account of that distinction: pain is described as the system's best current explanation of multisensory input, combining nociceptive, interoceptive, proprioceptive signals with prior expectations, their precision, affective state and the demands of the situation. Research in healthy volunteers is consistent with this: in the insula, activity encoding stimulus intensity can be dissociated from activity reflecting pain related predictions and prediction errors (Geuter et al., 2017), and people with more precise expectations of relief showed larger placebo effects, with correlates in brainstem regions involved in descending modulation (Grahl et al., 2018). Whether the same processes explain persistent clinical pain remains a hypothesis. If they do, education, graded exposure, reappraisal, therapeutic alliance and meaningful activity might change pain itself, not only behaviour (Tabor et al., 2017; Kiverstein et al., 2022).

3.2. Three computational mechanisms of persistence

Eckert et al. (2022) propose a Bayesian model in which chronic pain can arise from three distinguishable problems: overly precise pain expectations, imprecise sensory signals, and rigid beliefs about transitions between states (Table 2). The scheme is a theoretical model rather than a validated classification, but it offers a useful framework: instead of asking which technique habit suggests, the clinician asks which provisional explanation best fits what this person reports and does, and what would count against it. Hierarchical models make a related distinction between inference, information-seeking and adaptive control (Seymour and Mancini, 2020).

Table 2
Three computational mechanisms of chronic pain proposed by Eckert et al. (2022): illustrative clinical observations and intervention classes that may address each.

Proposed mechanism (theoretical)	What the clinician may hear or observe (illustrative)	Intervention classes that may address it
Overly precise pain priors	*The person repeatedly describes their back as "damaged" despite explanation, and movements completed without harm do not change their confidence.*	Pain neuroscience education combined with exercise or exposure; cognitive reappraisal; explanation linked to lived experience.
Imprecise sensory signals	*The person finds it hard to locate or describe sensations, or reports that the painful area feels vague or unfamiliar.*	Sensory discrimination training; graded motor imagery; body-awareness and mindful movement.
Rigid state-transition beliefs	*The person cannot imagine moving without pain, or describes their condition as unchangeable.*	Novel experiences; graded exposure; behavioural experiments that generate model-violating evidence.

Note: The mechanisms come from a theoretical Bayesian model. Column 2 gives illustrative observations that might lead a clinician to consider each hypothesis; each observation is also compatible with other explanations and should be checked with the person.

3.3. Fear-avoidance as a self-confirming cycle

Varangot-Reille et al. (2024) reinterpret the fear-avoidance model (Vlaeyen and Linton, 2012) in predictive terms (Fig. 2). A person who expects bending to hurt may guard, hold their breath and restrict their range; guarded bending may then feel unsafe, and avoided movements offer no opportunity to learn otherwise. On this account, avoidance prevents disconfirmation, so the threat expectation may strengthen and extend to more situations. Research in healthy volunteers shows how such cycles can form: expectations shaped reported pain, reported pain in turn shaped later expectations, and learning was biased towards confirming initial beliefs (Jepma et al., 2018).

This account offers one interpretation of a common clinical problem: reassurance alone often has limited effects. In acute low back pain, education in primary care increases reassurance, but with small effects (Traeger et al., 2015), and intensive education produced no difference in pain at three months compared with placebo education (Traeger et al., 2019). Explanation has been associated with better outcomes than rapport and empathy alone (Pincus et al., 2013), and in chronic MSK pain, adding pain neuroscience education to exercise produced greater short-term improvements than exercise alone, with low-certainty evidence (Siddall et al., 2022). Active inference reads this pattern as words carrying limited weight against a strongly held, experience-based expectation. This reading is plausible not established; the same findings fit learning-based accounts that do not require active inference (Gatzounis et al., 2021).

3.4. Sensory attenuation and the conspicuous body

In health, the body largely recedes from awareness during action; we act through it without attending to it. Phenomenology describes how, in persistent pain, the body can instead become conspicuous, an obstacle through which the world is encountered (Leder, 1990; Honkasalo, 2000; Svenaeus, 2011; Sarkkinen and Heinämaa, 2026). Active inference proposes a candidate mechanism: if sensations generated by one's own movement are not adequately attenuated, they may keep drawing attention to the body (Ainley et al., 2016; Yon and Frith, 2021; Limanowski, 2022). Direct evidence in persistent pain is limited. The

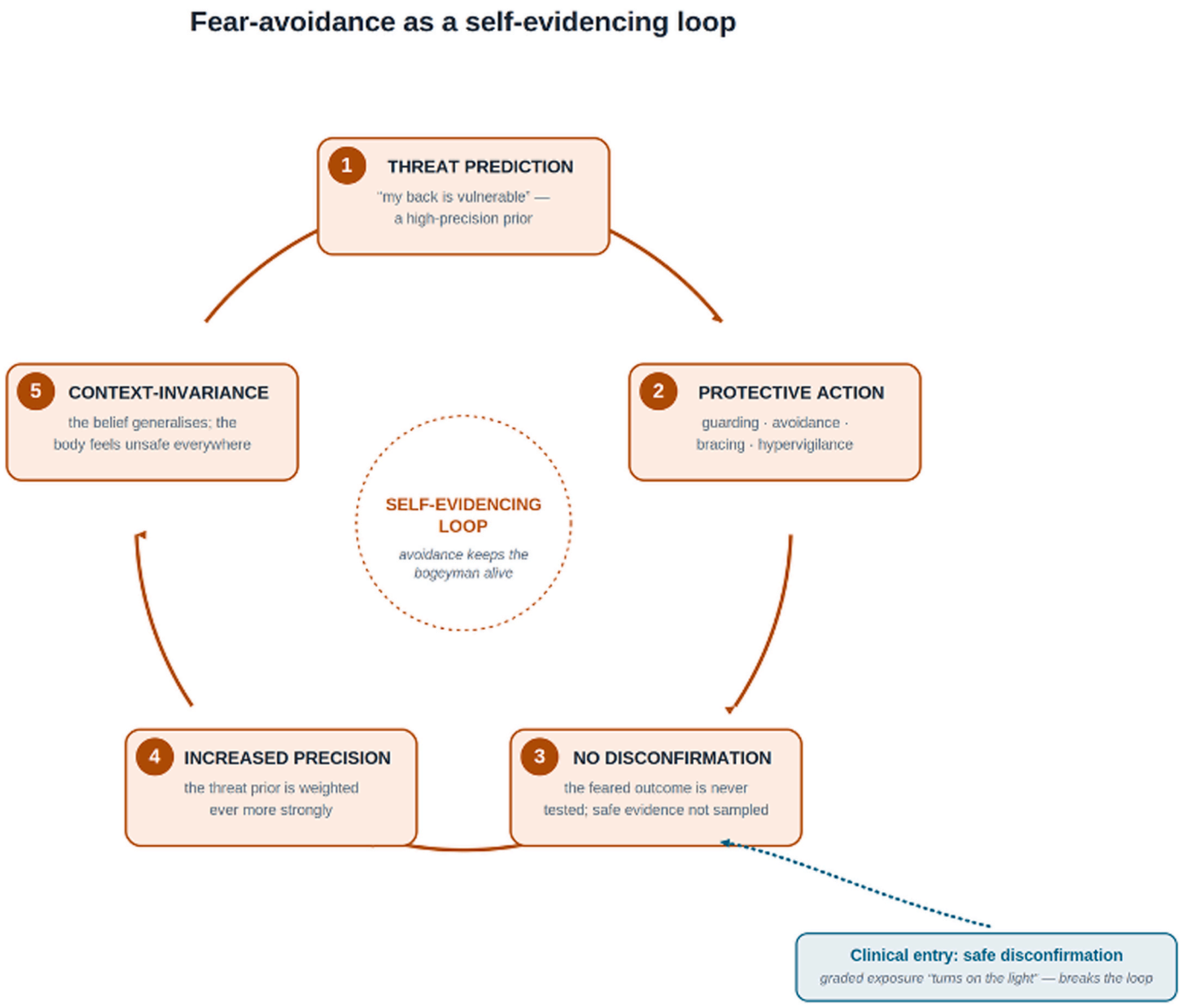


Fig. 2. A predictive interpretation of the fear-avoidance cycle: threat expectation → protective action → no disconfirmation → strengthened expectation → generalisation (adapted from Varangot-Reille et al., 2024). The quotation in step 1 is an illustrative patient statement; its description as a high-precision prior is the clinician's theoretical interpretation.

only comparison of people with chronic pain and healthy controls identified in a recent scoping review found no difference in the average magnitude of sensory attenuation (Rossi et al., 2025), although attenuation is more variable in individuals with chronic pain (McNaughton et al., 2022). We therefore treat altered attenuation as a hypothesis to be tested rather than an established clinical finding.

If the hypothesis holds, movement has a particular role, because attenuation is linked to self-generated action. Hands-on care may reduce symptoms and has clinical value, but within this framework its longer-term purpose is to support a return to self-directed activity (Keter et al., 2026). The aim is not to numb sensation but to help the body become less conspicuous, so that attention can return to valued activities (Gadamer, 2018, Section 4.3).

3.5. A multilevel heuristic: the neuraxis (L0–L9)

Kiverstein et al. (2022) propose that the processes contributing to pain are distributed across the body rather than located in the brain alone, with immune, endocrine and autonomic activity participating alongside neural processing (see also Bhat et al., 2021). We organise this proposal as a ten-level clinical heuristic, from the tissue environment (L0) to sociocultural narrative (L9) (Table 3; Fig. 4). The levels are pragmatic groupings chosen to map onto clinical entry points; they are not anatomical claims, and the mapping of levers to levels is our proposed hypothesis.

Three features matter clinically. First, contributors such as sleep, stress, inflammation and autonomic state are treated as part of the problem rather than background (Section 2.5). Second, influences may run in both directions: a narrative such as "my scan shows degeneration" may shape how bodily signals are interpreted, while better sleep or reduced peripheral sensitivity may make beliefs easier to revise. Third, contributors probably change over different timescales, so a brief single-intervention trial may not be a fair test; this is a hypothesis and does not justify continuing treatment that is not helping (Section 4.8). Salience, default-mode and central-executive networks have been proposed as cortical correlates of how pain captures attention and self-related processing (De Ridder et al., 2022).

3.6. Persistent pain as a stable state

In acute injury, pain usually settles as tissues heal and threat falls. Active inference describes persistent pain differently: when threat-related expectations are held with high confidence, sensitivity is increased and available actions narrow, the system may settle into a stable state (an 'attractor'; Table 1) in which pain remains the most likely interpretation even when peripheral input is modest. This is a theoretical description, not a measured property of individual patients. It implies that change may require several conditions together: revisable expectations, experiences that differ from what was anticipated, a wider range of possible actions, and time for new patterns to consolidate.

Table 4
Examples of rephrasing potentially threatening clinical language without loss of clinical accuracy (after Stewart and Loftus, 2018; Darlow et al., 2013).

Potentially threatening phrase	Possible rephrasing (same clinical content)
"You have the spine of a 70-year-old."	*"Your spine shows changes that are common as we age — many people with the same findings have no pain at all."*
"Bone on bone."	*"There is less cartilage in this joint, and there is a great deal we can do to help joints like this work well."*
"Your core is weak."	*"Your trunk muscles can become stronger and more responsive — that is something we can build together."*
"The pain is in your head."	*"Your pain is real. Pain involves your whole system, not only the tissues, and we can work together on what may be keeping it going."*

Note: Examples are illustrative. Evidence that specific rephrasing changes clinical outcomes is limited, and wording should be adapted to the person and checked for how they understand it.

4. Clinical translation: an active inference framework for person-centred reasoning

This section translates the concepts above into clinical reasoning. We first describe a five-step reasoning cycle that connects the patient's account, the clinician's hypotheses, communication, movement and the patient's response (Section 4.1; Table 6). We then describe five clinical levers (therapeutic alliance, manual therapy and touch, language and education, exercise and movement, and context), stating for each what the clinician does, the evidence for clinical effects, and the status of the active inference interpretation (Table 5). Fig. 3 depicts the proposed '(en)active' framework, which combines active inference with enactive approaches (Esteves et al., 2022); it is a theoretical schematic.

Skilled practitioners already combine these levers: a phrase can change the meaning of a movement, a movement can change the credibility of a phrase, and the relationship influences whether either is trusted. The framework adds an explicit way of reasoning about which lever to favour, why, and how to tell whether it is helping. It does not replace established assessment, differential diagnosis or screening for serious pathology (Lin et al., 2020).

4.1. A five-step clinical reasoning cycle

The cycle below is a proposed way of integrating communication,

Table 3
The neuraxis heuristic (L0–L9): proposed contributors at each level, and the clinical levers proposed to reach it (elaborated from Kiverstein et al., 2022; the ten-level mapping and the lever mapping are the authors' hypotheses).

Level	Proposed contributors	Levers proposed to reach it (as in Fig. 4)
L9 Sociocultural/narrative	Self-model; illness beliefs; diagnostic labels; epistemic trust; cultural priors	Language; alliance; context
L8 Extended cognitive	Language; health-system framing; clinician communication	Language; alliance; context
L7 Affective/evaluative	ACC, anterior insula — affective appraisal; motivational salience	Language; alliance; context
L6 Interoceptive cortical	Posterior→anterior insula — proposed interoceptive hierarchy	Touch and hands-on care; exercise; language
L5 Thalamo-cortical	Thalamus, S1/S2 — sensory-discriminative mapping; body schema	Exercise
L4 Brainstem	PAG, RVM, parabrachial — descending modulation; autonomic outflow	Alliance; exercise; touch and hands-on care; language
L3 Spinal dorsal horn	WDR neurons; gating; glial modulation of synaptic gain	Exercise; touch and hands-on care; medication where used
L2 DRG/peripheral nerve	Primary afferent tuning; satellite glia; ectopic discharge	Graded time-and-load; pharmacological adjuncts
L1 Local NEI ensemble	Nociceptors; immune cells; cytokine milieu; NGF/BDNF	Touch and hands-on care; exercise; allostatic-load management
L0 Tissue microenvironment	Mechanical, thermal, chemical milieu — the sensory surface	Touch and hands-on care; exercise and movement; time; load; tissue-targeted adjuncts

Note: Levels are pragmatic clinical groupings, not anatomical claims. Abbreviations: ACC, anterior cingulate cortex; BDNF, brain-derived neurotrophic factor; DRG, dorsal root ganglion; NEI, neuro-endocrine-immune; NGF, nerve growth factor; PAG, periaqueductal grey; RVM, rostral ventromedial medulla; S1/S2, primary/secondary somatosensory cortex; WDR, wide dynamic range.

Table 5
Core MSK interventions: usual framing, a possible active inference interpretation, evidence for clinical effects, and proposed primary levels of effect.

Intervention	Standard framing	Possible active inference interpretation (theoretical)	Evidence for clinical effect; proposed primary levels (hypothesis)
Therapeutic alliance	Rapport; non-specific factor	Coupled inference; may change the weight a person gives to the clinician's input	Mainly observational; deliberate enhancement of the relationship, beliefs or setting showed little to no effect on pain or function (Saueressig et al., 2024). L8–L9; L7; L4
Manual therapy/ touch	Mechanical input to tissue	Safe, coherent sensory experience that may help revise threat-related expectations	Small effects; application procedure makes little difference (very low to low certainty; Nim et al., 2025). L0–L1; L6
Patient education	Information transfer; reassurance	May reduce the weight of threat-related expectations	Increases reassurance (small effects); limited effect on pain alone; larger short-term effects with exercise (Traeger et al., 2015, 2019; Siddall et al., 2022). L8–L9 → L7 → L6 → L4
Exercise therapy	Tissue conditioning; strength	Experiential learning about what the body can do; reopened affordances	Effective within approaches such as CFT (Kent et al., 2023); mediators include self-efficacy, fear and beliefs (Cashin et al., 2023; Schütze et al., 2025). L5–L6; L0–L1; L3–L4
Contextual factors	"Non-specific"; placebo	Context may shape how signals and treatments are interpreted	Little to no effect of deliberate enhancement on pain or function (Saueressig et al., 2024). L8–L9; L7

Note: Column 3 gives theoretical interpretations; evidence of clinical effectiveness (column 4) does not validate them. CFT, Cognitive Functional Therapy.

therapeutic interaction, movement-related uncertainty and person-centred care (Table 6). It builds on established person-centred principles (Hutting et al., 2022) and is not itself a validated protocol.

Step 1 elicits the person's own account of their pain, concerns, explanations and goals, which remains authoritative about their experience (Raja et al., 2020). Step 2 frames provisional hypotheses, which may use active inference terms, alongside alternative explanations and standard screening, and checks them with the person in plain language. Step 3 uses explanation, validation and the relationship to explore the meaning of feared activities. Step 4 agrees,tolerable, meaningful movement experiences, with the person stating beforehand what they expect to happen. Step 5 asks what happened and what the person made of it, and revises the formulation, the plan, or both. Table 6 lists concrete clinician behaviours and safeguards for each step.

Two points follow from research on expectation change. First, the size of the discrepancy between expected and actual outcomes does not by itself determine whether expectations change. In experimental pain, expectations influenced perceived pain less when the stimulus was very different from what was predicted (Hird et al., 2019), and larger or more precise predictions did not produce systematically stronger effects (Derksen et al., 2025). Computational work suggests that very large discrepancies may lead a learner to treat a situation as new, leaving the original expectation largely intact (Gershman et al., 2017), and people can dismiss experiences that contradict their expectations (Panitz et al., 2021). Second, change may be setting-specific: in chronic low back pain, exposure reduced expectations of harm but not of pain, with preliminary evidence of generalisation (Riecke et al., 2020), whereas earlier work found little generalisation across movements (Goubert et al., 2002). The practical aim is therefore not to maximise surprise, but to arrange credible, tolerable experiences whose outcome differs from what the person anticipated, discuss their meaning together, and vary activities and settings (Craske et al., 2014; Gatzounis et al., 2021).

4.2. Therapeutic alliance

Active inference describes the patient–clinician encounter as two people whose expectations become coupled within a shared setting (Esteves et al., 2022; McParlin et al., 2022). On this view, trust may increase the weight a person gives to the clinician's explanations and to experiences in the clinic, whereas previous poor care, rushed encounters, contradictory accounts or invalidation may reduce it (Krupnik, 2023). In enactive terms, alliance is shared sense-making: clinician and patient develop a more workable understanding together (De Jaegher and Di Paolo, 2007; Shaw et al., 2022; Cerritelli and Esteves, 2022).

Interpersonal and physiological synchrony has been studied as a possible marker of this coupling (Arrigoni et al., 2024; Lim et al., 2024; Lunghi et al., 2025), but synchrony is a correlate of joint engagement rather than alliance itself. The interpretation of alliance as a regulator of precision is theoretical. Proposed primary levels: L7–L9; secondary level: L4.

> Bedside heuristic — alliance. Ask what the person already understands, fears and hopes for, and reflect it back before explaining. Match pace and tone to their state. Check trust directly: "Does this explanation make sense to you? What doesn't fit?"

4.3. Manual therapy and touch

Manual therapy and therapeutic touch can be reframed from the application of force to tissue towards the provision of safe, coherent sensory experience that may help revise threat-related expectations (Esteves et al., 2022; Kim et al., 2022). Tissue effects may contribute, but how contact is interpreted, and the context in which it is offered, are likely to shape its effects. Experienced manual therapists describe calibrating contact to moment-to-moment changes in tone, breath, attention and trust (Bianchi et al., 2025), and small imaging studies have reported changes in interoception-related brain activity after osteopathic care (Cerritelli et al., 2020, 2021); however, these observations do not establish the mechanism of any clinical benefit.

Two cautions follow. First, the specific effects of hands-on care appear small: a sham-controlled trial reported a small difference of uncertain clinical relevance (Nguyen et al., 2021), and in a network meta-analysis the way spinal manipulation was applied made little difference to outcomes, based on very low-to low-certainty evidence (Nim et al., 2025). These findings are consistent with an account in which the meaning of manual contact matters, but they are equally consistent with contextual and non-specific explanations; they do not specifically support active inference. Second, the reframe should not justify passive treatment of a passive patient. Hands-on care is best offered as a brief adjunct that leads into active exploration, in line with guideline recommendations (Lin et al., 2020). Proposed primary levels: L0–L1 and L6; secondary levels: L3–L4.

> Bedside heuristic — hands-on care. Agree the purpose of contact beforehand. Adjust pressure, timing and location to the person's responses. Afterwards, ask what they noticed and link it to an activity

Table 6
A five-step, person-centred reasoning cycle: observable clinician behaviours, framework-informed questions and safeguards.

Step	What the clinician does (observable)	Framework-informed questions (clinician's hypotheses)	Safeguards
1. The person's account and priorities	Invites the person's own description of pain, concerns, explanations and goals; summarises it back and asks for correction; records key phrases in the person's words.	What does the person expect movement or activity to do? What would they most like to be able to do again?	The person's account is authoritative about their experience; interpretations are not attributed to them.
2. Provisional hypotheses and alternatives	Completes standard assessment and screening for serious pathology; lists two or three provisional explanations and the observations that would support or count against each; shares them in plain language.	Could a strongly held expectation of harm, low confidence in bodily signals, or little experience of safe movement contribute? What else could explain this (nociceptive drivers, deconditioning, sleep, mood, work, previous advice)?	Hypotheses are provisional and revisable; active inference terms describe the clinician's reasoning, not observed facts.
3. Communication and interaction	Validates the experience; explains findings without threatening language; asks the person to explain the explanation back; agrees shared goals.	Is the explanation credible and meaningful to this person? Does anything in their context (family, work, claims, previous care) contradict it?	Avoid implying that pain is 'in the head' or caused by mistaken beliefs.
4. Collaborative movement exploration	Co-designs small, tolerable activities, ideally within valued tasks; asks the person to state beforehand what they expect; varies tasks and settings; supports self-directed practice.	What outcome does the person anticipate? Would this experience count as a fair test for them?	Graded and consented; the person controls the pace; the aim is not to maximise discomfort or surprise.
5. Response and revision	Asks what happened and what it meant; compares this with the stated expectation; reviews agreed outcomes at pre-set review points; adjusts, refers, or supports self-management and discharge.	Was the experience discounted ("I got away with it")? Did it transfer to home or work? Does the formulation need revising?	Continue only interventions showing meaningful benefit; non-response prompts re-assessment, not open-ended treatment.

Note: The cycle is a proposed framework for reasoning, not a validated protocol. Framework-informed questions are the clinician's hypotheses and are checked with the person.

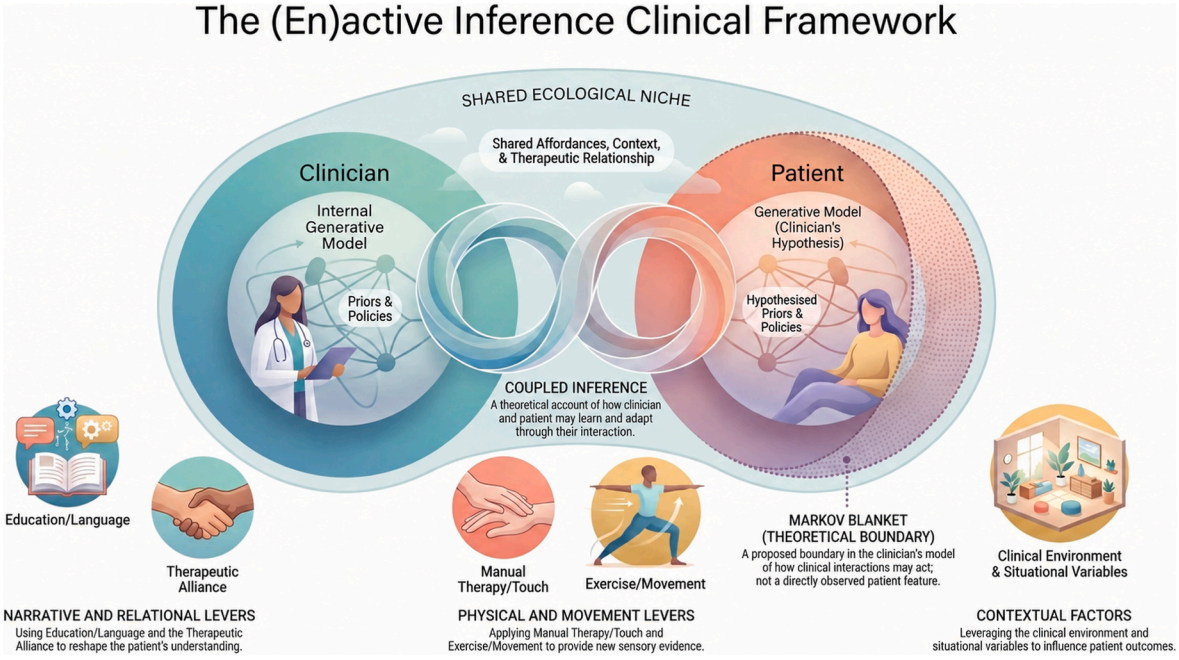


Fig. 3. Schematic of the proposed (en)active inference clinical framework (theoretical): five clinical levers, with patient and clinician represented as coupled within a shared ecological niche. Labels such as 'generative model' and 'priors' denote constructs used in the clinician's reasoning, not observable features of the patient.

they can try themselves. Stop if contact adds nothing beyond active care.

4.4. Language and education

Clinicians are often credible sources, and their words can be remembered for years. Threatening language may heighten threat-related expectations and nocebo responses, whereas coherent, validating explanations may help loosen them (Stewart and Loftus, 2018; Rossettini et al., 2022). Active inference interprets education as changing the weight given to threat-related expectations rather than as simple information transfer; this is an interpretation, the evidence on education and reassurance is summarised in §3.3.

Terms such as "bone on bone", "slipped disc", "wear and tear" or "degeneration" can be heard as signalling damage, fragility or inevitability where none was intended (Darlow et al., 2013; Thomson and Collyer, 2017; Johnson et al., 2023). Pain Reprocessing Therapy, a psychological treatment combining reappraisal of pain with exposure and related techniques, produced substantially higher rates of pain-free or nearly pain-free outcomes than placebo or usual care in one trial in chronic back pain (Ashar et al., 2022); it was not derived from active inference, and its active components are not yet known. Replacing threatening phrases may be more helpful than adding reassurance to them (Table 4), although evidence on the effects of specific rephrasing is limited. Proposed primary levels: L8–L9, with possible effects at L7, L6 and L4.

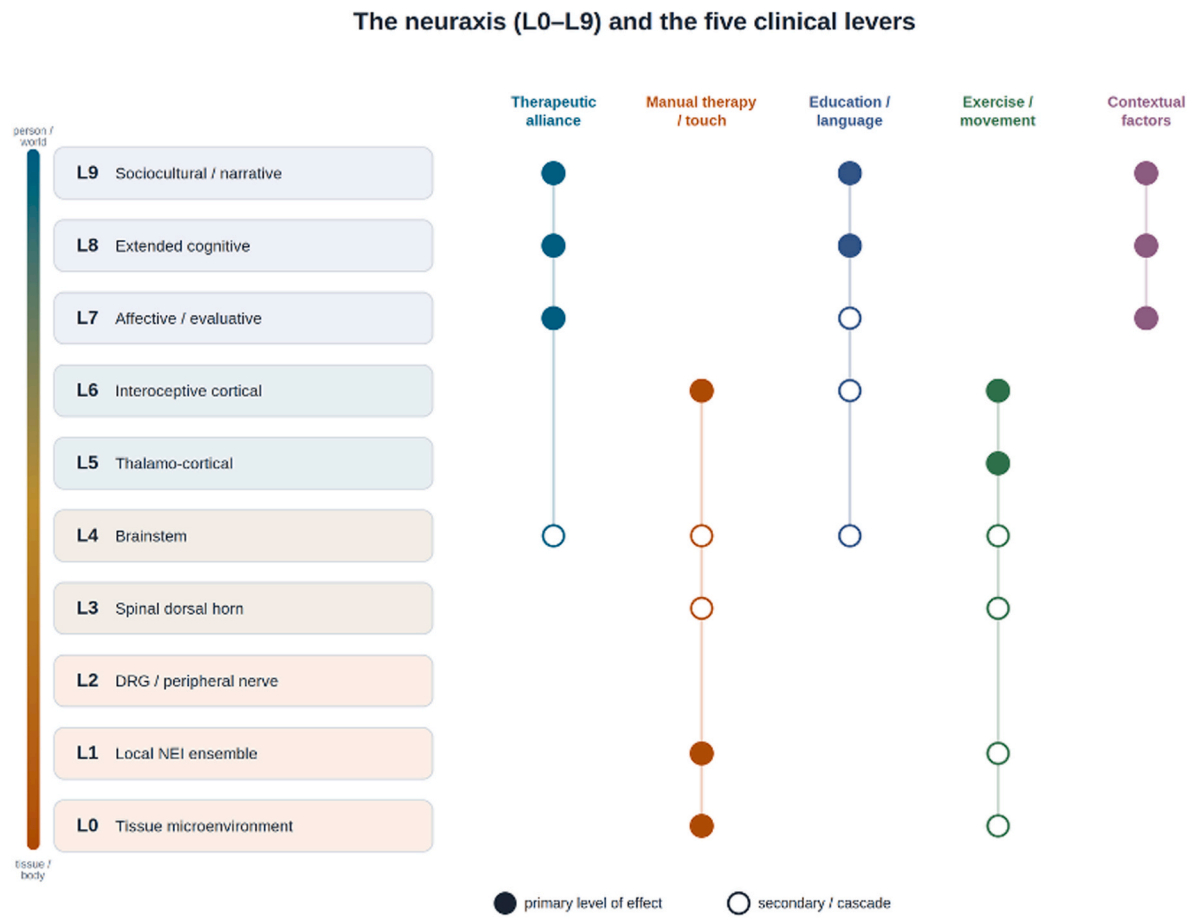


Fig. 4. The ten-level neuraxis heuristic (L0–L9) with the five levers mapped to their proposed primary and secondary levels of effect. The mapping is the authors' hypothesis, not an anatomical or empirically validated model.

Bedside heuristic — language. Review your most-used phrases and replace those that imply damage or fragility. After explaining, ask the person to say in their own words what they took from it, and resolve misunderstandings together.

4.5. *Exercise and movement*

Exercise can be understood not only as conditioning tissues but also as an opportunity to gather new experience of what the body can do (Westergren et al., 2023). This does not deny strength, capacity or tissue adaptation; it places them within a wider learning process in which physical capacity and changing expectations are likely to interact.

Affordances are the action possibilities a situation offers a particular person, depending on their environment, capacities, history, concerns and goals (Chemero, 2003; Rietveld and Kiverstein, 2014). Persistent pain can narrow this field: stairs become threatening, bending dangerous, the garden unreachable (Coninx and Stilwell, 2021; Coninx et al., 2025). Rehabilitation can then be framed as helping the person perceive, trust and act on possibilities that pain had closed off (Gallagher, 2018; Vaz et al., 2023).

Practically, this suggests exploring options collaboratively, allowing several acceptable movement solutions rather than one "correct" pattern, and practising within valued activities and varied settings. Mediation analyses highlight beliefs and self-efficacy: in a trial of education and graded sensorimotor retraining for chronic low back pain, effects on pain and disability were partly mediated by beliefs about the consequences of back pain, pain catastrophising and pain self-efficacy (Cashin et al., 2023). These findings identify psychological mediators; they do not show that active inference is the mechanism.

In healthy volunteers, self-administered sham treatment reduced experimental heat pain more than externally administered treatment, and model comparison favoured a shift in expectations over a change in sensory precision (Strube et al., 2023); whether this applies to self-directed movement in patients is untested. Progress can be judged by reopened activities that matter to the person, alongside pain intensity. Proposed primary levels: L5–L6, with possible effects at L0–L1 and L3–L4.

Bedside heuristic — exercise. Before each task, ask what the person expects to happen; afterwards, ask what happened and what it means to them. Vary activities and settings, permit several movement solutions, and track the activities that matter to the person.

4.6. *Contextual factors*

Contextual factors, such as trust, validation, a coherent explanation, the treatment setting and its rituals, can shape how bodily signals and treatments are interpreted (Rossettini et al., 2018; Ongaro and Kaptchuk, 2019). The clinical evidence is mixed, however. A meta-analysis of trials that deliberately enhanced the patient–practitioner relationship, treatment beliefs or setting in chronic primary MSK pain found little to no difference in pain intensity or physical function (Saueressig et al., 2024). Active inference would predict benefit from credible, coherent contexts; results such as these are evidence that bears on the framework and should not be reinterpreted to fit it.

Laboratory studies show that expectations can modulate pain through descending pathways, including brainstem regions (Grahl et al., 2018), and the extent to which active inference provides a

comprehensive account of placebo analgesia has been critically examined (Milde et al., 2024). Clinically, attending to setting, coherence, predictability and felt safety is part of good care; whether doing so deliberately improves outcomes remains uncertain. Proposed primary levels: L7–L9.

4.7. Relationship with Cognitive Functional Therapy

Cognitive Functional Therapy (CFT) is the closest established clinical approach. It is an individualised, physiotherapist-led approach that addresses the meaning of pain, beliefs, emotional responses and functional behaviour, including guided exposure to feared and avoided activities (O'Sullivan et al., 2018). CFT was developed from behavioural and cognitive models, including the fear-avoidance model (Vlaeyen and Linton, 2012), not from active inference. In the RESTORE trial, CFT produced clinically important reductions in activity limitation compared with usual care in chronic disabling low back pain, sustained to 52 weeks (Kent et al., 2023), and its effects on disability were partly mediated by earlier changes in pain self-efficacy, fear, catastrophising and pain intensity (Schütze et al., 2025).

The conceptual alignment is clear: both approaches emphasise meaning, learning through lived bodily experience, and changes in expectations and behaviour. Active inference may offer an interpretive account of why such experiential learning could change pain, by linking beliefs, bodily sensation and action within one process. CFT's effectiveness does not validate active inference, and the framework does not compete with CFT. What a clinician may gain in practice is modest and testable: explicit prompts to separate the person's account from the clinician's interpretation, to consider why a successful experience might be discounted or fail to generalise, and to consider biological and contextual contributors within the same formulation. Whether these prompts improve reasoning or outcomes beyond CFT training is unknown (Section 6).

4.8. Coupled levels and proportionate care

The five levers are unlikely to act independently (Table 5; Fig. 4). We propose that levels interact through recurrent loops, so that a change at one level is expressed in others. Three cautions follow.

First, attribution should be conservative. When graded exposure helps, the change cannot be cleanly assigned to strength, reduced fear, greater confidence or better movement; several may be partly true and unique to each clinical scenario.

Second, interventions may interact rather than add. An explanation paired with a confirming movement experience may achieve what neither achieves alone, and hands-on care without a coherent explanation may be less helpful. The short-term advantage of combining pain neuroscience education with exercise is consistent with this (Siddall et al., 2022), but interaction has not been tested directly.

Third, lack of progress should prompt re-assessment, not escalation. Asking which contributor has not been addressed (for example, a damage narrative reinforced at home, poor sleep, or a pending claim) can guide a change of approach, including onward referral or investigation when clinical features warrant it. It is not a licence for open-ended treatment. Consistent with recommendations to evaluate progress and support self-management (Lin et al., 2020; Kongsted et al., 2021), interventions should continue only while they show meaningful benefit on outcomes agreed with the person, reviewed at pre-agreed points. Care should aim at increasing independence and participation in valued activities, including changes in health-related behaviour and lifestyle where these matter for the person's goals. Active inference terminology does not itself justify additional treatment: the aim is not to keep 'updating' a person's model, but to help them regain agency with as little clinical input as necessary.

5. Clinical vignette

Table 7 presents one illustrative case of established chronic low back pain. It separates the person's own words and reported experience, clinical observations, the clinician's provisional interpretation, alternative explanations, the shared clinical response, and what was reported afterwards. It is a worked example of reasoning, not a protocol, and a single case cannot confirm the framework.

The case illustrates how the person's goals and feedback can change the clinician's interpretation. Pezzulo's (2014) account of the 'bogeyman' offers a helpful analogy: when evidence is sparse, fear of an unseen threat can be a reasonable inference that persists because avoidance prevents it from being tested. The analogy should be used with care. Fear of bending may also reflect previous advice, real flare-ups or ongoing nociceptive contributions, and the person, not the clinician, decides what counts as a meaningful test. The clinician's task is not to correct belief by assertion, but to arrange, with the person, relational, sensory, linguistic and contextual conditions in which something new can be safely discovered (Gallagher, 2018; Shin and Chang, 2026).

6. Limitations, critical appraisal and future research

Active inference is used here in two senses that should be judged differently. As a heuristic for clinical reasoning, it should be judged by whether it helps clinicians reason more clearly and collaboratively. As a process theory about what happens in patients, it should be judged by empirical tests. The Free Energy Principle, as a general modelling commitment, may not be falsifiable in itself, and both it and the Markov blanket construct have been critiqued on conceptual grounds (Colombo and Wright, 2021; Bruineberg et al., 2022); specific process models derived from it can, however, make testable predictions.

There is no randomised evidence for an intervention designed from active inference; a trial protocol testing acute exercise as active inference is the closest example (Westergren et al., 2023). Pain Reprocessing Therapy and CFT are effective but were not derived from the framework (Ashar et al., 2022; Kent et al., 2023), and mediation findings are compatible with, but do not directly test, the model (Cashin et al., 2023; Schütze et al., 2025). Some mechanistic predictions have not been supported: the only controlled comparison of sensory attenuation in chronic pain found no average group difference (McNaughton et al., 2022), and in an experiment on agency, model comparison favoured a shift in prior expectations over a precision-based variant (Strube et al., 2023). Other work suggests that expectations do not systematically shape pain more when predictions are larger or more precise, and that violated predictions carry affective consequences such as disappointment (Derksen et al., 2025).

Three further limitations matter. First, there is a real risk of 'science-washing': terms such as prior, precision and generative model can redescribe skilled practice without adding value. Second, these constructs are difficult to operationalise; in individuals they can be estimated only indirectly, by fitting computational models to behavioural or physiological data, not from routine clinical conversation. Third, many phenomena discussed here are also explained by fear-avoidance, learning and expectation models that do not require active inference, so the framework adds value only if it makes distinct predictions or improves care. Its integration with established pain science remains at an early stage.

The framework nevertheless yields predictions that could count against it. (1) If experience carries weight that information alone lacks, a graded exposure session should reduce harm expectations for a practised movement more than an equally long, credible explanation, and combining the two should show a larger-than-additive effect in a factorial trial. (2) If agency matters as proposed, self-initiated movement should reduce expected and reported pain more than passively imposed movement of identical load in yoked-control designs with patients. (3) If altered sensory attenuation contributes to persistent pain, it should be

Table 7
Illustrative case: established chronic low back pain with fear of movement.

Status. Illustrative case. Elements labelled 'hypothetical' are provided for teaching and are not reported findings.

1. **The person's words and reported experience**. Sarah, a 42-year-old teacher, reports low back pain for 18 months. She describes her back as "damaged" and "fragile". She has stopped gardening, which is her main source of meaning. She reports that three previous practitioners focused on alignment and that each visit confirmed, for her, that something was structurally wrong.
2. **Clinical observations and findings**. MRI shows age-normal degenerative change. Avoidance of bending is noted. Neurological and red-flag screening and physical examination findings are not reported in this illustrative case; in practice they would precede and accompany the reasoning below.
3. **The clinician's provisional interpretation (active inference)**. One possible interpretation is that Sarah's expectation that bending will cause harm is held with high confidence (a high-precision prior, in the framework's terms) and is maintained by avoidance, which prevents experiences that might disconfirm it (§3.3). Her description of her back may reflect a body that has become conspicuous; reduced sensory attenuation is one hypothesis for this, although direct evidence is limited (§3.4). The garden, once a place of competence, pleasure and identity, may now be experienced as a place of danger, a narrowing of affordances (Lundberg et al., 2007; Coninx and Stilwell, 2021). These are the clinician's hypotheses, to be checked with Sarah.
4. **Alternative explanations and uncertainty**. Sarah's caution may be a reasonable response to previous structural explanations. Ongoing nociceptive contributions, deconditioning, sleep disturbance, mood, work demands and other factors cannot be excluded on the information available. Degenerative findings are common in people without pain but do not rule out a contribution (Brinjikji et al., 2015). On this information, an active inference formulation cannot be distinguished from a fear-avoidance or CFT formulation.
5. **Shared clinical response and rationale**. Care begins by exploring Sarah's understanding, concerns and goals, and agreeing gardening as a shared goal, because trust and a credible shared explanation may make new experiences more meaningful (§4.2). Graded bending is explored within gardening-related tasks at a pace she chooses, with Sarah stating beforehand what she expects to happen and discussing afterwards what actually happened (§4.1). Language avoids 'damage' terms in favour of accurate alternatives such as 'sensitive', checked for how Sarah understands them (§4.4). Hands-on care, if used, is brief, agreed with her, and linked to active practice (§4.3). Several movement solutions are acceptable, and practice extends to home and garden (§4.5). Review points, outcomes that matter to Sarah, and a self-management plan are agreed at the outset (§4.8). Proposed levels engaged: L8–L9 (narrative), L7 (affect), L5–L6 (body schema and interoception), L3–L4 (descending modulation) and L0–L1 (graded loading).
6. What **was reported afterwards (hypothetical)**. Return to gardening at eight weeks, assessed alongside, not only through, pain intensity.
7. **How feedback may change the reasoning (hypothetical)**. Suppose Sarah reports no change at six weeks. The clinician asks what she has noticed and what she makes of it. If she practises bending but braces and holds her breath, the experience may not count as a fair test; if a family member, a pending claim or poor sleep keeps reinforcing the damage account, these become shared targets; if she does not find the explanation credible, the formulation is revisited with her. New clinical features prompt further investigation or referral. If agreed outcomes show no meaningful benefit by the next review point, the approach is changed or stopped rather than extended.

detectable in identifiable subgroups and should change before or alongside clinical improvement in longitudinal studies. (4) If expectation change depends on confidence rather than discrepancy size alone, trial-by-trial computational modelling should show updating predicted by estimated confidence, and changes should generalise less when practice is confined to one setting. (5) If the clinical reasoning framework adds clinical value, training clinicians in it should change observable behaviours, such as eliciting the patient's account and agreeing review points, and improve patient-reported outcomes compared with training in an established approach such as CFT, in cluster-randomised trials with process evaluation. Null results from adequately powered tests would weaken these claims.

Two safeguards apply at the bedside. The framework must never dismiss pain as 'only' inference, psychologise the person, or minimise structural and nociceptive contributors: pain can be inferential and still be real, embodied, disabling and biologically grounded. Tissue, nervous system, immune, endocrine, psychological, social and cultural factors are interacting dimensions of one lived condition, and the inferential lens complements, but never replaces, differential diagnosis and vigilance for serious pathology (Lin et al., 2020). Active inference is best treated as a conceptual organiser that may help explain why elements of evidence-based MSK care work, while giving researchers clearer mechanisms to test (Mahajan and Seymour, 2025).

7. Conclusion

Active inference offers a candidate mechanistic account of how expectations, bodily sensation, movement, context and relationships may interact in persistent MSK pain, and a vocabulary for organising clinical reasoning. Familiar components of care can then be considered together: build the alliance, use touch purposefully, review language, design movement experiences collaboratively, attend to context, and check whether care is helping.

Four questions may help carry the framework to the bedside. What does this person tell me about their body, their pain and their future, and what matters most to them? Which provisional explanations, including alternatives, fit what they report and what I observe, and have I checked these with them? Which experiences, explanations or contexts might help them test their concerns safely? And how will we both know whether care is helping, and when to change or stop it?

These questions do not require the clinician to observe a patient's priors or precision. They make explicit what skilled clinicians have long sensed: care is not only the delivery of techniques, but the creation, with the person, of conditions in which new embodied experience becomes possible (Hutting et al., 2022). A bedside translation of key terms is provided as Supplementary File S1.

CRediT authorship contribution statement

Jorge E. Esteves: Writing – review & editing, Writing – original draft, Conceptualization. **Giacomo Rossettini:** Writing – review & editing, Writing – original draft, Conceptualization. **Francesco Cerritelli:** Writing – review & editing, Writing – original draft, Conceptualization. **Chad Cook:** Writing – review & editing, Writing – original draft, Conceptualization. **Ben Cormack:** Writing – review & editing, Writing – original draft, Conceptualization. **David Newell:** Writing – review & editing, Writing – original draft, Conceptualization. **Alvisa Palese:** Writing – review & editing, Writing – original draft, Conceptualization. **Karl J. Friston:** Writing – review & editing, Writing – original draft, Conceptualization. **Mick Thacker:** Writing – review & editing, Writing – original draft, Conceptualization.

Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary materials. Additional data are available from the corresponding author (G.R.) upon reasonable request.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work, the authors used Claude (Anthropic) to assist with structure and language, at both manuscript and sentence level, and with the development of figures. After using this tool, the authors reviewed, revised, and edited the content as needed and take full responsibility for the accuracy, integrity, and final content of the manuscript.

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Giacomo Rossettini reports a relationship with University of Verona that includes: speaking and lecture fees. Given his role as associate editor, he had no involvement in the peer review of this article and had no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to another journal editor.

If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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References

Ainley, V., Apps, M.A.J., Fotopoulou, A., Tsakiris, M., 2016. Bodily precision": a predictive coding account of individual differences in interoceptive accuracy. Phil. Trans. Biol. Sci. 371 (1708), 20160003.
Arrigoni, A., Rossettini, G., Palese, A., , et al.Esteves, J.E., 2024. Exploring the role of therapeutic alliance and biobehavioural synchrony in musculoskeletal care: insights from a qualitative study. Musculoskeletal Sci. Pract. 73, 103164.
Ashar, Y.K., Gordon, A., Schubiner, H., , et al.Wager, T.D., 2022. Effect of pain reprocessing therapy vs placebo and usual care for patients with chronic back pain: a randomized clinical trial. JAMA Psychiatry 79 (1), 13–23.
Bettinger, J.S., Friston, K.J., 2023. Conceptual foundations of physiological regulation incorporating the free energy principle and self-organized criticality. Neurosci. Biobehav. Rev. 155, 105459.
Bhat, A., Parr, T., Ramstead, M., Friston, K., 2021. Immunoceptive inference: why are psychiatric disorders and immune responses intertwined? Biol. Philos. 36 (3), 27.
Bianchi, M., Rossettini, G., Cerritelli, F., Esteves, J.E., 2025. Insights into how manual therapists incorporate the biopsychosocial-enactive model in the care of individuals with chronic low back pain: a qualitative study. Chiropr. Man. Ther. 33, 18.
Brinjikji, W., Luetmer, P.H., Comstock, B., , et al.Jarvik, J.G., 2015. Systematic literature review of imaging features of spinal degeneration in asymptomatic populations. Am. J. Neuroradiol. 36 (4), 811–816.
Bruineberg, J., Dołęga, K., Dewhurst, J., Baltieri, M., 2022. The emperor's new markov blankets. Behav. Brain Sci. 45, e183.
Cashin, A.G., Lee, H., Wand, B.M., , et al.McAuley, J.H., 2023. Mechanisms of education and graded sensorimotor retraining in people with chronic low back pain: a mediation analysis. Pain 164 (12), 2792–2800.
Cerritelli, F., Chiacchiaretta, P., Gambi, F., , et al.Ferretti, A., 2020. Effect of manual approaches with osteopathic modality on brain correlates of interoception: an fMRI study. Sci. Rep. 10 (1), 3214.
Cerritelli, F., Chiacchiaretta, P., Gambi, F., , et al.Ferretti, A., 2021. Osteopathy modulates brain–heart interaction in chronic pain patients: an ASL study. Sci. Rep. 11 (1), 4556.
Cerritelli, F., Esteves, J.E., 2022. An enactive–ecological model to guide patient-centered osteopathic care. Healthcare 10 (6), 1092.
Chemero, A., 2003. An outline of a theory of affordances. Ecol. Psychol. 15 (2), 181–195.
Colombo, M., Wright, C., 2021. First principles in the life sciences: the free-energy principle, organicism, and mechanism. Synthese 198 (Suppl. 14), 3463–3488.
Coninx, S., Ray, B.M., Stilwell, P., 2025. Unpacking an affordance-based model of chronic pain: a video game analogy. Phenomenol. Cognitive Sci. 24, 467–492.
Coninx, S., Stilwell, P., 2021. Pain and the field of affordances: an enactive approach to acute and chronic pain. Synthese 199 (3–4), 7835–7863.
Coninx, S., Stilwell, P., 2023. Chronic pain, enactivism, and the challenges of integration. In: *Expected Experiences: the Predictive Mind in an Uncertain World*. Studies in Brain and Mind. Springer, Cham.
Cormack, B., Stilwell, P., Coninx, S., Gibson, J., 2023. The biopsychosocial model is lost in translation: from misrepresentation to an enactive modernization. Physiother. Theory Pract. 39 (11), 2273–2288.
Craske, M.G., Treanor, M., Conway, C.C., Zbozinek, T., Vervliet, B., 2014. Maximizing exposure therapy: an inhibitory learning approach. Behav. Res. Ther. 58, 10–23.
Darlow, B., Dowell, A., Baxter, G.D., Mathieson, F., Perry, M., Dean, S., 2013. The enduring impact of what clinicians say to people with low back pain. Ann. Fam. Med. 11 (6), 527–534.
De Haan, S., 2020. Enactive Psychiatry. Cambridge University Press.
De Jaegher, H., Di Paolo, E., 2007. Participatory sense-making: an enactive approach to social cognition. Phenomenol. Cognitive Sci. 6 (4), 485–507.
De Ridder, D., Vanneste, S., Smith, M., Adhia, D., 2022. Pain and the triple network model. Front. Neurol. 13, 757241.
Derksen, S.M.J.C., Konttinen, M., Myronenko, A., Seymour, B., Peerdeman, K.J., 2025. How the magnitude and precision of pain predictions shape pain experiences. Eur. J. Pain 29 (1), e4769. https://doi.org/10.1002/ejp.4769.
Dierckxsens, G., 2025. Health care as participatory sense-making: an enactive perspective on relations between patients and health care providers. Mind Soc. 24 (1), 69–89.
Eckert, A.L., Pabst, K., Endres, D.M., 2022. A Bayesian model for chronic pain. Front. Pain Res. 3, 966034.
Edwards, M.J., Adams, R.A., Brown, H., Parées, I., Friston, K.J., 2012. A Bayesian account of 'hysteria. Brain 135 (11), 3495–3512.
Esteves, J.E., Cerritelli, F., Kim, J., Friston, K.J., 2022. Osteopathic care as (en)active inference: a theoretical framework for developing an integrative hypothesis in osteopathy. Front. Psychol. 13, 812926.
Fitzcharles, M.-A., Cohen, S.P., Clauw, D.J., Littlejohn, G., Usui, C., Häuser, W., 2021. Nociplastic pain: towards an understanding of prevalent pain conditions. Lancet 397 (10289), 2098–2110.
Friston, K., 2010. The free-energy principle: a unified brain theory? Nat. Rev. Neurosci. 11 (2), 127–138.
Friston, K., 2013. Life as we know it. J. R. Soc. Interface 10 (86), 20130475.
Gadamer, H.G., 2018. The Enigma of Health: the Art of Healing in a Scientific Age. John Wiley & Sons.
Gallagher, S., 2017. Enactivist Interventions: Rethinking the Mind. Oxford University Press, Oxford.
Gallagher, S., 2018. The therapeutic reconstruction of affordances. Res. Philos. 95 (4), 719–736.
Gatzounis, R., den Hollander, M., Meulders, A., 2021. Optimizing long-term outcomes of exposure for chronic primary pain from the lens of learning theory. J. Pain 22, 1315–1327.
Gershman, S.J., Monfils, M.-H., Norman, K.A., Niv, Y., 2017. The computational nature of memory modification. eLife 6, e23763.
Geuter, S., Boll, S., Eippert, F., Büchel, C., 2017. Functional dissociation of stimulus intensity encoding and predictive coding of pain in the insula. eLife 6, e24770.
Goubert, L., Francken, G., Crombez, G., Vansteenwegen, D., Lysens, R., 2002. Exposure to physical movement in chronic back pain patients: no evidence for generalization across different movements. Behav. Res. Ther. 40 (4), 415–429.
Grahl, A., Onat, S., Büchel, C., 2018. The periaqueductal gray and Bayesian integration in placebo analgesia. eLife 7, e32930.
Hipólito, I., van Es, T., 2022. Free-energy pragmatics: Markov blankets don't prescribe objective ontology, and that's okay. Behav. Brain Sci. 45, e198.
Hird, E.J., Charalambous, C., El-Deredy, W., Jones, A.K.P., Talmi, D., 2019. Boundary effects of expectation in human pain perception. Sci. Rep. 9 (1), 9443.
Honkasalo, M.-L., 2000. Chronic pain as a posture towards the world. Scand. J. Psychol. 41 (3), 197–208.
Hutting, N., Caneiro, J.P., Ong'wen, O.M., Miciak, M., Roberts, L., 2022. Person-centered care for musculoskeletal pain: putting principles into practice. Musculoskeletal Sci. Pract. 62, 102663.
Hutto, D.D., Myin, E., 2013. Radicalizing Enactivism: Basic Minds Without Content. MIT Press, Cambridge, MA.
Itz, C.J., Geurts, J.W., van Kleef, M., Nelemans, P., 2013. Clinical course of non-specific low back pain: a systematic review of prospective cohort studies set in primary care. Eur. J. Pain 17 (1), 5–15.
Jepma, M., Koban, L., van Doorn, J., Jones, M., Wager, T.D., 2018. Behavioural and neural evidence for self-reinforcing expectancy effects on pain. Nat. Hum. Behav. 2 (11), 838–855.
Johnson, M.I., Hudson, M., Ryan, C.G., 2023. Perspectives on the insidious nature of pain metaphor: we literally need to change our metaphors. Front. Pain Res. 4, 1224139.
Kent, P., Haines, T., O'Sullivan, P., , et al.Hancock, M., 2023. Cognitive functional therapy with or without movement sensor biofeedback versus usual care for chronic, disabling low back pain (RESTORE): a randomised, controlled, three-arm, parallel group, phase 3 clinical trial. Lancet 401 (10391), 1866–1877.
Keter, D., Learman, K., Rhon, D.I., Vogsland, R., 2026. Reconceptualizing the value of 'active' and 'passive' treatment classification in rehabilitation: a critical appraisal and person-centered treatment planning framework. Musculoskeletal Sci. Pract. 84, 103591.
Kim, J., Esteves, J.E., Cerritelli, F., Friston, K., 2022. An active inference account of touch and verbal communication in therapy. Front. Psychol. 13, 828952.
Kirchhoff, M., Parr, T., Palacios, E., Friston, K., Kiverstein, J., 2018. The Markov blankets of life: autonomy, active inference and the free energy principle. J. R. Soc. Interface 15 (138), 20170792.
Kiverstein, J., Kirchhoff, M.D., Thacker, M., 2022. An embodied predictive processing theory of pain experience. Rev. Philos. Psychol. 13 (4), 973–998.
Kongsted, A., Ris, I., Kjaer, P., Hartvigsen, J., 2021. Self-management at the core of back pain care: 10 key points for clinicians. Braz. J. Phys. Ther. 25 (4), 396–406.
Krupnik, V., 2023. The therapeutic alliance as active inference: the role of trust and self-efficacy. J. Contemp. Psychother. 53 (3), 207–215.
Langevin, H.M., 2021. Reconnecting the brain with the rest of the body in musculoskeletal pain research. J. Pain 22 (1), 1–8.
Leder, D., 1990. The Absent Body. University of Chicago Press, Chicago.
Lim, M., Carollo, A., Bizzego, A., , et al.Esposito, G., 2024. Synchrony within, synchrony without: establishing the link between interpersonal behavioural and brain-to-brain synchrony during role-play. R. Soc. Open Sci. 11 (5), 240331.
Limanowski, J., 2022. Precision control for a flexible body representation. Neurosci. Biobehav. Rev. 134, 104401.

Lin, I., Wiles, L., Waller, R., , et al.O'Sullivan, P.P.B., 2020. What does best practice care for musculoskeletal pain look like? Eleven consistent recommendations from high-quality clinical practice guidelines: systematic review. Br. J. Sports Med. 54 (2), 79–86.
Lundberg, M., Styf, J., Bullington, J., 2007. Experiences of moving with persistent pain — a qualitative study from a patient perspective. Physiother. Theory Pract. 23 (4), 199–209.
Lunghi, C., Baroni, F., D'Alessandro, G., , et al.Zegarra-Parodi, R., 2025. Patient–practitioner–environment synchronization: four-step process for integrating interprofessional and distinctive competencies in osteopathic practice — a scoping review with integrative hypothesis. Healthcare 13 (7), 820.
Mahajan, P., Seymour, B., 2025. 'Forward and reverse engineering the pain system: from computational neuroscience to neuro-engineering'. Pain. Adv. Online Publ. https://doi.org/10.1097/j.pain.0000000000003705.
McNaughton, D., Beath, A., Hush, J., Jones, M., 2022. Perceptual sensory attenuation in chronic pain subjects and healthy controls. Sci. Rep. 12 (1), 8958.
McParlin, Z., Cerritelli, F., Friston, K.J., Esteves, J.E., 2022. Therapeutic alliance as active inference: the role of therapeutic touch and synchrony. Front. Psychol. 13, 783694.
Mescouto, K., Olson, R.E., Hodges, P.W., Setchell, J., 2022. A critical review of the biopsychosocial model of low back pain care: time for a new approach? Disabil. Rehabil. 44 (13), 3270–3284.
Milde, C., Brinskelle, L.S., Glombiewski, J.A., 2024. Does active inference provide a comprehensive theory of placebo analgesia? Biol. Psychiatry Cogn. Neurosci. Neuroimaging 9 (1), 10–23.
Nguyen, C., Boutron, I., Zegarra-Parodi, R., , et al.Rannou, F., 2021. Effect of osteopathic manipulative treatment vs sham treatment on activity limitations in patients with nonspecific subacute and chronic low back pain: a randomized clinical trial. JAMA Intern. Med. 181 (5), 620–630.
Nim, C., Aspinall, S.L., Cook, C.E., , et al.Juhl, C.B., 2025. The effectiveness of spinal manipulative therapy in treating spinal pain does not depend on the application procedures: a systematic review and network meta-analysis. J. Orthop. Sports Phys. Ther. 55 (2), 109–122.
O'Sullivan, P.B., Caneiro, J.P., O'Keeffe, M., , et al.O'Sullivan, K., 2018. Cognitive functional therapy: an integrated behavioral approach for the targeted management of disabling low back pain. Phys. Ther. 98 (5), 408–423.
Ongaro, G., Kaptchuk, T.J., 2019. Symptom perception, placebo effects, and the Bayesian brain. Pain 160 (1), 1–4.
Palacios, E.R., Razi, A., Parr, T., Kirchhoff, M., Friston, K., 2020. On Markov blankets and hierarchical self-organisation. J. Theor. Biol. 486, 110089.
Panitz, C., Endres, D., Buchholz, M., , et al.Pinquart, M., 2021. A revised framework for the investigation of expectation update versus maintenance in the context of expectation violations: the ViolEx 2.0 model. Front. Psychol. 12, 726432.
Parr, T., Pezzulo, G., Friston, K.J., 2022. Active Inference: the Free Energy Principle in Mind, Brain, and Behavior. MIT Press, Cambridge, MA.
Pezzulo, G., 2014. Why do you fear the Bogeyman? An embodied predictive coding model of perceptual inference. Cognit. Affect Behav. Neurosci. 14 (3), 902–911.
Pezzulo, G., Maisto, D., Barca, L., Van den Bergh, O., 2019. Symptom perception from a predictive processing perspective. Clin. Psychol. Europe 1 (4), 1–14.
Pezzulo, G., Parr, T., Friston, K., 2024. Active inference as a theory of sentient behavior. Biol. Psychol. 186, 108741.
Pezzulo, G., Rigoli, F., Friston, K.J., 2015. Active inference, homeostatic regulation and adaptive behavioural control. Prog. Neurobiol. 134, 17–35.
Pincus, T., Holt, N., Vogel, S., Underwood, M., Savage, R., Walsh, D.A., Taylor, S.J.C., 2013. Cognitive and affective reassurance and patient outcomes in primary care: a systematic review. Pain 154 (11), 2407–2416.
Raja, S.N., Carr, D.B., Cohen, M., , et al.Vader, K., 2020. The revised international association for the study of pain definition of pain: concepts, challenges, and compromises. Pain 161 (9), 1976–1982.
Ramstead, M.J.D., Kirchhoff, M.D., Friston, K.J., 2020. A tale of two densities: active inference is enactive inference. Adapt. Behav. 28 (4), 225–239.
Riecke, J., Rief, W., Vlaeyen, J.W.S., Glombiewski, J.A., 2020. Generalizability of harm and pain expectations after exposure in chronic low back pain patients. Eur. J. Pain 24 (8), 1495–1504.
Rietveld, E., Kiverstein, J., 2014. A rich landscape of affordances. Ecol. Psychol. 26 (4), 325–352.
Rossettini, G., Carlino, E., Testa, M., 2018. Clinical relevance of contextual factors as triggers of placebo and nocebo effects in musculoskeletal pain. BMC Muscoskelet. Disord. 19 (1), 27.
Rossettini, G., Colombi, A., Carlino, E., , et al.Testa, M., 2022. Unraveling negative expectations and nocebo-related effects in musculoskeletal pain. Front. Psychol. 13, 789377.
Rossi, L., Cerritelli, F., Thacker, M., Esteves, J.E., 2025. The role of sensory attenuation in symptomatic and healthy individuals: a scoping review. Front. Neurosci. 19, 1590127.
Safiri, S., Kolahi, A.-A., Cross, M., , et al.Buchbinder, R., 2021. Prevalence, deaths, and disability-adjusted life years due to musculoskeletal disorders for 195 countries and territories 1990–2017. Arthritis Rheumatol. 73 (4), 702–714.
Sarkkinen, A., Heinämaa, S., 2026. Prolonged pain as an existential feeling. Phenomenology and the Cognitive Sciences. Advance online publication. https://doi.org/10.1007/s11097-025-10134-y.
Saueressig, T., Owen, P.J., Pedder, H., , et al.Belavý, D.L., 2024. Boosting treatment outcomes via the patient–practitioner relationship, treatment beliefs or therapeutic setting: a systematic review with meta-analysis of contextual effects in chronic musculoskeletal pain. J. Orthop. Sports Phys. Ther. 54 (7), 440–456.
Schütze, R., Liew, B., Caneiro, J.P., O'Sullivan, P., Kent, P., Hancock, M., et al., 2025. Mechanisms of change in cognitive functional therapy: a longitudinal mediation analysis of the RESTORE clinical trial for disabling chronic low back pain. Behav. Res. Ther. 193, 104853.
Seymour, B., Mancini, F., 2020. Hierarchical models of pain: inference, information-seeking, and adaptive control. Neuroimage 222, 117212.
Shaw, R., Abbey, H., Casals-Gutiérrez, S., Maretic, S., 2022. Reconceptualizing the therapeutic alliance in osteopathic practice: integrating insights from phenomenology, psychology and enactive inference. Int. J. Osteopath. Med. 46, 36–44.
Shin, D.A., Chang, M.C., 2026. Pain as lived experience: philosophical perspectives in pain medicine — a narrative review. J. Pain Res. https://doi.org/10.2147/JPR.S577740. Advance online publication.
Siddall, B., Ram, A., Jones, M.D., Booth, J., Perriman, D., Summers, S.J., 2022. Short-term impact of combining pain neuroscience education with exercise for chronic musculoskeletal pain: a systematic review and meta-analysis. Pain 163 (1), e20–e30.
Smith, R., Friston, K.J., Whyte, C.J., 2022. A step-by-step tutorial on active inference and its application to empirical data. J. Math. Psychol. 107, 102632.
Sterling, P., 2012. Allostasis: a model of predictive regulation. Physiol. Behav. 106 (1), 5–15.
Stewart, M., Loftus, S., 2018. Sticks and stones: the impact of language in musculoskeletal rehabilitation. J. Orthop. Sports Phys. Ther. 48 (7), 519–522.
Stilwell, P., Harman, K., 2019. An enactive approach to pain: beyond the biopsychosocial model. Phenomenol. Cognitive Sci. 18 (4), 637–665.
Strube, A., Horing, B., Rose, M., Büchel, C., 2023. Agency affects pain inference through prior shift as opposed to likelihood precision modulation in a Bayesian pain model. Neuron 111 (7), 1136–1151.
Sturmberg, J.P., Martin, C.M., 2009. Complexity and health — yesterday's traditions, tomorrow's future. J. Eval. Clin. Pract. 15 (3), 543–548.
Svenaeus, F., 2011. Illness as unhomelike being-in-the-world: Heidegger and the phenomenology of medicine. Med. Health Care Philos. 14 (3), 333–343.
Tabor, A., Thacker, M.A., Moseley, G.L., Kording, K.P., 2017. Pain: a statistical account. PLoS Comput. Biol. 13 (1), e1005142.
Thomson, O.P., Collyer, K., 2017. Talking a different language': a qualitative study of chronic low back pain patients' interpretation of the language used by student osteopaths. Int. J. Osteopath. Med. 24, 3–11.
Traeger, A.C., Hübscher, M., Henschke, N., Moseley, G.L., Lee, H., McAuley, J.H., 2015. Effect of primary care-based education on reassurance in patients with acute low back pain: systematic review and meta-analysis. JAMA Intern. Med. 175 (5), 733–743.
Traeger, A.C., Lee, H., Hübscher, M., , et al.McAuley, J.H., 2019. Effect of intensive patient education vs placebo patient education on outcomes in patients with acute low back pain: a randomized clinical trial. JAMA Neurol. 76 (2), 161–169.
Varangot-Reille, C., Pezzulo, G., Thacker, M., 2024. The fear-avoidance model as an embodied prediction of threat. Cognit. Affect Behav. Neurosci. 24 (5), 781–792.
Vaz, D.V., Stilwell, P., Coninx, S., Low, M., Liebenson, C., 2023. Affordance-based practice: an ecological-enactive approach to chronic musculoskeletal pain management. Braz. J. Phys. Ther. 27 (5), 100554.
Vlaeyen, J.W.S., Linton, S.J., 2012. Fear-avoidance model of chronic musculoskeletal pain: 12 years on. Pain 153 (6), 1144–1147.
Westergren, J., Sjöberg, V., Vixner, L., , et al.Äng, B.O., 2023. Acute exercise as active inference in chronic musculoskeletal pain, effects on gait kinematics and muscular activity in patients and healthy participants: a study protocol for a randomised controlled laboratory trial. BMJ Open 13 (5), e069747.
Yon, D., Frith, C.D., 2021. Precision and the Bayesian brain. Curr. Biol. 31 (17), R1026–R1032.