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Hypnosis and Mindfulness for Chronic Pain Management Through the Lens of the Free Energy Principle

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A B S T R A C T

Chronic pain is a multifaceted condition that significantly impacts quality of life and poses challenges for effective management. Non-pharmacological interventions, such as hypnosis and mindfulness meditation, have emerged as promising approaches for alleviating pain. This review examines the mechanisms and comparative effectiveness of these therapies through the lens of the free energy principle, a unifying framework in neuroscience that conceptualizes pain as a mismatch between predicted and actual sensory inputs, resulting in increased free energy. Hypnosis operates by leveraging top-down modulation to recalibrate the brain's predictive models, thereby reducing the sensory and affective dimensions of pain through the targeted engagement of the dorsolateral prefrontal cortex (DLPFC) and anterior cingulate cortex (ACC). In contrast, mindfulness fosters bottom-up sensory processing and acceptance, minimizing prediction errors by engaging the anterior insular cortex and orbitofrontal cortex to promote emotional regulation and sensory integration. Comparative studies, including randomized trials in Veterans, demonstrate that both hypnosis and mindfulness provide sustained reductions in pain intensity, interference, and associated psychological symptoms, outperforming education-based controls. Hypnosis shows particular efficacy in altering sensory pain perception, while mindfulness excels in reducing emotional reactivity to pain. By integrating the free energy principle into the neuropsychological model of pain, this review highlights how these therapies recalibrate predictive coding processes to reduce pain perception. Future research should focus on optimizing these interventions and exploring their synergistic potential in clinical settings.

Keywords: *Hypnosis, Mindfulness, Chronic Pain, Management, Free Energy.*

1. Introduction

Chronic pain is a significant public health issue, affecting approximately 19% of adults in the US, with particularly high prevalence among Veterans. Its complex nature involves biological, psychological, and socio-professional factors, making it challenging to treat comprehensively. Pharmacological treatments often provide limited relief, come with side effects, and fail to address the multidimensional aspects of chronic pain, such as sensations, emotions, behaviors, and cognitions. This has led to a growing emphasis on non-pharmacological interventions, including hypnosis and mindfulness meditation, which have shown promise in managing chronic pain (1, 2).

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The free energy principle, a unifying theory in neuroscience, provides a novel framework for understanding how these interventions modulate pain. According to this principle, the brain minimizes "free energy"- a measure of uncertainty or prediction error- by continuously updating its internal models to better predict and adapt to sensory inputs. Pain, as a multidimensional experience, can be conceptualized as a mismatch between predicted and actual sensory inputs, resulting in a heightened perception of free energy. Hypnosis and mindfulness can be understood as interventions that reduce this free energy by recalibrating the brain's predictive coding processes, thereby alleviating the perception of pain (3).

2. Hypnosis for Pain Management

Hypnosis is a cognitive-behavioral technique that involves focused attention and suggestion to alter perception and experience. It has been shown to reduce pain intensity, pain interference, depression, and anxiety, while improving quality of life in patients with chronic pain (1, 2). Hypnosis is effective for both acute procedural pain and chronic pain conditions, with benefits observed in both short- and long-term outcomes. Given its favorable side-effect profile, self-hypnosis training is considered a viable first-line approach for chronic pain management (4).

3. Mechanisms of Hypnosis: A Free Energy Perspective

From the perspective of the free energy principle, hypnosis operates by leveraging top-down modulation to recalibrate the brain's predictive models of pain. Through focused attention and suggestion, hypnosis creates a state in which the brain's expectations about pain are altered, effectively reducing the mismatch between sensory input and internal predictions. This process minimizes free energy and reduces the perception of pain.

- Sensory Modulation: Hypnotic suggestions can specifically target the sensory dimension of pain, leading to changes in activity within the primary somatosensory cortex (S1). This modulation reduces the intensity of pain perception by altering the brain's representation of nociceptive input (5).
- Affective Modulation: Hypnosis also reduces the unpleasantness of pain by modulating the anterior cingulate cortex (ACC), which encodes the affective dimension of pain. This dissociation between sensory and affective components highlights the flexibility of hypnosis in targeting different aspects of the pain experience (6).
- Attention and Control: Hypnosis engages the dorsolateral prefrontal cortex (DLPFC), a region involved in attention and executive control. By focusing attention away from pain and toward hypnotic suggestions, the brain reallocates resources to reduce the salience of pain signals, thereby further minimizing the free energy associated with pain (Faymonville, 2000).

4. Mindfulness for Pain Management

Mindfulness meditation focuses on cultivating present-moment awareness and acceptance of pain without emotional reactivity. It has been shown to reduce pain intensity and improve mood, sleep, and overall functioning in chronic pain conditions (7) (Zeidan, 2016). Unlike hypnosis, mindfulness engages brain regions such as the orbitofrontal cortex and anterior insular cortex, which are associated with cognitive modulation and emotional acceptance of pain (8).

5. Mechanisms of Mindfulness: A Free Energy Perspective

Mindfulness reduces free energy by fostering bottom-up sensory processing and recalibrating the brain's response to pain through acceptance and non-reactivity. This approach minimizes prediction errors by aligning the brain's expectations with the actual sensory experience of pain, thereby reducing the mismatch between the two.

- Acceptance and Reappraisal: Mindfulness engages the anterior insular cortex and orbitofrontal cortex, regions involved in emotional regulation and cognitive reappraisal. By promoting acceptance of pain, mindfulness reduces the emotional salience of pain signals, thereby minimizing free energy associated with affective distress (8, 9).
- Attention Regulation: Mindfulness enhances activity in the medial prefrontal cortex (mPFC), which is involved in attention regulation and self-referential processing. This allows individuals to observe pain without becoming emotionally reactive, reducing the brain's need to generate maladaptive predictions about pain (Zeidan, 2016).
- Sensory Integration: Mindfulness strengthens connectivity between the somatosensory cortex and higher-order brain regions, improving the brain's

ability to integrate sensory inputs with internal models. This reduces the uncertainty associated with pain and aligns sensory processing with reality, thereby lowering free energy (10).

6. Comparative Effectiveness: Insights from Research

A growing body of research has compared the effectiveness of hypnosis and mindfulness for chronic pain management, highlighting their unique strengths and long-term benefits:

1. Veterans Study: A randomized clinical trial compared hypnosis (HYP), mindfulness meditation (MM), and an active education control (ED) for Veterans with chronic pain. Both HYP and MM demonstrated sustained benefits in reducing pain intensity, pain interference, and depressive symptoms at 3- and 6-month follow-ups, while the benefits of ED dissipated over time.
2. Meta-Analyses: Hypnosis has been shown to produce moderate to significant analgesic effects in both experimental and clinical pain settings, with long-term benefits observed in chronic pain populations (4, 11). Similarly, mindfulness-based interventions have demonstrated improvements in pain intensity, depression, and quality of life, although their effects are often more minor when compared to active control groups (7).
3. Long-Term Outcomes: Studies have shown that self-hypnosis skills are retained by patients up to 12 months post-treatment, with significant reductions in pain intensity and anxiety (12, 13). Mindfulness, on the other hand, fosters long-term changes in brain connectivity and pain acceptance, which contribute to sustained improvements in pain outcomes (9).
4. Combined Interventions: A study comparing self-hypnosis combined with cognitive-behavioral therapy (CBT) to other interventions found that hypnosis/CBT led to significant improvements in pain intensity, quality of life, and perceived control over pain, with benefits persisting at 12-month follow-ups (14).

7. Conclusion

Hypnosis and mindfulness are effective, non-pharmacological interventions for mechanical musculoskeletal pain, each with unique mechanisms and applications. Hypnosis primarily reduces free energy by altering sensory and affective pain predictions through suggestion-driven modulation, while mindfulness minimizes free energy by fostering acceptance and recalibrating sensory processing. The findings from comparative studies underscore the sustained benefits of hypnosis and mindfulness over time, compared to education-based interventions. Future research should focus on direct comparisons in clinical settings and the integration of hypnotic and meditative interventions to reduce pain and related complications, leveraging the potential for increased free energy in various biopsychosocial systems, in a more integrative and practical approach.

Authors' Contributions

Not applicable.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethical Considerations

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