

Spotlight

Same but different: how agency modulates pain perception

Katja Wiech ^{1,*}



Why is analgesic treatment more effective when it is self-administered? Strube *et al.* compare two possible accounts and show that the effect of agency on perception is linked to a shift in expectation (prior) rather than to reduced likelihood precision, highlighting that agency has a profound impact on the entire perceptual process.

Agency, defined as a sense of control over actions and their consequences, is a key building block in many aspects of our lives – from feelings of autonomy and self-efficacy to societal constructs such as legal responsibility [1]. In addition to its role in these more complex contexts, agency affects sensory perception. For instance, pain is perceived as less intense when it is self-inflicted (e.g., [2]), and patient-controlled analgesia can be more effective than when the same treatment is administered by an external agent [3]. Although this effect has been known for a long time, our understanding of the underlying mechanisms is still rudimentary.

In a recent study, Strube *et al.* showed that agency effects on the outcome of a sham analgesic treatment are implemented via a shift in expectation (prior) that impacts on the entire perceptual process [4]. Using a computational modeling approach, they tested two competing accounts of agency effects on perception in an experimental treatment model in healthy volunteers (Figure 1A–C). The likelihood precision modulation model postulates that, in self-generated sensations, less emphasis is placed on sensory input,

for example by allocating less attention to incoming nociceptive information. The alternative model proposes that agency sets up a strong expectation (prior) through a shift towards the anticipated sensation in the arbitration process between bottom-up and top-down information that determines the perceptual outcome (termed the 'prior shift model' in [4]).

In a conditioning procedure, participants learned to either expect a strong or weak reduction of their experimentally induced heat pain by applying sham transcutaneous electrical nerve stimulation (TENS). Crucially, the participants could either trigger the TENS device themselves or needed to wait for the experimenter to start the treatment (Figure 1D). In line with the prior shift model, the expectation of strong pain reduction and self-treatment both led to greater pain reduction, but did not interact as postulated under the assumption of reduced precision likelihood (Figure 1E). Electroencephalography (EEG) recordings revealed that the influence of agency could already be detected when participants were informed that they could trigger the treatment themselves, but it was also present during subsequent stimulus and treatment delivery. By contrast, expectations of a strong or weak treatment effect only affected the pre-stimulus EEG signal. This indicates that, although simple expectations of different treatment outcomes manifest themselves when the relevant information becomes available, agency effects affect the entire time period from anticipation to stimulus receipt.

Studying the effects of agency on perception is far from trivial. With agency can come other features, such as stimulus predictability, which may overlap with agency but are nevertheless distinct. Strube *et al.* [4] carefully controlled for potential confounds to ensure that the conditions were matched for cognitive and motor demands as well as for the time between motor

activity and the onset of 'treatment'. Moreover, they were also able to exclude that variations in treatment effects were due to differences in stimulus duration which could have led to habituation or sensitization. Most importantly, by combining self-controlled or externally controlled treatment with an expectation of either a weak or strong treatment effect, their factorial design allowed the authors to translate their predictions into two dissociable response patterns, each of which was indicative of one of the two models (Figure 1E).

The question of how agency affects perception is the subject of ongoing debate. Early accounts based on motor control theory postulated that sensory attenuation is the result of subtraction (or cancellation) of the expected action outcome from early sensory processing. This predictive cancellation ensures that processing resources can be allocated to unexpected externally produced input rather than to expected self-generated sensory information. However, this explanation has been challenged by several observations, including sharpened rather than suppressed sensory representations of the expected outcome [5,6]. Instead, the likelihood precision hypothesis that is derived from the framework of active inference [7] posits that agency is linked to a less precise representation of sensory input (e.g., because attention is diverted away from the incoming information) whereas the prior shift model assumes that agency already has an impact on the perceptual processes before the arrival of sensory information. By formally comparing both accounts within the same experiment and controlling for confounding factors, Strube *et al.* provide strong evidence in favor of the prior shift model.

The findings of this study will undoubtedly inspire further investigations to better understand the influence that agency can have on perception not only in healthy individuals but also in clinical populations. Several health conditions, most notably

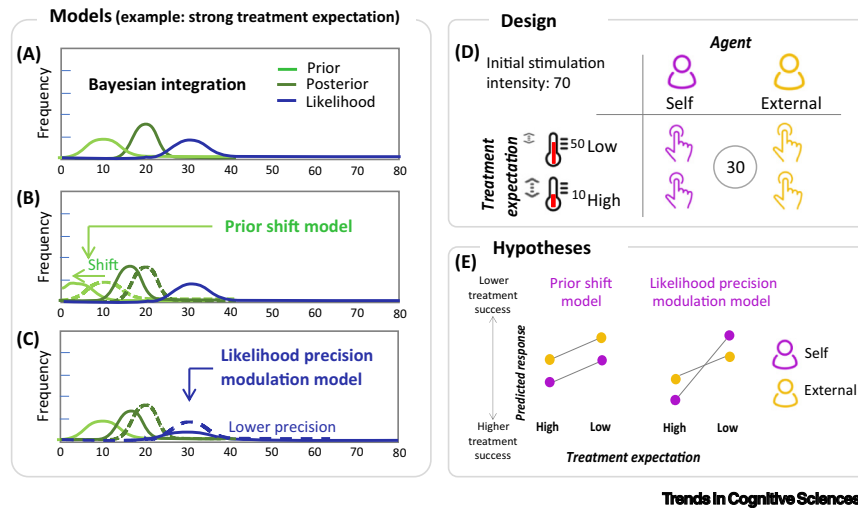


Figure 1. Agency affects pain perception. (A) In Bayesian inference, the prior probability represents our initial belief about the probability that a hypothesis is correct before we observe any data. It is combined with the likelihood (or distribution) of observed data to obtain the posterior probability. Agency can affect the prior probability or likelihood precision (shown here only for expected strong analgesia). (B) Prior shift model: agency shifts the expectation (prior) towards strong analgesia. (C) Likelihood precision modulation model: agency reduces the likelihood precision, indicating that the data are less informative. (D) The experimental design included two within-group factors: self versus external agency over 'treatment', and expectation of a high versus low analgesic effect. 'Treatment' was either started by the participants (self-agency) or by the experimenter (external agency). To induce a weak treatment expectation, the intensity of the heat stimulation was – unknown to the participant – lowered from 70 (on a scale of 0–100) to 50 during a conditioning procedure before testing. An expectation of strong analgesia was induced by lowering the intensity to 10. During the actual experiment, an intensity of 30 was applied throughout. (E) The prior shift model predicts an additive effect, whereas the reduced likelihood precision model predicts an interaction between the two factors. This figure contains elements that are very similar to the those of the original figure [4].

psychiatric disorders such as schizophrenia and depression, are characterized by a distorted sense of agency [8]. How this alteration shapes the treatment expectations of the patients and thus treatment outcome is largely unclear. Patient involvement and empowerment, which are intended to promote a sense of agency and active contribution to treatment efforts, have increasingly become pillars of modern medical interventions. Which information creates a strong sense of agency, and thereby provides sufficiently robust expectations to shift (symptom) perception in a particular individual, could first be explored under experimental conditions. The elegant methodological approach employed by Strube *et al.* provides the necessary tools to answer these questions.

In its broader definition, agency can take many forms. Although voluntary action selection and motor control are often considered to be key components, the reduced version used by Strube *et al.*, in which participants could only decide when (but not whether) the treatment was applied, was clearly sufficient to enhance analgesic outcome. The fact that cognitive psychologists often prefer the term 'sense of agency' emphasizes that it is the perception of agency rather than agency itself that is decisive for its effect [9]. Similarly, it has been argued that 'choosing' is a key ingredient of sensory attenuation through agency [10]. Indirect forms of agency, including action delegation, which may even lack both motor execution and action selection, could therefore still function as surrogates for those who

are unable to exercise agency in a narrow sense. Conceptualizing agency as a continuum, rather than assuming that it is either present or absent, would make space for the exploration of more nuanced manifestations. That we sometimes even claim agency over an outcome that is entirely divorced from our actions is a testament to the deep-rooted belief that our actions can make a difference.

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Declaration of interests

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¹Wellcome Centre for Integrative Neuroimaging (WIN), Nuffield Department of Clinical Neurosciences, University of Oxford, Oxford, UK

*Correspondence:
katja.wiech@ndcn.ox.ac.uk (K. Wiech).
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