The epistemic and pragmatic value of non-action: a predictive coding perspective on meditation

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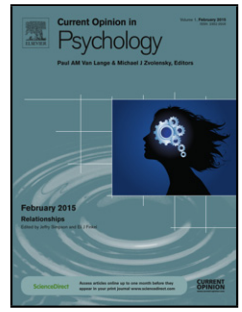

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The epistemic and pragmatic value of non-action: a predictive coding perspective on meditation

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Highlights:

- A general mechanistic understanding of meditation steeped in neuroscience is needed
- The active inference framework appears optimally suited for this purpose
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- We illustrate the approach for the case of focused attention meditation (FA)
- The alternation of attention and distraction in FA is epistemically and pragmatically relevant
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- The meditative non-action is crucial in this process

Abstract:

The surge of interest about mindfulness meditation is associated with a growing empirical evidence about its impact on the mind and body. Yet, despite promising phenomenological or psychological models of mindfulness, a general mechanistic understanding of meditation steeped in neuroscience is still lacking. In parallel, predictive processing approaches to the mind are rapidly developing in the cognitive sciences with an impressive explanatory power: processes apparently as diverse as perception, action, attention and learning, can be seen as unfolding and being coherently orchestrated according to the single general mandate of free-energy minimization. Here we briefly explore the possibility to supplement previous phenomenological models of focused attention meditation by formulating them in terms of active inference. We first argue that this perspective can account for how paying voluntary attention to the body in meditation helps settling the mind by down-weighting habitual and automatic trajectories of (pre)motor and autonomic reactions, as well as the pull of distracting spontaneous thought at the same time. Secondly, we discuss a possible relationship between phenomenological notions such as opacity and de-reification, and the deployment of precision-weighting via the voluntary allocation of attention. We propose the adoption of this theoretical framework as a promising strategy for contemplative research. Explicit computational simulations and comparisons with experimental and phenomenological data will be critical to fully develop this approach.

Introduction:

In recent years, the cognitive neuroscience community has taken a substantial interest in the purported effects of contemplative practices. Most of the studies have focused on developing psychological or phenomenological models of meditation, or on investigating the behavioral outcomes, neural correlates, or changes in specific cognitive functions or biological markers of meditative practice [1–3]. While this is a common developmental trajectory for pioneering research topics, we believe that significant further advances will depend on the successful modeling of the processes engaged by meditation within a mechanistic and quantitative framework of wide explanatory power, which can link together the core notions of attention, action and perception.

The theory of predictive processing, especially in its more articulated proposal of the free-energy minimization principle (FEP) by Karl Friston, seems to possess such an appeal [4]. According to the FEP, biological systems fundamentally obey the single imperative of minimizing the long-term average surprise. For living beings, this means avoiding the likelihood of finding themselves in states at odds with their phenotype, and can be easily understood in terms of the physiological notion of homeostasis, where large deviations of the essential internal parameters from their viable ranges can be critically disruptive, and ultimately put survival at risk [4].

The highly-connected architecture of the brain makes it an organ exquisitely specialized for modelling the causal structure of the organism's environmental niche. Crucially, its function is not to build an exhaustive and perspective-free representation of the world, but rather to equip the organism with the sufficient information to act efficiently and rapidly enough to stay alive. This requires the capacity of inferring the external causes of stimulation through the ever present sensory veil, where hypotheses about the state of affairs of the world are iteratively tested by comparing the expected sensation under the hypothesized cause with the actual sensory input. Such hypotheses (or beliefs) represent the probabilistic *prior* information that, combined with the actual response from the world, allows an efficient Bayesian solution to the problem of inverting the internal *generative* model of how sensations are caused; notably, in this scheme, the beliefs themselves are learned via the same inferential process (*empirical Bayes*) [4].

Although a self-organizing system cannot minimize surprise directly cannot - this would require unmediated access to the state of affairs of the world. – it can operate so to minimize its "free energy", a quantity derived from both statistical physics and information theory that provides an upper bound to the average surprise of sampled sensory data, given a generative model of the world [5]. In organisms, under reasonable assumptions, free energy is approximated by prediction error, that is, the discrepancy between the expected and the actual sensations. It follows that biological systems are able to minimize average surprise, and thus to remain *viable*, simply by minimizing the long-term average of prediction error[1]. In practice, the process unfolds within a multi-level, hierarchical neural architecture where the upper levels encode predictions for the state of the lower levels, and the computed prediction error at each stage is the only information that travels upward as a teaching signal for updating the initial predictions.

Now, prediction error can be minimized in two ways: either (i) by changing the predictions, that is, updating the beliefs embedded in the internal model of the world in the direction of the actual sensory input or (ii) by acting upon the world, in order to make it a better match for the predictions. The first mode of prediction error minimization underlies the processes of perception and learning, while the second mode rests on action. These two strategies are complementary under the common goal of minimizing surprise, and may coexist both synchronically (i.e. when differentially deployed across the various hierarchical levels of the internal model at a given time), and diachronically (when they alternate at a given hierarchical level across time). The term "active inference" is often used to highlight their interplay, and to stress the fact that in living organisms action is integral to the inferential process [7].

Notably, it is the expected reliability of the various ascending prediction error streams that is pivotal in orchestrating the modes of prediction error minimization across the full hierarchy of the generative model, depending on the specific context. Intuitively, it is clear that a prediction error signal that is deemed trustworthy should be allotted a large weight in revising the original hypothesis. On the contrary, if an ascending prediction error signal is noisy or unreliable, it is best to down-weight its informational message and bank relatively more on previously learnt information. In other words, prediction error should be *precision-weighted*, where precision is a measure of the (inverse) variance of the signal. The twist here is that the brain has to estimate not only the upcoming sensory signal (1st order prediction) but also its precision (2nd order prediction), a more difficult task that requires integrating information over time [7].

[1]Note that, in a changing environment, the effective long-term minimization of the average prediction error does not proscribe, in fact *prescribes*, transient excursions into surprise-rich ventures : the latter equip the system with an enhanced capacity to face unexpected mutations of its environmental niche, underwriting the crucial role of sporadic novelty-seeking behavior [6].

Most importantly for our purposes, the top-down deployment of (expected) precision corresponds, in the FEP theory, to the process of attentional allocation and is realized via localized neuromodulatory activity [8]. Attending to a specific stimulus or sensory stream thus means to enact and maintain an expectation of high precision for the corresponding ascending prediction error and, neurally, to increase the post-synaptic gain of the cells carrying that signal, so to become maximally receptive to the incoming sensations. Conversely, being distracted away from a certain stimulus source corresponds to a decrease of the expected precision for the related prediction error, which then loses its power to inform and correct perception.

Virtually all meditative techniques assign a paramount role to disciplined attention. Furthermore, the Buddhist tradition gives particular relevance to the notion that our everyday perceptions and behaviors are unduly constrained by mental constructs and habits. Finally, the complexity of the mind-body nexus for what concerns cognitive and emotional functions is fully acknowledged and embedded in meditative practice in the form of posture and breathing regulation. From the above considerations, it is easy to see that the FEP framework appears optimally suited for the scientific investigation of contemplative practices. In fact, it ties together in a coherent theoretical scaffold the core meditative notions of attention (top-down deployment of precision weighting), the conditioning power of habitual Self-related patterns of thought and behavior (priors), and the embodied nature of cognition and emotion (interoceptive inference). While this theoretical approach has already been endorsed in a few opinion pieces [9–12], and is gaining momentum in the community, its application to meditation-related experimental measures is still in its infancy [13]. The present article aims to provide not a detailed FEP-based manifesto for contemplative research --- a task which would require a more formal and extensive effort --- but rather an illustrative example of framing a previously proposed phenomenological model of focused attention (FA) meditation [14] in terms of active inference.

Technique and phenomenology of FA meditation

It may be useful to briefly recall the essential features of FA meditation. At the beginning of the session, the practitioners are commonly instructed to adopt a stable sitting posture, with a comfortably upright spine (process 1a). The focus of attention is then deliberately oriented to a chosen object, such as a localized breathing sensation (process 1b), and sustained via the continuous monitoring of the quality of attention and the arising of distractors (process 1c). Nonetheless, sooner or later attention is bound to stray from its intended target (process 2); the typical instructions for dealing with such events involve recognizing them (process 3a), “unsticking” attention from the distracting content (process 3b), and reorienting attention back to the chosen meditative target (process 4)[2]. Process 3b can employ various strategies, such as cognitive reappraisal of distractors (e.g. ‘it is just a thought’), decentering[16], cognitive defusion [17], or dereification [3], although the specificity of these strategies

[2] Process 3b and 4 are often conflated in meditative instructions, with the advice to redirect attention to the chosen target as soon as one realizes he/she had been distracted. Some accounts, however, indicate the possibility of simply freeing attention from the grip of the distracting content, before redirecting it to the chosen target, an ability that is developed further in non-dual meditative practices [15][14].

is still actively debated. The above outlined processes have shown to be mediated by different functional brain networks including attention-related networks (processes 1,4), the salience network (process 3a), and the default-mode network (DMN) (process 2) [18].

While minimization of free-energy (or surprise) is ultimately geared towards the preservation of the organism, in the short term it can be viewed as having two interrelated purposes. One is of a pragmatic nature, historically linked to the cybernetic notion of the brain as a control system aimed at ensuring that the internal parameters of the organism remain within their viable ranges [19]. The other is of an epistemic nature, aimed at foraging novel information that in time (i.e. through learning) will enhance the overall predictive power of the generative model. Similarly, FA meditation is traditionally supposed to fulfill a two-fold goal: a pragmatic one, of settling the mind through the disciplined regulation of attention, and an epistemic one, of gaining an intimate knowledge about the constructive and dynamical nature of mental function (e.g. recognizing the impermanence of a thought) [14].

In order to discuss the pragmatic aspect of FA meditation, it is useful to introduce the notion of *policy* as a sequence of actions [4]. We will define here action as the process of minimizing the discrepancy between predicted and actual internal states not by adjusting the initial prediction, but by initiating changes that ultimately result in modifying the chain of bottom-up afferent signals. This is attained by a targeted top-down deployment of precision that renders the initial prediction temporarily refractory to modification, and thus endows it with the necessary life span for the action to be completed. Notably, when thus defined, the term action can subsume overt behavioral action (when predicted proprioceptive states are fulfilled by actual body movements), interoceptive action (when predicted visceral and homeostatic states are fulfilled by autonomic and hormonal changes [20]), and mental action (when predicted states of hierarchically-intermediate layers of the generative model are fulfilled by the modulation of message-passing processes in the layers below them [21]).

Importantly, at any given moment, several policies may be competing for selection. During FA meditation, however, this competition is simplified, involving on the one hand the FA policy[3] and, on the other, the policy enlisted by the spontaneous fluctuation of attention away from its intended target, consisting in the sequences of mental actions entailed by spontaneous memory recall (e.g. a recent, affectively-loaded exchange with a close friend), ongoing homeostatic needs (e.g. feeling thirsty), future goals (e.g. a weekend plan) and, more generally, mind-wandering. From this point of view, meditation can be seen as a method for becoming familiar with regulating policy selection [22], using a simplified, training situation.

The dynamic alternation of the percept of the chosen attentional target and the content of mind-wandering inaugurates a creative dialectical process that can be decomposed as follows. In the first phase (*thesis*), attention is held on the prescribed target, while sitting in a stable posture; this phase quickly brings about a decrease of sensory surprise. In the second phase (*antithesis*), attention is appropriated by distracting mental content (i.e. spontaneous thoughts and sensations), with potentially

[3] And policies directly related to it, e.g. the plan of a long-term commitment to meditative practice in the context of a spiritual path.

associated bodily effects (e.g. autonomic arousal following the appearance of an anxiogenic thought, muscle tension); at the same time, prediction errors about the expectations entailed by the FA policy (which is being unheeded) start to build up. The third phase (*synthesis*)**,** involves the realization that attention has slipped, and one has been engaging in mind-wandering unawares, and corresponds to the peak of the FA policy's prediction error. This phase also concerns the accommodation of such prediction error through subtle changes of the parameters of the internal model, a process at the basis of both the pragmatic expertise gained in meditative practice and its epistemic value, i.e. the reflexive capacity to recognize the constructive and impermanent nature of mental processes and the Self. Notably, the role of inaction in the process outlined above is essential, as it is through the disciplined top-down deployment of increased precision to sensory (especially interoceptive and proprioceptive) afferences that the alternation of FA and mind-wandering is regulated and brought to consciousness. In a sense, inaction can be viewed as a fourth aspect of this dialectical scheme[4], and corresponds to the phenomenal quality of "letting go" of the distractor and to its dereification at the same time. Attention can then be re-oriented to the initial object in a last step as in phase 1. It is worth noting that once the FA policy is well-learnt by expert meditators, the arising of spontaneous mental content does not necessarily jeopardize it. Neuroimaging findings of a better sustained attentional performance in individuals whose ventral attention network's activity is less negatively correlated with that of the default mode network[24] support indeed the notion that the capacity for detecting unexpected but relevant stimuli[25] may be linked to its relative autonomy from the gating effect of mind-wandering.

A predictive processing framing of FA meditation

Let us now turn to a more detailed analysis of the processes engaged by FA meditation from a predictive processing perspective. Generally, the motion from a state of focused attention to mind-wandering can be seen as involving shifts in both the expected sensory state *and* the expected precision of bottom-up prediction errors. When the prescribed focus is lost, the prediction of sensory states drifts from the expectation of the bodily signals related to the FA instructions (i.e. those associated with the regulation of posture, breathing, gaze), to the expectation of the bodily sequels of spontaneous mental events; similarly, high precision weighting drifts from the more basic sensory layers to hierarchically-higher cognitive layers encoding the mental content of mind-wandering.

As discussed above, a condition of inaction seems to be crucial in meditation, although, in a typically paradoxical fashion, the path to inaction seems to begin with the selection of a particular set of actions (policies). In order to attain overt behavioral inaction, we regulate the posture; in order to attain visual inaction, we keep the gaze central; in order to attain *mental* inaction (i.e. to avoid the moving around of attention and mind-wandering), we focus attention on a specific target. For this reason, we will henceforth refer to this peculiar meditative stance with the term "non-action".

We will begin by examining the first phase of the FA dialectical process described in the previous section, which involves sustaining a heightened attention to posture and

[4] The potential connection between the proposed scheme and the four-fold logic of Nagarjuna's tetralemma (http://www.orientalia.org/printout470.html) could be worth of further exploration; see also, for a similar argument, the Preface to "Master Dogen's Shobogenzo", by Gudo Nishijima and Chodo Cross[23][22][21].

breathing, while maintaining immobility. From the FEP perspective, this corresponds to the selection of a policy that includes the mental action of setting a high precision for the sensory prediction errors associated to the chosen attentional target and the prescribed bodily posture. Since the influences of bottom-up prediction errors and top-down predictions are always in a competing relationship for what concerns the inferential process, this attentional act also entails a reduction of the import of prior beliefs; furthermore, by providing a countermove to the sensory attenuation that accompanies and makes overt action possible, it effectively facilitates immobility.

As the external environment exhibits typically a low variance during a meditative session – the meditation place is quiet and peaceful, the posture immobile, and the breathing regular – this first phase is likely to quickly set up an expectation of reduced newsworthiness from the sensory channels, which implies that the saliency of the meditative object is naturally bound to fade and endogenous mental material come to the fore. From a slightly different perspective, the onset of mind-wandering could also be ascribed to the fact that when contingent sensory signals are readily explained away, the incessant mechanism of free-energy minimization is freed to operate on policies detached from the here and now, such as those related to the autobiographical priors associated with the activity of the DMN. This transition leads to a phase of temporary absorption where the meditator tends to forget both his/her body and surroundings, a phenomenon of sensory decoupling similar to the proprioceptive attenuation taking place during overt action [26], and supported by brain imaging data [27]. This is the second phase of the dialectic scheme, where the FA policy is weakened and the set of mental actions that make up mind-wandering are carried out, with the meditator generally unaware of having lost his/her intended attentional focus. Note, however, that the proprioceptive and interoceptive prediction errors related to the FA policy are not completely suppressed, and when they have reached a sufficient magnitude (e.g. due to a slouching off of the sitting posture or to having lost contact with the breathing sensations), they may trigger a perceptual shift. At this time, the meditator realizes that he/she has just been unintentionally engrossed in a distracting thought, thus stopping the unfolding of the mind-wandering episode in its tracks and effectively reducing its duration (third phase). Thus, while mind-wandering itself operates outside voluntary control, its temporal trajectory is indirectly constrained by the priors of the FA policy, and several studies have indeed provided evidence for an enhanced regulatory capacity of both mind-wandering and DMN activity in meditators (e.g. [24,28,29]).

As the meditator becomes more acquainted with the practice, he/she may acquire the skill to remain dynamically poised between the subtle anchoring to the prescribed attentional target and the increasing pull of the spontaneously arising mental content. It is tempting to see this condition as a kind of "lucid daydreaming", optimally suited for the phenomenal "opacification" of mental processes [21]. A mental event is said to be transparent when we have conscious access to its content, but not to its non-intentional structure or construction process [30]. Crucially, transparency provides the phenomenal quality of being directly "in touch" with the represented entity, and is therefore linked to our subjective confidence in its "reality" [31]. The opacification of mental events during meditative practice is thus equivalent to fostering their dereification (Lutz et al. 2015), so that their provisional, constructed, dependent and ultimately impermanent nature begins to be intimately realized. [5]

In summary, the increased capacity of both non-engagement with, and active disengagement from, the largely automatized and predetermined courses of mental activity that is practiced in meditation, seems not only to make the meditator realize the extent to which he/she is usually driven by such habitual schemes unawares, but also to endow him/her with an increased capacity to counteract their attractive power. Thus, beyond the epistemic value described in the previous section, the regular practice of meditation may also carry the pragmatic value of facilitating cognitive flexibility and creativity, out of an increased freedom from inveterate mental schemata. This interpretation is in line with several empirical findings that show the impact of meditation practices on down-regulating affective and cognitive habits (e.g. [32]).

Concluding remarks

The ideas presented in this brief exposition will obviously need to be developed further, especially for what concerns the role of affective and interoceptive processes *vis-à-vis* the notion of Self, the generalization to other contemplative techniques (e.g. open monitoring), and the accommodation of other features of the phenomenological spectrum of experiences related to meditation. In our opinion, the success of the effort depends crucially on the ability of computational models to account for and predict experimental data. We believe that such strategy is a fitting response to Francisco Varela's neurophenomenological invitation to establish mutual constraints between invariant structural features of experience, neural and somatic substrates, and formal dynamical models [33].

As a final consideration, it is important to mention that the policies related to meditative practice are influenced by (or co-dependent with) a host of other policies, related to the motivational, cultural and the social spheres. For instance, FA can be practiced as a mere stress-management technique, or part of a broader spiritual and altruistic path. This is where religious myths and beliefs, cultural practices and rituals, and shared social mores become relevant, and the complete decontextualization of meditative practice into "just mindfulness" carry a significant risk of considerably weakening its transformative power (for a discussion see [34]). As society can be viewed as essentially another self-organizing system of a larger scale than the individual, it is our hope that future research will be able to leverage the theoretical power of the FEP framework to bridge these classically disconnected dimensions.

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AUTHOR DECLARATION

None

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