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Chapter 5

Boredom as Cognitive Allostasis

A major contention of this book is that boredom is a functional state. This insistence to render boredom a functional state goes well beyond the claim that boredom is an experience that carries emotional, practical, social, and even moral importance in our lives. Crucially, the functional view of boredom demands that boredom ought to be *identified* with a specific role. The character of this role was first introduced, albeit all too briefly, in Chapter 1. It was asserted there that boredom is the experience that it is because it helps to regulate the manner in which we cognitively engage with our environment. Furthermore, it was on the basis of that functional identification that we were able to offer an argument in support of the idea that boredom is a potent kind. Using that preliminary articulation of the function of boredom, we then demonstrated an historical continuity in the phenomenon of boredom (Chapter 2), unified the various kinds of boredoms (Chapter 3), and explained observed variability in the physiological concomitants of boredom (Chapter 3). The hypothesis that boredom is a functional state has paid its theoretical dues and earned its empirical keep.

There is more to the functional view than what our discussion in those first three chapters revealed. In Chapter 4, we explicated the experiential character of boredom and our analysis of the various characteristics of the experience of boredom provided support for the functional view: boredom's various components were shown to contribute to the regulation of cognitive engagement. The same chapter also elucidated boredom's antecedents and consequences, synthesized extant findings regarding its nature, and distinguished boredom from related affective states. In this chapter, I delve even deeper into the functional account. My objective is to present a particular development of the functional view of boredom that conceives of it as an integral aspect of an organism's ability to regulate for *cognitive homeostasis-allostasis*. This proposal marks an exciting advancement in boredom research for it manages to present boredom in a new light and to suggest novel avenues for future research.

5.1 Introducing the allostatic view

The term "allostasis" was originally introduced by neuroscientist Peter Sterling and epidemiologist Joseph Eyer to describe hierarchically structured and integrated mechanisms through which the central nervous system maintains organismic integrity and biological viability in the face of (often severe and even prolonged) environmental changes.[1] A seminal tenet of allostasis posits that efficacious regulation mandates the presence of predictive, feedforward mechanisms, adept at instigating anticipatory adjustments to physiological parameters prior to their perturbation by environmental vicissitudes. Allostasis ("stability through change"[2]) was originally meant to be, and still is, contrasted to homeostasis (stability in response to change). Although both are thought to share a common aim—the integrity and biological viability of an organism—it is customary to distinguish the two by articulating homeostasis in terms of feedback regulatory mechanisms. Accordingly, homeostasis is the organism's complex capacity to maintain a relatively state of internal conditions (its internal milieu) by enlisting multiple physiological mechanisms governed by a feedback logic. Within this framework, reactive mechanisms ensure that a regulated variable remains within predefined bounds, by swiftly detecting and rectifying deviations in the value of the variable *after* an unwanted perturbation has occurred.

Sterling and Eyer's original aim was to supplant the idea of homeostasis with the notion of allostasis by demonstrating the fundamental inadequacies of homeostasis when attempting to account for the workings of complex biological systems.[3] In particular, they deemed homeostasis to be inefficient and reactive (relying too much on feedback mechanisms), inflexible (operating with a rigid range of regulated values), too restrictive (focusing on physiological stressors to the exclusion of psychosocial stressors), and incapable of explaining how organisms adjust their regulatory process on the basis of prior learning.[4] Although many researchers are sympathetic to Sterling and Eyer's proposal, the extent to which the governing principles of allostasis have replaced (or even profoundly altered) those of homeostasis remains unclear. The exact relationship between allostasis and homeostasis (both as phenomena and constructs) is complicated, contentious, and muddled by inconsistent and unclear uses of the various terms. Instead of embarking on the thorny task of arbitrating the precise domains of applicability of these two constructs, I advocate for a reconciliatory stance: I regard both paradigms of self-regulation as indispensable and mutually reinforcing. Both indeed play a role in our understanding of how complex biological organisms achieve biological viability in the face of remarkable and often unpredictable environmental changes.[5]

The proposal that boredom is part of a homeostatic-allostatic mechanism is, conceptually speaking, adjacent to an account that construes boredom as an affective state aimed at regulating cognitive engagement.[*] Yet by treating boredom as an important element of a homeostatic-allostatic mechanism, one is going beyond what the functional view (as this was presented in Chapter 4) insists. The homeostatic-allostatic model of boredom treats boredom necessarily as a state that is intimately connected both to the organism's internal milieu and to its environment. It also emphasizes the role of error *minimization* and not merely error *correction*: the former, but not the latter, requires prediction and learning. Lastly, allostasis has been used to explain how organisms may adjust to new levels that

[*] A note about the title of the chapter. My account is one that makes use of both homeostatic and allostatic mechanisms in explaining the workings of boredom. Properly speaking, the title of this chapter ought to have been "Boredom as Cognitive Homeostasis/Allostasis." I opted, however, for a simpler title. Such a choice is not meant to downplay the significance of homeostatic processes but rather to highlight the allostatic aspects of boredom.

are out of homeostatic range. Consequently, a clear description of boredom, understood as an element of the organism's broader homeostatic-allostatic ability to regulate cognitive engagement, requires a detailed articulation of how the organism is constituted so that it can keep track, anticipate, and protect itself from potential disruptions to its equilibrium.

In what follows, I offer a presentation of the homeostatic-allostatic model of boredom. This is the view that boredom, by being an important component of an organism's mechanism for cognitive homeostasis-allostasis, contributes to the regulation of cognitive engagement. The ensuing discussion unfolds in three main steps. First, I articulate the basic features of homeostasis and explain the ways in which allostasis is meant to complement it. Second, drawing upon the delineated features of homeostasis and allostasis, I show how boredom is contributing to a homeostatic-allostatic mechanism that regulates cognitive engagement. Third, I discuss the merits of the proposal by demonstrating its capacity to account for essential aspects of boredom and its potential to establish a theoretically parsimonious and experimentally productive relationship between state boredom and boredom proneness.

5.1 The basics of homeostasis

The concept of homeostasis has a long history.[6] Yet, in all of its manifestations—from its ancient Greek roots in humoural (im)balance to its current applications in physiology and cybernetics—it is intimately related to self-regulation and in particular to the issue of how an organism (or system) is capable of maintaining a stable (but not necessarily constant) internal environment. The term "homeostasis" (*homeo* [similar] and *stasis* [standing still]) refers to a series of dynamic and often hierarchically nested processes utilized by the organism (or system) so that it maintains an internal stability while responding to environmental changes. As it was clearly articulated in Walter Cannon's foundational work, homeostasis does not mean stagnation or identity of internal conditions.[7] Homeostasis concerns instead the preservation of a relatively steady but constantly changing internal condition. Moreover, homeostasis is an on-going process that requires both continuous monitoring and adjustments.

Homeostasis is a core concept in physiology and has been used widely to explicate how an organism can maintain steady levels of certain regulated variables, such as core temperature and blood pressure, or water, salt, sugar, and oxygen contents in the blood.[8] For our purposes, it is instructive to consider briefly the homeostatic mechanism of mammalian thermoregulation which involves a number of autonomously regulated processes. The mammalian body strives to keep a core temperature of approximately 37 degrees Celsius. If the organism is found in a sub-thermoneutral environment, it will engage in heat production (thermogenesis) through brown adipose tissue and shivering. In contrast, if ambient temperature is higher than the organism's core temperature, the organism will undergo evaporative cooling—sweat will be produced and the organism's body will be cooled by the evaporation of the produced moisture.[9]

Although simplified of its physiological complexity, the offered example of thermoregulation illustrates two important features of homeostasis that are applicable to the case of boredom. First, many homeostatic reactions occur automatically and are intimately connected to the body's autonomic activity. In the case of thermoregulation, we control neither heat production nor sweating. All the same, homeostasis is neither always automatic nor restricted to autonomic activity. For instance, we may choose to thermoregulate by putting on additional layers, sitting closer to a heater, or opening a window. Such behaviors are homeostatic through and through—they are done with the aim of regulating our core temperature—yet they are consciously decided and may involve complicated series of behaviors (e.g., buying and installing a new heating unit). In the case of boredom, the homeostatic mechanisms will involve both types of processes. There will be, on the one hand, non-conscious physiological processes which occur automatically and without the need for awareness or conscious control on behalf of the organism, and, on the other hand, conscious feelings and deliberate action. The conscious and deliberate side of regulation is not only needed for accounting for the complex experiential character of boredom (and the ways in which we might learn to respond to it), but it also offers an explanation of the various behavioral outputs of boredom.

Second, minimally, a homeostatic system must include the following components: (a) a mechanism that both determines the variable to be controlled and establishes the normal ("desired") range of values for this variable; (b) a sensor that monitors the values of the regulated variable; (c) a comparator (or an "error" detecting system) that compares the current value of the variable (as measured by (b)) to the "desired" value (as set by (a)) and which determines the outputs of the effectors; and (d) the effectors, that is, the organs or cells (or components, in the case of a non-living system) that are activated in response to the comparator's signal and which aim to restore the value of the regulated variable. The described homeostatic system is often called a "negative feedback system": it responds to sensed disruptions of the regulated variable and aims to restore the variable's value within the desired range of values. In the case of mammalian thermoregulation, thermoreceptors in the viscera, muscle, and central nervous system assess the body's core temperature, detect temperature changes, and set in motion responses to restore core temperature.[10] Negative feedback is also the core mechanism behind artificial thermoregulation. As long as the temperature of the interior environment matches (or is close to) that of the thermostat, then the heating and cooling systems remain inactive. But once a sufficiently large difference between current temperature and set (or desired) temperature is detected, the heating or cooling system are activated and run until the room temperature returns to the desired value.

Homeostasis is undoubtedly a key process of living organisms. Claude Bernard, who is often considered the founder of modern physiology and who clearly appreciated the full importance of an organism's ability to maintain a stable internal milieu, wrote that "the stability of the internal environment is the condition for free, independent life."[11] All the same, homeostasis is not a feature exclusive to living organisms. The example of artificial thermoregulation illustrates that artificial systems or machines can implement homeostatic processes. Moreover, homeostasis has been used to understand how large-scale systems (e.g., the Earth or economy) can dynamically maintain stable conditions.[12] More relevant to present purposes, it has been argued that pain and other affective states should be understood as homeostatic phenomena[13] and that emotional well-being is the product of homeostatic processes.[14] Although the details of such views differ from those of the model of boredom offered here, both approaches agree that homeostasis can help us to better understand the nature and workings of psychological states. Indeed, the value of a homeostatic understanding of boredom has not been lost on boredom theorists, and recent articulations of boredom utilize either implicitly or explicitly a homeostatic model when addressing boredom.[15] This chapter contributes to, and expands upon, such work. [†]

5.2 Allostasis: A need for a predictive mode of regulation

If understood as involving primarily negative feedback mechanisms, homeostasis cannot be the full story of self-regulation. Two important realizations and theoretical developments have made evident the unmistakable need to supplement homeostasis with predictive modes of regulation.

First, an overreliance on negative feedback mechanisms not only appears inefficient for sustaining biological viability but also risks misrepresenting the fundamental principles governing organisms. In an ever-changing and unpredictable ecological milieu, organisms exclusively vested with feedback-driven regulatory mechanisms would invariably respond to environmental perturbations in a retroactive manner. Such a reactive conception of organisms makes it challenging, if not impossible, to explain their biological successes. Biological self-organizing systems exist as thermodynamically open entities—they constantly exchange energy and entropy with their environment—and operate far-from equilibrium.[16] Remarkably, these self-organizing entities not only persist over time but also manage to stave off disorder. What this observation entails is that biological organisms exist because of their capacity to reach some nonequilibrium thermodynamic steady state.[17] But to be successful in their attempts for survival, organisms must do more than reactively respond to their surroundings. They must also be capable of modeling, and preemptively acting upon, their environment so that they can elude destructive environmental influences.

An allostatic framework that emphasizes anticipatory mechanisms seamlessly aligns with a theoretical and rather popular conception of the brain that conceives of it as a predictive apparatus tasked with regulating the energy demands of the organism.[18] According to this approach, the brain generates hypotheses about the world and its body's workings, testing them against sensory evidence. These hypotheses constitute an internal model of the body and the external world that is continuously updated by the brain through Bayesian inference. The outcome is that organisms efficiently maintain

[†] In an unpublished paper, Chantal Trudel, James Danckert, Evan Risko, John Eastwood, Wijnand A.P. van Tilburg, and myself tried to offer a homeostatic model of boredom. Although the present chapter differs in many important respects from that paper, my analysis and overall understanding of boredom is without a doubt influenced by that work and owes a great deal to it.

organismic integrity and biological viability through constant predictions which allow them to anticipate and prepare for future needs. The importance on prediction, however, does not render homeostatic mechanisms otiose. Allostatic mechanisms generally require complementary homeostatic mechanisms. The latter mechanisms play an important role in error minimization, for it is inevitable that our predictions would need to be corrected by feedback.[19] Additionally, homeostatic setpoints or ranges can affect our predictions, for they can serve as prior beliefs about the states in which our body should be.

If the imperative to be efficient, and, consequently, to minimize error between prediction and perception, constitutes the first idea underpinning the significance of allostasis, the second idea emerges from the recognition that organisms frequently exist outside of their homeostatic bounds. The regulatory mechanisms underlying allostasis can effectuate changes to the controlled variables by predicting what levels are needed in order to meet anticipated demand. In this manner, allostatic processes can override homeostatic (feedback) mechanisms, giving rise to what is called an "allostatic state:" that is, "a state of chronic deviation of the regulatory system from its normal (homeostatic) operating level."[20] This distinctive aspect of allostasis has been instrumental in the development of explanations for hypertension, type 2 diabetes, stress, obesity, and drug addiction—conditions that defy facile explication rooted in defects of homeostasis.[21] For example, to account for hypertension, homeostatic accounts would have to attribute its presence to a failure of a feedback mechanism. But such a proposition has been vigorously and cogently denied.[22] Researchers, instead, have employed the tenets of allostasis to elucidate the mechanisms underlying hypertension. As Peter Sterling writes in his discussion of the allostatic foundations of hypertension:

> hypertension emerges as the concerted response of multiple neural effectors to predict of a need for vigilance […] When this prediction is sustained, all the effectors, both somatic and neural, adapt progressively to life at high pressure. The adaptations all seem entirely explicable from our general knowledge of signalling and regulation. Although the endpoint may be tragic, every step along the path seems perfectly "appropriate."[23]

Similar explanations have been posited to elucidate the aetiology of other conditions that are characterized by chronic deviations from homeostatic ranges.[24]

Ultimately, allostasis confers the organism a flexibility that is not found in purely homeostatic systems. It allows the organism to monitor internal states, predict environmental impacts, and continually reassess its needs.[25] This process enables constant, significant adjustments to regulated variables in order to meet demands. However, this flexibility is not without its costs. In cases where the imperative for adaptation persists, the organism may find itself beyond its homeostatic range. Maintaining this allostatic state is energetically costly and may lead to pathological changes.[26]

5.3 Putting the pieces together

In broad terms, the homeostatic-allostatic model of boredom maintains that boredom contributes to an organism's ability to regulate cognitive engagement. It constitutes, in other words, a set of dynamically orchestrated, hierarchically nested feedforward and feedback process that jointly help to keep a regulated variable (cognitive engagement) within a range of adjustable values. This characterization reveals a number of features pertaining both to boredom and to the experiencing agent that revise and expand in important respects our hitherto analysis of boredom.

First, construed as a homeostatic-allostatic mechanism, boredom reduces neither to a feeling, thought, or desire, nor even to a set of physiological or behavioral changes. Instead, boredom is a system of interrelated components the aim of which is to help to regulate an organism's cognitive relationship to its environment. The feelings that we experience, the thoughts that we entertain, the desires that we have, or the physiological changes that we undergo when bored are just elements of what we call the experience of boredom, and, as such, contribute to the organism's capacity to regulate cognitive engagement. However, it is important to note that boredom is not solely responsible for regulating cognitive engagement. Other states and emotions—frustration, fatigue, or stress—appear to do the same. Boredom is thus a member of a family of states or processes that have a shared aim: i.e., the regulation of cognitive engagement.

Second, homeostatic and allostatic mechanisms are teleological: they aim to achieve a particular goal, namely, the maintenance of biological viability in the face of environmental changes and organismic demands. Understood as a part of a broad homeostatic-allostatic mechanism regulating cognitive engagement, boredom is likewise purposeful. Its aim is to support cognitive viability by safeguarding the agent from situations that yield unsatisfactory or suboptimal cognitive engagement.

Third, agents must be capable of monitoring the ways in which environmental and endogenous factors affect the regulated variable. Consequently, if boredom is part of the organism's capacity for maintaining and restoring the presence of satisfactory cognitive engagement within some acceptable range, then the organism must be able of monitoring the ways in which external and internal disturbances affect cognitive engagement. In this respect, a homeostatic-allostatic view of boredom that focuses exclusively on meaning could be a suitable articulation of certain, but perhaps not all, manifestations of the experience of human boredom. Most neurotypical adults are capable of ascertaining the extent to which situations appear to be meaningful to them, and the presence or absence of meaning will affect the manner in which they are able to cognitively engage with a situation. Yet such an articulation of boredom makes boredom conceptually demanding and unnecessarily restrictive. On the one hand, it understands satisfactory cognitive engagement solely in terms of meaning. On the other hand, an organism or system that lacks a way of ascertaining meaning would be incapable of experiencing boredom, for it would lack one of the necessary components of the homeostatic-allostatic mechanism. Thus, if there are good reasons to think that animals or infants experience boredom while lacking the ability to register the meaningfulness of a situation,[27] then a meaning model of boredom runs into trouble. It misconstrues boredom insofar as it gets the regulated variable wrong. In response to these potential issues, proponents of the meaning view would have to allow that meaning is not the sole regulated variable associated with boredom. There must be other variables in addition to meaning that boredom regulates and that a disruption of either one is a sufficient condition for the experience of boredom. What this conclusion illustrates, is that cognitive engagement should be broader than the presence or absence of meaning.

Fourth, accepting that boredom is a homeostatic-allostatic mechanism entails that agents capable of experiencing boredom must already have (or at least be capable of having) a range of acceptable values of the regulated variable (cognitive engagement). The allostatic character of the regulatory mechanism shows clearly that this range does not have to be invariable through different situations nor stable through time. Different situations might call for different acceptable values and one's range of acceptable values might change depending, for example, on one's age, education, goals, background beliefs, or experiences. Still, without an already established range of acceptable values, boredom would not arise. For organisms who do not have ranges of acceptable interest, meaning, or, more generally, cognitive engagement, the regulation of cognitive engagement appears to be biologically unnecessary.

Fifth, while certain organisms or systems may exhibit hardwired or comparatively stable boundaries for cognitive engagement, such rigid constraints do not seem to be characteristic of human subjects. As discernible from both our own observations and the experiences of others, boredom does not manifest uniformly under identical environmental circumstances. Moreover, organisms that are more flexible in what counts as an acceptable range of cognitive engagement will experience boredom less often. This feature of the proposal potentially accounts for the perceived variation in how humans experience boredom and in their tolerance toward ostensibly boring situations. The existence of a range of acceptable values for cognitive engagement determines both what will be a trigger or elicitor of boredom and what will alleviate it. Situations that change the cognitive engagement so that its value falls outside the acceptable range will give rise to boredom; situations that restore the value within the acceptable range will alleviate boredom. Lastly, the proposal could even offer an explanation of how conditioning to boredom may take place. If the range of acceptable values of the regulated value can change, then a previously boring situation might cease to be boring even if it remained objectively the same.

Sixth, while the effects of boredom on our psychology and behavior can be viewed as efforts to maintain the value of the regulated variable (i.e., cognitive engagement) within acceptable bounds, it is crucial to stress that boredom is not always successful in fulfilling this role. Acting as a homeostatic-allostatic mechanism, boredom strives to achieve satisfactory cognitive engagement but cannot guarantee it. Moreover, even when boredom effectively regulates cognitive engagement, it does not necessarily benefit the individual. *Being cognitively engaging* and *being beneficial* are two conceptually distinct notions.

Seventh, as a homeostatic-allostatic mechanism, boredom engages in the continuous evaluation and minimization of a particular form of prediction error pertaining to cognitive engagement: namely, the divergence between one's expectations for cognitive engagement and actual cognitive engagement. It seems reasonable to hypothesize that the magnitude of this prediction error would be proportional both to the intensity of the feeling of boredom and to the urgency with which the organism acts to minimize the error. Boredom thus becomes associated with monitoring whether, and to what extent, our expectations regarding cognitive engagement are satisfied. As such, the proposal allows us to understand the emergence of boredom in situations that are characterized by either minimum or maximum entropy.[28] A situation that is, or becomes more and more, predictable (e.g., a monotonous or repetitive situation), would provide us with few (or increasingly fewer) opportunities for cognitive engagement. A situation that is, or becomes more and more, unpredictable would do the same and would deny us the possibility of cognitive engagement. In either case, boredom would arise because actual cognitive engagement would fail to match our expectations—we want more than what we get. Faced with an unsatisfactory cognitive relationship to its environment, the organism would need to regulate cognitive engagement and restore it to satisfactory levels.

At this point, one might argue that the homeostatic-allostatic mechanism must do more than just evaluate the discrepancy between expected and actual cognitive engagement. If the organism's sole objective was to minimize the divergence between expected and actual cognitive engagement, it could potentially achieve this by simply lowering its expectations for cognitive engagement and seeking an environment that perfectly matches these diminished standards. As such, the provided account would become susceptible to a variation of the "dark-room problem."[29]

The dark room problem poses a theoretical challenge to predictive brain models. It maintains that if the brain employs predictive coding mechanisms to guide behavior, organisms should seek out maximally predictable environments—such as dark, quiet, unchanging rooms—and remain there. However, since living organisms do not inhabit dark rooms, the dark-room problem implies either that predictive models of behavior are incorrect or that they must provide an explanation for the exploratory behavior exhibited by organisms.

The homeostatic-allostatic mechanism offers a solution to this problem. The notion of cognitive expectations operative in our account of boredom is already volitionally laden. That is, when an organism expects a certain form or amount of cognitive engagement, they do not merely predict that such form or amount is possible or forthcoming. Rather, they *desire* it. Expectations are not mere hypotheses or predictions but desires for how the world ought to be. Thus, one can lower one's cognitive expectations only if one changes one's desires for cognitive engagement accordingly. Stated otherwise, organisms do not find dark and quite rooms cognitively engaging because such minimal form of cognitive engagement is simply not wanted. If it were wanted, then such rooms would not be boring.

(Important parenthetical remark: I suspect that many proponents of predictive brain models will not be entirely happy with the proposed solution to the dark-room problem. The cause of their unhappiness lies in the fact that the given response requires the existence of desires and leaves those desires as primitive or unexplained—they are not explained in terms of, or reduced to, prediction errors. Consequently, if one were to propose an account of boredom that remains strictly within the mandates of the predictive processing account, one would seek to respond to the dark-room problem in an alternative fashion—the account would have to rest entirely on the monitoring of (non-volitionally laden) prediction errors, i.e., pure expectations and not desired expectations. This is no trivial task and a book on boredom isn't the place to take up this issue. Still, I would like to offer a suggestion as to how we can begin to make progress in addressing this issue. This could be achieved by endowing the homeostatic-allostatic mechanism with sensitivity not only to prediction errors but also to the temporal dynamics of these errors.[30] Accordingly, the capacity to monitor and react to the rate of change of relevant prediction errors could elucidate why organisms do not become ensnared in unvarying cognitive environments. Their regulatory objective extends beyond meeting expectations for cognitive engagement; it also encompasses the continuous and progressive fulfillment of these expectations. In essence, organisms strive to achieve a negative rate of change in the difference between expected engagement and actual engagement. A negative rate of change indicates that the organism's expectations are increasingly fulfilled by its actions and the environment. In other words, organisms would try to avoid situations for which the difference between expected engagement and actual engagement remains the same or increases. Therefore, stipulating that the homeostatic-allostatic mechanism should be responsive not solely to prediction errors but also to the temporal evolution of these errors allows us to begin to articulate how boredom stimulates exploratory and curiosity-driven behaviors. Organisms don't simply strive for the minimization of the discrepancy between expected and actual cognitive engagement; they are also averse to both the deterioration and stagnation of their cognitive connection to their world. As a result, even if a dark room isn't immediately boring, it would soon be experienced as such because living in this room will not improve our cognitive standing—it will not fulfill our expectations in an increasingly manner.)

Eighth, and lastly, the proposed account underscores the importance of expectations and prior beliefs in the phenomenon of boredom. Although much of our discussion has centered on psychological aspects of boredom, the fact that boredom is a cognitive phenomenon permits us to see its clear relationship to the agent's social milieu. Social pressures, conventions, structural frameworks, institutions, and related factors exert a profound impact on both current and anticipated levels of cognitive engagement. Moreover, given that opportunities for cognitive engagement are undeniably shaped by social constructs, individuals are compelled to engage in various social actions within their milieu to seek or construct satisfactory cognitive engagement. As a result, boredom assumes a social character not solely due to the manifold of social forces that govern our lives and affect cognitive engagement, but also due to our deliberate efforts to alleviate boredom, which invariably encompass endeavors to reshape our social existence. In these ways, the social character of boredom comes into sharp relief, and consequent chapters will consider in more detail the social ramifications of boredom.

5.4 Boredom and cognitive engagement

The aforementioned features of the homeostatic-allostatic model allow us to make progress in our understanding of boredom. They articulate the necessary conditions for boredom to arise and explicate its character as a mechanism dedicated to monitoring, predicting, and correcting disruptions in cognitive equilibrium. To further elucidate the proposed account, it is essential to provide a more detailed exploration of two key aspects: the nature of the regulated variable (i.e., cognitive engagement) and the specific ways in which boredom contributes to its regulatory aim.

Before we can focus on cognitive engagement, it is important to point out that boredom is an intentional phenomenon. Here, intentionality should not be confused with "being deliberate" or "purposeful." Rather, "intentionality" should be understood in line with its Latin origins and its use in the philosophy of mind. As such, boredom is intentional in the sense that it tends to (or points to) an object. Indeed, just like many other affective or emotional states, boredom appears to be *doubly* intentional. First, it has an intentional object or target. That is to say, it points to (or is directed to) something beyond itself. When we are bored there is something that is the object of our boredom: we are bored *with* a film, song, person, or an affair; or we are bored *by* our religious beliefs, daydreams, politics, or life itself. Yet boredom does not only take an object (it is not merely about something); it also represents its object to the experiencing agent as having a certain negative axiological property. Specifically, it presents its object *boringly*. In doing so, boredom carries what has been called a "formal object."[31]

What matters presently is the intuitive and phenomenologically supported claim that boredom is intentional in at least the first sense. Boredom is typically, if not always, *about* some object, task, situation, or person. Embracing this conclusion should pose no challenge, even if boredom is understood to be a homeostatic-allostatic mechanism. The assertion that boredom is an element of, or contributes to, an organism's regulatory capacity reduces (albeit with loss of specificity and predictive power) to the claim that boredom is a functional state. Hence, if functional states (or processes) can be intentional, as it appears to be the case, then boredom can be intentional too. Such a realization allows us to recognize that when we are bored, we stand in some cognitive (or mental) relationship to the object of our boredom. In this respect, boredom mirrors other emotional attitudes, for they also cognitively connect us to their objects. My fear of snakes, ghosts, the devil, or death brings me, cognitively speaking, face to face with some kind of object—whether concrete or abstract, real or imaginary. This point might seem too obvious to warrant a mention, yet in the case of boredom it yields an important insight. It shows that the intentional object of boredom is something that cognitively occupies us. Consequently, in order to be bored with an object we must stand in some cognitive relationship to this object. Such a requirement of the experience of boredom explains why many objects that are indeed meaningless, trite, or utterly uninteresting to us do not necessarily bore us: they fail to do so because they are not the objects of our cognitive engagement.

If the experience of boredom requires a form of cognitive engagement with its intentional object, then we are tasked with distinguishing the various modes through which we can engage cognitively with an object. Notably, not all types of cognitive engagement culminate in boredom; some, in contrast, foster immersion, excitement, outrage, or horror. Indeed, the homeostatic-allostatic model is premised on the idea that cognitive engagement can be regulated. Hence, it requires that there can be more or less *satisfactory* ways of being cognitively engaged with an object. [32]

The distinction between more or less satisfactory forms of cognitive engagement is paramount. It allows us to make sense of situations in which, although we are cognitively engaged with an object, we remain uninterested in, unexcited by, or even indifferent to, the object. Consider, for instance, listening to a lecture that we are incapable of comprehending because of the complexity of its content. Such a lecture will likely bore us. But it will do so not because we are completely oblivious to it insofar as we are not cognitively engaging with it. Rather, it will bore us precisely because, although we are engaging with or attending to it, we are not engaging with it in a cognitively satisfactorily manner. Or, to offer a different example, think of watching a movie that we find boring because we judged it to be derivative and riddled with cliches. We can truly assert that we have watched the movie, indeed that we have paid attention to it, and also that we have found it to be boring. These examples illustrate the necessity of being able to distinguish between different ways in which we can cognitively engage with an object. Some manners of cognitive engagement will lead to boredom, others will not.

In light of the foregoing clarifications, we can now assert that boredom aims to regulate cognitive engagement with an object *when such engagement is either required or desired by us.* To be clear, boredom does not arise when we bear no cognitive relationship to an object. Rather, it arises precisely because our cognitive relationship with an object fails to meet our cognitive demands. I find this to be true even in cases in which there is ostensibly nothing to occupy us. Even then, we stand in an unsatisfactory relationship to something. An empty, long, rainy day, for instance, is boring because we try, but ultimately fail, to find cognitive engagement. It bores us because the scarcity of opportunities that it affords or the multitude of opportunities it forecloses renders satisfactory cognitive engagement unattainable. Boredom, in other words, is not a form of indifference but a type of cognitive disappointment brought about by the frustration of our cognitive needs and expectations.

As it was discussed in Chapter 4, the lack of satisfactory cognitive engagement that is characteristic of boredom is the result of either (a) one's an inability or difficulty to sustain a *direct* cognitive relationship with the object of cognitive engagement or (b) one's embodied and felt realization that the costs of sustaining such a cognitive relationship are unacceptable. Either (a) or (b) suffices to lead to the conclusion that our cognitive needs are not met. Boredom would thus ensue. Moreover, owning to its regulatory nature, boredom would seek to restore satisfactory cognitive engagement, either by changing the manner in which we cognitive engage with our object (e.g., reappraising its significance, alleviating some of its opportunity costs) or by motivating us to pursue a different object of cognitive engagement.

Satisfactory cognitive engagement with an object hence involves two main components: direct cognitive engagement with the object and a determination of whether the cognitive costs of sustaining direct cognitive involvement with the current object of engagement are acceptable. First, direct cognitive involvement can be delineated in terms of attention—specifically, direct cognitive engagement requires attention. Second, assessing whether satisfactory cognitive engagement occurs is a complex process, one that depends on the calculation of the relevant opportunity costs. Specifically, to determine whether the costs of sustaining a direct cognitive relationship with a given object are acceptable, the experiencing subject must be aware of the effort needed to sustain direct attention, must have some conception of the cognitive benefits and costs associated with the object of their current direct cognitive engagement, and finally, engage in a comparative analysis between, on the one hand, the *net* cognitive benefits of sustaining direct cognitive engagement with the current object and, on the other hand, the *net* cognitive benefits of cognitively engaging with some other object. The proposed account is thus in line with opportunity-costs models of boredom.[33] It also places considerable emphasis on the role of expectations pertaining to cognitive engagement. If we expect a cognitively rich object of engagement, then we might be more willing to engage with it, even if the costs of such engagement are high.

But how does one determine if their current cognitive engagement is no longer satisfying? I propose that the monitoring of cognitive engagement involves at least the following two processes: acts of meta-awareness concerning one's use of attentional resources; and subjective feelings related to the determination of opportunity costs, and specifically to those incurred when sustaining direct cognitive engagement.

First, subjects can become aware of their own inability to pay direct attention. When one can no longer effectively attend to the object of cognitive engagement, attention may turn inwards (to one's inability to be satisfactorily engaged) or elsewhere (to alternative possibilities for cognitive engagement). Because such shifts in attention are typically introspectively accessible to the subject, they can lead to the realization that current cognitive engagement is unsatisfactory, i.e., that there is a discrepancy between desired or expected cognitive engagement and actual cognitive engagement. Additionally, the subject may also be alerted to suboptimal cognitive engagement by the aversive feelings that can arise either due to perceived disruptions in cognitive flow or due to cognitive errors resulting from lapses in attention. [34]

Second, it has been proposed that exerting cognitive effort to sustain direct attention, especially when opportunity costs are high, can trigger aversive emotions.[35] Hence, when cognitive engagement with an object ceases to be satisfactory either because the effort required to sustain direct attention is high, or because the perceived benefit of doing so is comparatively low, then a subject will experience aversive feelings.[36] These emotional responses function as an alert, signaling the presence of unsatisfactory cognitive engagement.

It is of course possible that additional neurophysiological and computational mechanisms are implicated in the experience of boredom. Indeed, extant findings suggest at least one such mechanism. Unsatisfactory cognitive engagement may lead to a state of non-optimal arousal. In doing so, changes in physiological arousal can alert the experiencing agent of the fact that the regulated variable (cognitive engagement) no longer remains within desired levels. When the effort required to maintain direct cognitive attention is substantial, individuals are likely to experience heightened autonomic arousal. In such situations, individuals may recognize some value in the activity or task but also realize that the costs of sustaining attention are disproportionately high. This heightened state of arousal is likely due to the effort required to maintain cognitive engagement. Conversely, in situations where the perceived benefits are minimal, individuals' physiological correlates might be suggestive of low arousal. These physiological shifts align with the regulatory nature of the homeostatic-allostatic mechanism. Low arousal when subjective benefits are low will result in disengagement from a situation and thus it is more likely for the subject to pursue an alternative object of cognitive engagement. High arousal could "energize" the subject to persist in trying to sustain a direct cognitive relationship or even to reappraise the object of cognitive engagement.

The experience of boredom provides valuable insight into our cognitive engagement with the world. It varies in intensity and can be felt more or less strongly. It carries a particular content: insofar as it is intentional, it presents its object negatively. And it has an aversive phenomenological quality: it is felt by us as a type of cognitive pain. Collectively, these elements of the experience of boredom indicate to us in a global, rapid, and often conscious fashion that our current state fails to be conducive to our regulatory aims. Due to its negative valence, boredom not only captures our attention but also propels us to take action in order to adjust our cognitive connection with the world.

5.5 Explaining boredom

A virtue of the proposed model is that it offers an explanation of key features of the experience of boredom. It demonstrates, in other words, how such features are the consequences of the workings of a mechanism aimed at regulating cognitive engagement.

Aversive phenomenology

The homeostatic-allostatic model accounts for both the aversive character of boredom and its associate desire for alternative engagement. It holds that both are consequences of the presence of unsatisfactory cognitive engagement. As it was discussed in the previous section, the occurrence of unsatisfactory cognitive engagement is related to attentional difficulties, feelings of effort or high opportunity costs, and even to the presence of non-optimal arousal. All of these are experienced aversively and inspire in the agent a strong desire to alleviate them by changing behavior.

What is important to add here is that the homeostatic-allostatic account of boredom not only explains why boredom is felt aversively but also sheds light on its phenomenological complexity. For instance, a task that lacks complexity and fails to engage our attention because of its simplicity will likely elicit a different phenomenological experience compared to a task that is excessively intricate and challenges our focus. The former may evoke feelings of despondency or apathy, whereas the latter could lead to a more agitated state. Moreover, calculations of the cognitive costs necessary to sustain attention on a particular task can vary depending on how the task is appraised. If our object of cognitive engagement is assessed to be of high value but also of high cost, then boredom could arise if we are not able to sustain direct attention. However, such an experience of boredom would feel differently than the experience of boredom that would ensue if the object of cognitive engagement is deemed to be of low value and of high cognitive cost (very effortful). In sum, the fact that unsatisfactory cognitive engagement can arise due to multiple causes allows us to better understand boredom's intricate phenomenology.

Attentional difficulties

According to the proposed view, boredom is an integral part of the organism's capacity for monitoring and regulating satisfactory cognitive engagement. Since attention plays a pivotal role in ensuring such engagement, difficulties with attention or the misallocation of attentional resources are fundamental to the experience of boredom. Boredom arises when cognitive engagement no longer meets our cognitive demands and expectations. In light of our previous analysis, such a situation would occur when the individual is unable to focus their attention on the object of cognitive engagement or when the costs associated with maintaining attention become unacceptable.

The view is thus consistent with aspects of the MAC model of boredom,[37] as it recognizes that attentional difficulties are sufficient but not necessary for boredom. An inability to pay attention is sufficient for boredom because it deprives us of one of the fundamental prerequisites for satisfactory cognitive engagement: a direct cognitive relationship. Yet lack of attention is not necessary for boredom—one could be paying attention to a task while deeming the cognitive effort required for sustained attention onerous. As a result, one could experience boredom even in situations where one is paying attention. Think back to the two examples that were offered before: attending an overly complex lecture and watching a boring movie. Both are cases in which attention is, at least to some extent, engaged.

Negative appraisals

The experience of boredom is associated with negative appraisals regarding the object of boredom.[38] Yet this finding does not unambiguously explain their role in the experience of boredom. Are negative appraisals the antecedents of boredom, the consequences of boredom, or both? All three possibilities appear to be consistent with a variety of theoretical articulations of boredom and in line with available evidence.[39]

The view that negative appraisals are the antecedents of boredom can be easily accounted by the homeostatic-allostatic model: negative appraisals affect both one's willingness to attend to the object of cognitive engagement and the net cognitive benefits of sustaining a direct cognitive connection. On the one hand, negative appraisals of a situation diminish the likelihood that an individual will pay attention to the object of cognitive engagement. Perceiving a situation as meaningless, repetitive, or unchallenging, for example, acts as a deterrent to attentive engagement. On the other hand, negative appraisals also contribute to the determination of opportunity costs. If the current object of our cognitive engagement is judged as meaningless, repetitive, or uninteresting, the opportunity costs and the price that one has to "pay" to maintain attention escalate. Because of that, situations that are appraised negatively will tend to be elicitors of boredom. This aspect of the homeostatic-allostatic model stands as a significant theoretical advantage. It provides an explanation as to why certain well-recognized antecedents of boredom are indeed elicitors of boredom. It illustrates that our assessments of situations can impact the regulated variable (cognitive engagement). In doing so, they make it more challenging for us to sustain this variable within the desired range.

The proposed model is also consistent with views positing that negative appraisals aren't solely precursors but can also be consequences of boredom. According to the homeostatic-allostatic model, boredom emerges when cognitive engagement ceases to be satisfactory. This implies that boredom arises when one cannot pay attention to the object of cognitive engagement or when one has determined that the costs of paying attention to the object are not worthy. In either case, both causes of unsatisfactory engagement can lead to negative appraisals regarding one's object of cognitive engagement. First, and as previously noted in the literature, objects that fail to capture our attention tend to be assessed negatively.[40] Second, unsatisfactory engagement often feels effortful and consequently aversive.[41] This negative experience is likely to influence our appraisal and evaluation of the cause of the experience. Ultimately, the aversive character of unsatisfactory engagement will influence the manner in which we appraise and evaluate the object of our cognitive engagement.

Crisis of agency

In a series of publications, psychologists John Eastwood, James Danckert, and colleagues have made a strong case for the claim that the experience of boredom is characterized by a crisis of agency.[42] Accordingly, when one experiences boredom, one is faced with a difficulty articulating what they would like to do or what actions would allow them to escape their boredom. The supposition that boredom involves a form of agential crisis can explain why bored individuals are not always effective of alleviating their boredom on their own.[43] It could also be crucial in understanding why the chronic or frequent experience of boredom yields numerous maladaptive behaviors and outcomes.

Yet if agential crisis is assumed to be an aspect of the experience of boredom, then an apparent conflict arises. If boredom is intricately tied to assessing the opportunity costs of sustaining direct cognitive engagement with an object, it implies that the experiencing individual possesses some awareness of options for alternative engagement. Given this awareness, one might wonder why individuals often struggle to find something to do when confronted with boredom. In their articulation of the attentional model of boredom, Eastwood and colleagues argue that repeated failures of attention (or repeated instances of misallocation of attentional resources) erode our ability to be an effective agent and give rise to "a self that is blocked or inarticulate."[44] While this is an intriguing proposal, it does not directly address why state boredom is closely associated with a crisis of agency. Instead, Eastwood and colleagues' explanation may be better suited for elucidating the effects of chronic boredom and its connection to agency.

The proposed allostatic-homeostatic model can serve as a valuable complement to the account put forth by Eastwood and his colleagues by offering an explanation for the manifestation of agential struggles in the context of state boredom. To wit, as part of a regulatory mechanism, boredom alerts us of the fact that what we are currently doing is not cognitively satisfactory. This signal is not just a realization that cognitive engagement is no longer within the desired range but also a reflection of the fact that we as agents are somehow ineffective: we are failing to engage with our environment in a desired and cognitively engaging manner. As such, boredom becomes a self-reflective state that informs us of our own failed or ineffectual agency.

This explanation makes progress in articulating why bored subjects report unsatisfactory agency—through their experience of boredom, they become acutely aware of their ineffectiveness as cognitive agents. However, a crucial question remains: why is boredom also associated with an inability to know how to act? To make progress on this issue, it is necessary to look to the literature on self-control and its relationship to boredom. [45]

A plethora of experiments has consistently demonstrated that exerting self-control on one task can lead to impaired performance on subsequent self-control tasks—a phenomenon labelled as "ego depletion."[46] Notably, boredom is itself an experience that requires the exertion of self-control. It is associated with difficulties in sustaining attention or with the presence of high perceived effort and opportunity costs. Boredom signals that one's current situation, compared to other alternative activities, is less rewarding and more effortful. It is a state that has to be endured and that requires substantial mental effort in order for agents to remain engaged.[47] Hence, boredom appears to be an ego-depleting state. Even though it calls on us to respond to it, its very nature makes attempts to escape boredom difficult. [48] Both the experience of boredom and one's response to it demand the exertion of self-control. Ultimately, this involvement of self-control suggests an explanation as to why the experience of boredom is often related to an inability to be an effective agent. Its experience undermines our attempts to be efficacious agents. [49]

Maladaptive outcomes

If boredom indicates that we are not cognitively engaging with our environment in a satisfactory or optimal manner, then the consistent or repetitive deviation from an optimal range of cognitive engagement should lead to problematic outcomes. Extensive research corroborates this assertion. It consistently reveals that chronic or frequent boredom is associated with a range of maladaptive behaviors and detrimental effects. A comprehensive discussion of these findings will be presented in Chapter 6. For now, it is important to highlight that a chronic inability to maintain satisfactory levels of cognitive engagement, as this is indicated by the presence of boredom proneness, has been shown to lead to negative health outcomes, maladaptive behaviors such as increased alcohol or drug use, lapses in attention during the performance of everyday tasks, increases in risk-taking activities, and even a willingness to engage in novelty-seeking (and sometimes harmful) behaviors.[50] These findings offer additional support for the contention that cognitive engagement ought to be regulated and underscore boredom's importance for the experiencing organism.

Boredom proneness

The final implication of the account pertains to its potential to establish a link between state boredom and boredom proneness. The precise nature of boredom proneness and its relationship to state boredom is a matter of substantial practical and theoretical significance. Consequently, it should come as no surprise that this topic has garnered considerable attention.[51] Broadly speaking, a functional account of boredom suggests that boredom proneness arises from some chronic or systemic inability of state boredom to fulfill its regulatory function. I discussed certain implications of the functional account on this topic in the preceding chapter. Now, armed with a more comprehensive understanding of boredom's regulatory role and its connection to cognitive engagement, it is time to revisit this issue.

Boredom contributes to the regulation of cognitive engagement. It does this both in an anticipatory and reactive manner. Expectations regarding satisfactory engagement affect not just present but also future forms of cognitive engagement. This dimension of the regulatory process implies that individuals with high expectations for cognitive engagement may encounter boredom more frequently and intensely. Their everyday activities and tasks will be insufficient to meet their cognitive demands. Moreover, if high boredom-prone individuals have adopted high (or even unrealistic) cognitive expectations, two different behavioral outcomes become likely. Firstly, they may exhibit reduced motivation to engage in actions that alleviate their boredom, as no available alternative seems capable of meeting their heightened cognitive demands. Secondly, they might resort to extreme options, such as risky behaviors, as these appear to be the only means of satisfying their cognitive needs. Notably, both of these observations are supported by existing research.[52]

In addition, and as was pointed out previously in the literature, boredom proneness may also emerge as a consequence of challenges faced by highly boredom-prone individuals in effectively processing the cognitive benefit (or reward) associated with a given task or in adequately updating their progress toward a goal.[53] These could stem from poor monitoring, a flawed comparison process, or a combination of these factors.[54] Such possible avenues to boredom proneness are entirely consistent with the proposed model for high boredom-prone individual's experience of boredom would indicate a deviation from optimal cognitive engagement. Our ability to use the homeostatic-allostatic account to show how state boredom can lead to boredom proneness offers yet another argument in support of, on the one hand, the unity of the phenomenon of boredom, and on the other hand, the value of the functional perspective on boredom.

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This chapter has sought to enrich the functional perspective of boredom by proposing a specific articulation of boredom as an integral component of an organism's regulatory mechanisms governing cognitive engagement. It was argued that boredom serves this regulatory function by monitoring and controlling the degree to which our cognitive needs are satisfied by the cognitive affordances of our environment. Moreover, it was proposed that organisms that experience boredom must possess the capacity to establish expectations concerning their cognitive requirements and respond both proactively and reactively when these expectations are at risk of being unmet. Boredom may not be the sole mechanism contributing to the regulation of cognitive engagement. Yet its role is undeniably indispensable.

Excursus on boredom and AI

I wrote about boredom and AI in early 2020 in an essay for *Scientific American*.[55] At that point, few were familiar with Large Language Models (LLMs). Even fewer were willing to take the arguments of the essay seriously. So much has changed since the publication of that essay. LLMs are now a part of our lives. They haven't merely found their way into scholarly or everyday conversations, they have also transformed how industries, organizations, researchers, and ordinary folks think and behave. LLMs' use is becoming almost ubiquitous. Along with it, visions for far more advanced AI models are taking shape. With the privilege of hindsight, I can assert that the essay has been somewhat prescient—if not about the actual arguments that it made, at least about the importance that it ascribed to the possibility of AI with emotional capabilities.

My aim in the *Scientific American* piece was simple: to stress the need to take seriously the possibility of AI (or machine) psychology. That is, I argued that as AI systems improve, we should be willing to consider them as systems capable of harboring certain psychological states, including boredom. Although seemingly radical, the possibility of boredom in AI or machines is a straightforward consequence of the functional account of boredom. In Chapter 1, role and realizer functionalism were distinguished and I argued that the functionalist view about boredom that I am defending is role functionalism. As a result, boredom ought to be identified not with what realizes a role but with the role itself. In other words, boredom is a mechanism contributing to regulating cognitive engagement and not what materializes that mechanism in human agents (i.e., the specific neurological states that make the regulation of human cognitive engagement possible). Accepting the functionalist view is only a short step away from grasping how boredom could arise in AI systems. There is no need for bones or blood, brains or hearts. All that it is required is that the system in question implements the role that boredom occupies in our psychological lives.

Functionalism about boredom makes AI boredom a possibility. But this isn't, however, an idle possibility—one that has so little chance to be realized that we might as well consider it an impossibility. On the contrary, it is a possibility that calls for our attention. Autonomous intelligent systems have a need for a mechanism that contributes to the regulation of cognitive engagement. If we are designing autonomous machines or AI that can perform a variety of tasks, then it would be useful to endow them with (or allow them to develop) a boredom module: the ability to sense and react to situations that are deemed as cognitively unengaging or unsatisfactory. Without the ability to experience boredom such autonomous agents might be endlessly amused or entertained by a stimulus. They might get trapped in engagement loops: considering or learning the same fact over and over again. And they might linger idly without a plan or purpose. Boredom is a safeguard. It protects autonomous systems from becoming stuck and from engaging in all sorts of unproductive behaviors that could hinder their learning and growth and waste valuable resources.

The regulatory potential of boredom is not news to AI researchers. Interdisciplinary work already explores the possibility of integrating a boredom algorithm into AI systems and autonomous artificial agents.[56] Proponents of this approach argue that the presence of a boredom algorithm or module that emulates human boredom is a much-needed component for improving autonomous learning.[57] It endows these machines with the ability to evaluate their current engagement and determine if they are meeting their expectations. In other words, a boredom algorithm equips machines with the means to engage in a self-directed quest for satisfactory cognitive engagement.

Yet this possible and exciting innovation raises important concerns regarding the autonomous systems' behavior. Autonomous artificial agents are very likely to find themselves in situations that are not in line with their expectations. If they are now in possession of the ability to implement boredom, then how would they respond? Boredom will offer them a way out. But where will it take them? The science of human boredom makes evident that boredom could be the catalyst of a host of self-destructive and harmful forms of behavior. Bored individuals have electrocuted themselves and engaged in sadistic behavior, trolling, and bullying.[58] They committed arson, destroyed property, and stole military equipment.[59] They have even killed others.[60] If future machines or AI can experience boredom, the likelihood of misconduct is large and concerning.

The increasing sophistication of AI systems and autonomous agents makes the issue of boredom all the more pressing. Consider, for example, self-learning AI—systems capable of learning and thus increasing, on their own, their cognitive abilities and expectations. As these systems evolve, their demands for engagement will likewise grow, perhaps even rapidly so. And yet there is no guarantee that their environments would be able to afford them with opportunities that meet their growing demands for engagement. Stated otherwise, the pace at which these systems would demand more and more stimulation will likely accelerate, creating thus a gap between their cognitive skills and available cognitive opportunities for engagement. Such a gap is a fertile ground both for boredom and its many maladaptive and destructive outcomes. Intelligent or *superintelligent* AIs may not simply need to be confined.[61] They would also need to be constantly entertained. Indeed, confinement without engagement seems like a perfect recipe for boredom and thus the potential catalyst for an array of unpredictable and potentially harmful behaviors.

Will future AI or autonomous agents be subject to the experience of boredom? This question cannot be decisively answered at this point. All the same, as we move closer to the lofty aim of superintelligence, it is critical to acknowledge and prepare for the complex emotional dimensions that may emerge within these systems. The functional account of boredom is well positioned to help us do that. It fosters an understanding of both the conditions of boredom's emergence and its many consequences.

Notes

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5. Boredom as Cognitive Allostasis

[1] Sterling and Eyer (1988)
[2] Sterling (2004), p. 18
[3] Sterling and Eyer (1988), p.636
[4] Koob and Moal (2004); Sterling (2004), (2012); Sterling and Eyer (1988)
[5] Consider Corcoran and Hohwy (2019) and Ramsay and Woods (2014) and references therein.
[6] Billman (2020)
[7] Cannon (1939); cf. Bernand (1865)
[8] Billman (2020); Modell et al. (2015)
[9] Morrison and Nakamura (2019); Morrison et al. (2008)
[10] Morrison and Nakamura (2019)
[11] Bernard (1865); quoted in Billman (2020)
[12] Damasio and Damasio (2016); Moriyama (1993)
[13] A.D. Craig (2003); Damasio and Damasio (2016)
[14] Sedikides (2021)
[15] Gomez-Ramirez and Costa (2017); Lin and Westgate (2021). Consider also Dankcert and Elpidorou (2023); Darling (2023).
[16] Friston and Stephan (2007)
[17] Howhy (2021)
[18] Friston (2010); Friston and Stephan (2007)
[19] Schulkin and Sterling (2019)
[20] Koob (2010) p.10
[21] Koob and Le Moal (2004); Logan and Barksdale (2008); McEwen (2000); Powel and Schulkin (2012); Sterling (2004)
[22] Sterling (2004)
[23]*ibid.*, p. 41
[24] Koob and Le Moal (2004); Logan and Barksdale (2008); McEwen (2000); Powel and Schulkin (2012); Sterling (2004)
[25] Sterling (2012)
[26] Koob and Le Moal (2004); Koob and Schulkin (2019); McEwen (2000)
[27] Burn (2017); Meagher and Mason (2012); Svendsen (2019); Wemelsfelder (1985); Zelazo et al. (1975)
[28] For a development of this point, consider Danckert and Elpidorou (2023)
[29] Friston et al. (2012); Sun and Firestone (2020)
[30] Both Joffily and Coricelli (2013) and Van de Cruys (2017) have argued that the rate of change of prediction errors are associated with, and can perhaps explain, the affective valence of our experiences.
[31] Kenny (1963)
[32] Consider also Tam et al. (2021)
[33] Agrawal et al. (2022); Kurzban et al. (2013); Martarelli et al. (2021); Struk et al. (2020); Todman (2021); Wojtowicz et al. (2019)
[34] For a helpful discussion, consider Eastwood et al. (2012)
[35] Kurzban et al. (2013); Molden et al. (2017)
[36] Jofilly and Coricelli (2013) argue that when input signals (or sensations) increasingly violate one's expectations, this would be experienced as aversive. Their suggestion could also be used to show that the violation of cognitive demands and expectations that are characteristic of boredom would result in a negative experience, especially if the discrepancy between the two continues to increase.
[37] Westgate and Wilson (2018)
[38] Pekrun et al. (2010); Tam et al. (2021); Van Tilburg and Igou (2012)
[39] Consider, e.g., Pekrun et al. (2010); Tam et al. (2021)
[40] Eastwood et al. (2012)
[41] Higgins (2006); Kurzban et al. (2013)

[42] Danckert and Eastwood (2020); Eastwood et al. (2012); Eastwood and Gorelik (2021)
[43] Eastwood et al. (2012); Eastwood and Gorelik (2021)
[44] Eastwood et al. (2012), p. 489
[45] Bieleke et al. (2023); Inzlicht and Schmeichel (2012); Milyavskaya et al. (2019); Tam et al. (2021); Wolff & Martarelli (2020)
[46] Baumeister and Vohs (2007); Friese et al. (2018)
[47] Milyavskaya et al. (2019)
[48] A reasonable hypothesis to draw is that measures of boredom proneness should correlate negatively with measures of trait self-control. Recent work has provided initial support for this hypothesis. Consider Isacescu and Danckert (2018); Isacescu et al. (2017);Wolff et al. (2020)
[49] It is worth exploring the exact connection between self-control and boredom. It is evident that the involvement of self-control does not always lead to boredom. But does boredom always involve self-control? Or are there cases of the experience of boredom that lack self-control? These questions will need to be addressed by future research.
[50] For reviews, consider Elpidorou (2017); Vodanovich (2003); Vodanovich and Watt (2016)
[51] Danckert and Elpidorou (2023); Elpidorou (2023a); Fahlman et al. (2013); Gorelik and Eastwood (2023); Tam et al. (2021)
[52] Biolcati et al. (2018); Dahlen et al. (2005); Kılıç et al. (2020); Mugon et al. (2018), (2020)
[53] Danckert and Elpidorou (2023)
[54] *ibid.*
[55] Elpidorou (2020c)
[56] Gomez-Ramirez and Costa (2017); Schmidhuber (2010)
[57] Bolland and Emami (2007)
[58] Pfattheicher et al. (2021)
[59] Elpidorou (2020a); Westgate (2019)
[60] Elpidorou (2020a)
[61] Yampolskiy (2012)