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OUTLINE OF A NEUROPHILOSOPHICAL EXPLORATION OF ATTENTION

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Abstract. This article outlines a non-reductive neurophilosophical exploration of attention, arguing that its current scientific study is marked by ambiguities and internal inconsistencies. There are dominant reductive and anthropocentric assumptions that have led contemporary research on attention into conceptual dead ends—including an overreliance on so-called "analytical approaches", rigid dichotomies, and circular reasoning—that continue to obstruct the formulation of a coherent scientific definition of the phenomenon. To address these challenges, we advocate for the use of non-reductive biogenic frameworks, suggesting that attention can be reconceptualized as a complex and embodied process, essential for organisms to regulate adaptive behavior and maintain thermodynamic equilibrium. Ultimately, this article seeks to promote more robust neurophilosophical investigations of attention, integrating insights from neuroscience, psychology, and evolutionary biology, while emphasizing the indispensable role of philosophical reflection in advancing scientific understanding.

Keywords: attention • neurophilosophy • biogenic approaches • active inference • radical embodiment

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1. Introduction

There seems to be a strong impression that we perceive the world in a detailed and continuous manner, immediately accessible and passively apprehended. However, many scholars have challenged this view, describing perception as a proactive process that is highly selective and (en)active, as well as edited and shaped by bodily dynamics managed by our nervous system (Nobre & Kastner 2014, p.241). In these descriptions, perception is treated as a corporeal and interpretive act of collecting, organizing, and identifying stimuli, enabling the reporting and assimilation of relevant information or environments with which an organism engages. Here, attention plays a fundamental role, allowing living beings to selectively focus on some aspect of the information captured by their sensory apparatus, while ignoring other potential information, in order to guide the composition of what is reported and assimilated during perception.

Within the "Manifest Image",[1] attention clearly encompasses many aspects of our experiences. It involves both overt physical movement and more subtle, covert actions, like listening to a conversation. It can be either voluntary or involuntary, triggered by loud noises or strong smells, acting upon our thoughts and affecting our focus, memory, and decision-making (Wu, 2014). Sometimes, attention means searching for lost keys in a hurry; other times, it involves monitoring an interaction in order to remember essential details or to track something that must not vanish from sight. It can also require vigilance—remaining alert and responsive to changes (Prinz 2012)—and properly directing it might even be essential for our cognitive development (Watzl 2011), given that 'to attend' often simply means to care about what matters.

But in the "Scientific Image" of psychologists and neuroscientists, attention has been studied from different theoretical perspectives, in accordance with distinct methodologies, and across multiple scales (Watzl 2017). Due to the extensive and diverse literature produced by such a plural endeavor, the contemporary science of attention is plagued with ambiguities and a lack of precision concerning the very definition and core attributions of its target phenomenon. This indicates the existence of epistemological difficulties that, as we will see, are often acknowledged but have not been properly addressed by the field. With that in mind, the current article aims to expose some of these difficulties, as well as contribute to their eventual mitigation. More specifically, we believe the problem lies in a common set of reductive anthropogenic assumptions that have dominated the science of attention for much of its history. As we will argue, by replacing this set with a non-reductive biogenic one, it is possible to rethink the phenomenon in ways that alleviate internal divergences and overcome the main difficulties confronted by its scientific study. To do this, we begin with a brief history of attention studies (Section 2), followed by an overview of some of the epistemological issues currently faced by the field (Section 3). We then explore an alternative set of underlying assumptions for the science of attention (Section 4), and finally, based on the illustrative example of the Active Inference Framework, attempt to outline what the resulting neurophilosophical account of the phenomenon would imply for its study (Section 5). We conclude on a positive note while acknowledging the shortcomings of this endeavor and its status within the growing landscape of pragmatic and radically embodied approaches to cognition.

2. A brief history of attention

The origins of attention studies, just like the study of many other aspects of human cognition, have been traced back to ancient Western (Guo 2022; Jennings 2020) and Eastern philosophical ideas, with the latter coming mainly from the treatment given to the phenomenon in the Upanishads—"that which is necessary to believe and perceive"—and the Nyaya School of Hinduism—"an intermediary bottleneck between the self and the data received by sense faculties" (Jennings 2020; Müller, 1879). However, regardless of the philosophical tradition in question, these first formal inquiries into attention were often merged with those into perception and consciousness, as these phenomena were often operationalized in remarkably similar ways and accommodated into broader theories regarding the purported "mechanisms of the soul/mind" at least until the early modern period (Jennings 2020, p.11). Such theorizing fomented foundational philosophical debates about the limits of our sensors and mental agency in ways that would end up influencing the field to this day.

According to Christopher Mole (2025), the first attempt to develop a proper theory of attention as an individualized phenomenon occurred in 1738, when Christian Wolff devoted an entire chapter to the topic in his seminal empirical psychology textbook. This set the stage for subsequent scientific research, with particular reverberance within the Germanic world. In the 19th century, it was a pair of German scientists, Hermann von Helmholtz and Wilhelm Wundt, who pioneered the development of the experimental methods that would largely define the empirical study of the phenomenon. In his works, Wundt (1874/1948) operationalized attention as a proactive process that prepares, directs, and channels perception in an anticipatory manner, relying on past experiences and prior knowledge as a basis. In a somewhat similar intellectualistic vein, Helmholtz (1867/1924) argued that perception emerges through the interaction of memories and sensory stimuli, with attention selecting and prioritizing perceptual content, ultimately shaping these interactions and the ways individuals relate to their environment (Nobre & Kastner 2014, p.245). It was only years later, then, that William James, coming from the substantially distinct North American pragmatic tradition, famously declared that "everyone knows what attention is", before defining it as:

> [...] The taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, and concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others [...]. (James 1890, p.204).

Such description, although broad and intuitive, has been considered a fruitful synthesis of pragmatic philosophical ideas and the empirical mindset of Wundt and Helmholtz. In fact, it revealed key insights that have proven highly influential, such as the understanding of attention in processual terms and the suggestion that it is a kind of agent, capable of deciding what enters consciousness. Here, attention is the process of selecting and prioritizing perceptual information crucial to cognitive functioning, guiding individuals' adaptive behavior within their environment (Nobre & Kastner 2014, p.244). James's ideas pointed to most of the topics that the then-new experimental psychology would spend the next century trying to measure and manipulate.

By the first half of the 20th century, philosophy and psychology became officially distinct disciplines, a shift that ended up relegating consciousness primarily to philosophical inquiry, while attention became a more fitting subject of psychological study. However, despite an early wave of research on the psychology of visual attention, Mole argues that the field's first decades were marked by pessimism because of a lack of significant progress (Mole 2011b, p.xi). Nevertheless, psychologists never ceased exploring the phenomenon, and after Behaviorism, with the rise of Information Theory, scientific research on attention expanded to different modalities. One crucial reason for this resurgence was the dissemination of communication theories and the emergence of the problem of capacity in cognitive psychology. This refers to the limited amount of information that can be transmitted through a given sensory channel within a certain time frame. In the 1950s, psychologists began investigating our capacity to process complex language patterns using selective attention. Specifically, selective hearing emerged as a key phenomenon that could shed light on how we single out and process words in dynamic communicative contexts. Scientists like Edward Cherry (1953), Donald Broadbent (1958) and Anne Treisman (1964) introduced concepts such as "bottlenecks", "filters", and "processors", as powerful new metaphors within a quantitative framework for studying selective attention in informational terms. In other words, they were applying an engineering model to human cognition—an approach that, at the time, signaled a revolutionary step in psychological research.

But while models from cognitive psychology provided a map, neuroscientists developed the tools (e.g., EEG and fMRI) that most famously explored the territory. This explains why attention became so prominent in the neuroscience of vision, it provided a measurable, controllable way to assess how well these informational concepts fit the processes happening in the brain (Mole 2011b, p.xi–xii). More recently, these models have been explored, further developed, and expanded in philosophy, as some scholars have proposed theories and descriptions of attention that, in line with the field's original *modus operandi*, closely relate it to consciousness and other aspects of perception, cognition, and behavior. For example, Mole (2011a) defines attention as cognitive unison; Wayne Wu (2014) argues that it is the process of selection for action; and Sebastian Watzl (2017) claims that attention is what orders the mind.

Nowadays, studying attention has become paramount for both psychology and neuroscience due to the fundamental role current models attribute to it in cognition. Moreover, it appears to have direct implications for society. For instance, questions of selection and filtering carry significant implications and applications in education, with attentional skills serving as strong predictors of academic performance. These skills can be enhanced through targeted interventions and have been shown to influence developmental trajectories (Stevens & Bavelier, 2011; Gallen et al. 2023). Similarly, the philosophical link between attention and the self has gained new urgency in an age where our ability to direct focus is increasingly tied to well-being (Chang et al. 2004). Today, attention is the primary target of marketing and social media, as it is understood to be a form of time consumption that generates valuable data (Giraldo-Luque et al. 2020). Therefore, it is crucial that more and more researchers—especially philosophers —critically examine how this phenomenon is studied, contribute to the ongoing debate, and work toward deepening our understanding of it.

3. Some epistemological problems

Despite its apparent fruitfulness, the study of attention is fraught with inconsistencies. As Sabine Kastner and Anna Nobre (2014, p.5) point out, there is no scientific or philosophical consensus on a comprehensive and consistent definition of the phenomenon. Hence, contemporary authors are compelled to interpret it on their own terms (Divjak 2019, p.163). Indeed, even outside the experimental branch of the field, theorists and laypeople often conflate features of attention with other aspects of cognition, treating them as interchangeable (Nobre 2018, p.244).

In a recent meta-analysis, Bernhard Hommel and colleagues (2019) sought to explore the diversity of distinct abilities currently attributed to attention by psychologists and neuroscientists. Among other observations, the authors identified a worrying number of attributions that very likely do not even share the same mechanistic and/or functional basis, and in some cases even referring to clearly distinguishable cognitive processes (Hommel et al. 2019, p.2290). More recently, following an assessment of this same scenario, Golnaz Baghdadi and Mojdeh Rajabi (2021, p.4) attempted to synthesize the various forms of attention found in the literature by grouping their different attributions into a kind of schematic framework. In turn, Hommel and colleagues concluded that it would be unlikely for attention—if treated as a clearly defined, consistent, and functionally distinctive phenomenon—to be solely responsible for all of these attributes, especially given that each appears to have diverged from the others throughout their evolution and development.

Thus, the current context seems to highlight not only epistemological difficulties surrounding the study of attention but also disagreements about what is commonly presumed to be the ontology of its target phenomenon. In fact, Hommel and colleagues concluded that, contrary to James's assertion, "no one [in the field] seems to know what attention is" (Hommel et al., 2019, p. 2288). Developing a line of reasoning originally put forward by Britt Anderson (2011), the authors observed that this plurality of distinct attributions would illustrate only one of the problems currently affecting studies of the topic. After all, imprecision and ambiguity might hinder our ability to arrive at clear, conciliatory operationalizations or definitions, thereby potentially impeding epistemic progress. Nevertheless, these issues are merely the outcome of three other problems affecting the current state of attention studies, namely: (1) the near-exclusivity of so-called "analytical approaches"; (2) a tendency toward dichotomous thinking; and (3) its circular pattern of explanation (Hommel et al., 2019, p. 2288–2303).

3.1. Analytical approaches and dichotomization

The current science of attention seems to rely heavily on "analytical approaches." In brief, this refers to the constant pursuit of exhaustive definitions and operationalizations, based on the assumption that it is essential to link observations and experimental results to underlying processes, mechanisms, or functions that are supposedly fragmentable, reducible, and dissociable. In effect, this tendency ends up guiding the very starting point of empirically grounded studies toward decomposition and reduction of observed phenomena into increasingly abstract subcomponents, rather than pragmatically focusing on the cognitive-behavioral observations and results themselves. One influential example of this kind of reasoning can be found in Eric Kandel and colleagues' *Principles of Neuroscience*:

> "[...] To understand the [...] control of any behavior it is necessary to break down that behavior into key components, to then identify the regions of the brain responsible for each component, and to analyze the neural connections between those regions." (2021, p.237).

However, a growing number of critics have pointed out that this broader trend of seeking exhaustive and dissociable definitions and operationalizations of "mental terms" has proven to be a project doomed to failure, especially given the overdetermination present in phenomena studied by disciplines like psychology (Pessoa et al. 2021). The reductive focus of "analytical approaches" has therefore fostered the *a priori* multiplication of increasingly generic definitions and operationalizations, while also encouraging another common problem in the field: dichotomization—that is, the intuitive insistence on delineations grounded in binary configuration schemes—something that perhaps persists due to the implicit operation of our discrimination and categorization biases (Carruthers 2020). However, as Anderson claims (2011, p.2), there is no guarantee that the continuous bisection of a phenomenon will provide us with both a complete and truly disjoint partition of the "relevant space." For instance, endogenous and exogenous attention are truly distinct phenomena that comprehensively encompass the objectives of the field, or are they merely parts of a single organism-environment continuum? (Parvizi-Wayne 2024).

Thus, restricted to "analytical approaches" and binary differentiations, the science of attention would tend to underestimate and overlook the existence of complex dynamics and commonalities among its supposed subcomponents and of other "mental terms," as well as their implications, leading to an easy overlap or confusion of what they refer to. In other words, the fact that we could associate cognitive-behavioral results and observations with seemingly fragmentable, reducible, and dissociable entities would not necessarily imply that their supposed underlying processes, mechanisms, or functions must share those same properties. In reality, this kind of systematic attempt at "binary delimitation/differentiation" would lead to flawed or inconsistent conclusions, incapable of providing satisfactory elucidations for the field (Hommel et al. 2019, p.2289–2290).

3.2. Circular explanations and the reification of constructs

Another issue raised by Hommel and colleagues is that, in psychology and neuroscience, attention is widely used both as an *explanandum*—something to be explained by these disciplines—and as an *explanans*—part of the explanations they provide. Consequently, when studies on the topic eventually reference each other as preceding or foundational to their own elucidations, they can result in circular arguments or even pseudo-explanations (Hommel et al. 2019, p.2289–2290). This is a critical scenario that, in Anderson's opinion, is rooted in the pre-existence of an even more pervasive issue within these sciences: the reification of psychological constructs (Anderson 2011, p.4). Broadly speaking, this refers to the premature attribution of causal agency to an abstract, instrumentally conceived entity, something common in constructs that rely on overly economical and evocative phrasing, thus hindering their literal comprehension. In our case, the reification of attention by many contemporary scholars may be contributing to the dismissal of a more conciliatory yet precise treatment of the phenomenon, allowing it to be—on a case-by-case basis—axiomatically assumed as something obvious, concrete, and intuitively well-defined, capable of exerting causal influence.

As Adam Frank and colleagues observed (2024), this is actually symptomatic of a kind of "bifurcation of nature" that occurs across all sciences. Such a bifurcation begins with the surreptitious substitution of complex, tangible, and observable events with abstract, idealized, and often decomposed constructs. These constructs are manufactured within a scientific context and do not correspond to lived reality. Thus, the constant use of such abstractions has eventually led researchers to mistakenly replace concrete phenomena with these constructs and to believe—implicitly or explicitly—that they accurately represent subjective, lived experience. In the case of attention, the bifurcation of nature has historically led to what the authors call "an amnesia of experience", a scientific context that, across generations of researchers, opens up an enormous gap between the phenomenon they are supposedly studying in the laboratory and the subjective experiences that initially sparked the research (Frank et al. 2024, p.14). It is a gap that minimizes the importance of critically examining the constructs used in research and ends up obscuring any prior theorization and underlying philosophy.

Remember, for instance, that James treated attention as a psychological process. However, as Vincent Di Lollo noted (2018), much of what followed in its study was a proliferation of different ways of conceiving it as something both capturable and deployable. The very idea that attention functions as a filter, a resource bottleneck, or a spotlight—which became popular with the engineering models of the late 1950s—suggests that it acts not only as a causal agent but also as something precisely located somewhere in the brain. But while defining attention in metaphorical terms such as these has, indeed, enhanced our intuitive grasp of the phenomenon, it has also increased the semantic ambiguity surrounding it, hindering proper scientific understanding. In the author's view, the main problem is that such usage of psychological constructs has led research astray, given that scientists often use metaphors as analogies, treating things that are actually dissimilar as similar in specific, clarifying ways. For Di Lollo, this has misled the science of attention with a "sensation of illusory depth" while failing to properly specify what underlying mechanisms mediate the metaphorized function in the real-life phenomenon the field was supposed to study (Di Lollo 2018, p.46).

Therefore, it becomes difficult to determine whether, in the current state of our knowledge, attention is better understood as something that needs to be explained by psychologist and neuroscientists or as something employed in their explanations, especially without resulting in circular reasoning, where it and its possible subcomponents are both presumed and investigated (Hommel et al. 2019, p.2290). All signs suggest that the distinctions and categorizations currently underpinning the constructs and guiding the frameworks of our scientific elucidations may not be fully adequate, and therefore be one reason why there is so much academic confusion about the topic. As a result, the emerging challenge is to explore, in a rigorous and relatively comprehensive manner, whether there is a better way to approach, define, and operationalize attention—rather than merely limiting ourselves to the tendencies and axiomatic assumptions dominant in its current field of study (Anderson 2011, p.1–2).

3.3. Digging deeper

Notably, the ambiguities and imprecisions characterizing the field seem to have led Anderson to argue, more recently, that a parsimonious reading of the issue would support the conclusion that we should simply abandon the construct (Anderson 2023). Similarly, Di Lollo now considers attention a sterile concept, useless in scientific descriptions of events (Di Lollo 2018). In Anderson's opinion, eliminating the term could facilitate a pragmatic redirection of academic focus toward contextually observing behaviors that can be categorized as attentional (Anderson 2023, p.3). More radically, Luiz Pessoa and colleagues have even argued that all so-called "mental terms" should be excluded from scientific research, as they are epistemically sterile and do not reflect the complexities of our neural and bodily architectures. In the case of attention, the authors suggest that it would be more productive for researchers to investigate organisms' "selection mechanisms" instead (Pessoa et al. 2021, p. 16). More recently, Ruth Rosenholtz (2024) has even prohibited the use of the concept in her lab and, following Di Lollo, claimed that the neuroscience of vision does not need it at all, questioning whether it is necessary in science at large.

However, forcing the elimination of constructs or abstract entities requires a radical shift in the self-understanding of the very disciplines that study or employ them, and therefore this does not appear to be a viable strategy (Pigliucci 2020). Instead, it might be more feasible to follow the recommendations of some of the field's most prominent critics and restructure our understanding of attention by first shifting our focus to more basic levels of analysis. This would allow us to address the real complexity of the subcomponents currently associated with attention without confusing or inadvertently conflating our terminology with what it refers to (Pessoa et al. 2021, p.16). Such an exploration could help accurately map what is most centrally related to the phenomenon in question, making it possible to discard peripheral associations and focus on those indispensables to the scope of our analyses (de Waal & Ferrari 2010). In other words, while likely unable to solve all the problems discussed here, this approach might foster the emergence of more robust theories of attention, as it would allow us to treat it based on assumptions that are not only generalizable but also potentially simpler, more concrete, and easier to define and operationalize (Anderson 2023, p.4).

With this landscape in mind, it has been recognized that "helping scientists clarify boundary questions or those that transcend the traditional limits of their disciplines"—along with elucidating issues overdetermined by empirical evidence and guiding the accommodation of alternative interpretations often neglected by the sciences— "is a function of philosophy" (Pigliucci 2019, p.16). Therefore, we believe that the critical scenario currently characterizing attention studies is an extremely fertile ground for philosophical reflection and engagement. In particular, the subfield of philosophy most focused on the kind of interdisciplinary dialogue implied here is non-reductive neurophilosophy, which seeks to develop philosophical insights based on data from sciences that empirically study the brain and behavior, and then reintroduce such developments in a way that establishes a virtuous, symmetric feedback loop between the work of philosophers and scientists (Gouveia 2022, p.181-227).

4. Changing perspectives on attention

According to critics, then, the first practical step to avoid dissonances similar to those already present in the field would be to de-emphasize anthropogenic approaches in the study of attention. This means moving away from intuitively discriminated and categorized conceptions when delineating possible subcomponents. Instead, the focus should shift toward promoting biogenic approaches, which prioritize the analysis of fundamental processes, mechanisms, and functions. These are then subsequently integrated and elaborated into generalizable and empirically well-founded constructs, taking into account their evolution and development (de Waal & Ferrari 2010).

Anthropogenic approaches typically originate from hypotheses based on generic categories and discriminations rooted in our own intuition and self-characterization. Historically, this type of approach became the *status quo* in psychology because it facilitated the comparison and identification of possible convergences and similarities between human behavior and that of other animals, using constructs derived from our own self-understanding (Gardner & Gardner 1969). However, this has proven to be unnecessarily limiting. After all, it seems unreasonable to expect non-human animals to possess dispositions that are sufficiently traceable and measurable through anthropocentric and anthropomorphic categories (Barrett 2020). In other words, it is more plausible to conjecture that evolution endowed them with their own unique configurations which, in their own way, are likely as rich and complex as ours (Povinelli 2000; Silk et al. 2005). From this conclusion, a growing number of scholars are opting for biogenic approaches, which are typically conducted through an evolutionary framework. That is, the use of etiological tools and reasoning seems to allow for better comparative theorization of the core subcomponents involved in cognitive-behavioral analysis, exploring how these may have evolved and diversified while also accounting for the inevitable constraints and adaptations that emerged at each stage of their developmental history (Cisek 2019).

Given the objectives of the present article, this seems to indicate that a suitable starting point for a non-reductionist neurophilosophical exploration of attention would be the most basic forms of orientation and control in the interaction between living beings and their environments—whose main aspects are more commonly explored through the principle of organism–environment co-determination (Corris 2020). According to this principle, living beings can be defined as thermodynamically open, autopoietic systems that are "far from equilibrium." That is, systems that, through their interactions and transformations, continuously regenerate themselves, forming relational networks that produce their own constitutive states, thereby composing locally concrete units that are always striving to maintain their thermodynamic equilibrium (Varela 1979).To maintain this, organisms must rely on their interactions with the environment, navigating it in such a way that they revisit, over time, homeostatically favorable states, even in the face of continuous and random environmental fluctuations. And in doing so, they modify their environment and their relationship to it, which, in turn, modifies what they are able to perceive from it—in a process of co-determination that lies at the heart of the perception–action cycle of all living beings (Friston, 2005; 2010).

From this, it becomes possible to deduce that, for an organism's internal dynamics, the niche it inhabits—that is, the portion of the environment accessible to it—would be nothing more than the consequences of its own actions, as captured through its sensory inputs. These inputs, in turn, would strictly depend on what is afforded by a habitable environment. Thus, we cannot speak of an environment without an organism acting within it, since, according to this principle, living beings bring forth the very environment in which they dwell (Maturana, 1987). Consequently, there is a kind of coupling between organisms and their environments, with the existence of both, as relatively concrete and well-defined entities, depending on—and varying with—their cyclical and dynamic interrelations.

Here, any action taken by an organism within its niche will depend, first and foremost, on its phenotypic constraints, such that these end up creating interrelational regularities with the environment. These regularities draw the organism toward a specific set of environmental conditions that it is likely to encounter throughout its life (Sims 2021, p.XXXI). These can then be understood as a map of its niche and of its behavior within it. And because they establish an indirect mapping of the interaction, over time, between organismic and environmental dynamics, these maps can also be interpreted as a record of the outcomes of something like the organism's "sub-personal estimations" regarding the environmental causes of changes in its constitutive states.

However, drawing from increasingly popular predictive frameworks for the study of cognition, a growing number of scientists and empirically grounded philosophers have argued that the existence of such a record would allow us to understand the internal dynamics of living beings as performing inferences about their niches (Corcoran et al. 2020). The fundamental observation here is that, thanks to this inferential character, organism-environment co-determination would provide a predictive/anticipatory "nature" to the internal dynamics of living beings and, consequently, their behavior. This, in turn, would be what enables organisms, throughout their evolution and development, to respond to potential disturbances from their environment or to avoid physiologically stressful and homeostatically destabilizing conditions even before they occur, that is, to proactively preserve their thermodynamic equilibrium through allostasis.

Up to this point, the elucidation provided by the principle of co-determination sheds light on the origins of the perception-action cycle by describing organisms that, in order to survive, must maintain their thermodynamic equilibrium in the face of environmental fluctuations and, in doing so, distinguish themselves from and gain a certain degree of autonomy over their surroundings. However, to maintain this equilibrium, living beings must act within—and upon—their environments, and by doing so over time—both ontogenetically and phylogenetically—they end up mapping the inter-relational regularities of their niche, giving precedence to those that are favorable to their existence. In this context, what the usage of predictive frameworks would allow us to propose is that, as their actions are progressively optimized in relation to this attractor set of environmental conditions, organisms become better able to infer and, therefore, anticipate, the causes of the effects their environment produces on their sensory apparatus.

Logically, it's evident that, at this initial scale of analysis, the level of granularity required for a non-reductionist neurophilosophical exploration of the various particularities commonly grouped under the label of attention does not yet exist. After all, such a preliminary description provides only the normativities and regularities that seem to guide the general functioning of all living beings, endowing them with a very basic form of predictive/anticipatory vigilance within their respective niches.

However, we can observe that its focus on the importance of sensory preparation and anticipation for survival, adaptability, and, consequently, the evolution of organisms, already resonates well with part of what is traditionally attributed to attention by the line of reasoning initiated by James, Wundt, and Helmholtz. That being the case, it remains for us to outline how a cautious extension of such a description to the cognitive-behavioral scale of analysis could guide the first steps of a symmetric, neurophilosophical integration of neuroscientific, psychological, and evolutionary evidence. To this end, we will turn to the illustrative case of a particularly popular predictive framework, Active Inference, and how its biogenic assumptions would justify such endeavor.

5. Rethinking attention

More specifically, Active Inference posits that the internal dynamics of organisms can be understood as implying a kind of implicit generative model of their niche, aimed at predicting and coping with incoming sensory information (Linson et al. 2018, pp.2–3). In this scenario, the minimization of prediction errors—that is, the adjustment between this model and the information received from stimuli—occurs in two distinct yet related ways: (1) the organism adjusts the "predictions" contained in its model regarding relevant environmental variables through what is called "perceptual inference"; or (2) it modifies the sensory information itself by acting upon its niche to bring received stimulations closer to what is predicted by its model, proactively increasing its consistency through what is commonly referred to as "(en)active inference." Based on the principle of co-determination, this suggests that, to maintain their thermodynamic equilibrium, living beings must preserve the alignment between their implicit models and the niches they aim to predict. Any significant discrepancies must, in the long term, be minimized if they are to survive (Waade 2020, p.7–11).

From our perspective, it is important to emphasize that this foundational assumption is currently being extended to elucidate the evolution, development, configuration, and function of biological systems across different spatiotemporal scales. This ranges from microscopic phenomena to intermediate levels of analysis, and even to broader, large-scale processes envisioned as metanarratives for scientific and philosophical inquiry. And while at first counterintuitive and obscured by its formalism, the logic driving these generalizations is simple and straightforward (Ramstead et al. 2018, p. 2–3): (1) to maintain its integrity as a relatively well-bounded thermodynamic system, any biological entity must, in the long term, limit the entropy of its own constituent states; (2) given that the existence of such a system can be defined as the probability of it remaining, over time, within its relatively narrow set of potentially adequate constituent states, limiting its entropy necessarily corresponds to maximizing that probability—which is equivalent to minimizing its statistical *surprisal* (i.e., the likelihood of being in an undesirable state); (3) by extension, any living being needs, over time, to minimize its *surprisal*. And this can be achieved precisely through the minimization of prediction errors—both directly, through (en)active inference, and indirectly, through perceptual inference, limiting the occurrence of undesirable states by reducing significant divergences between its model and the niche it aims to predict; (4) finally, this survival through the minimization of prediction errors can be conceived as a process of optimizing implicit models, stimulating their adaptation through the progressive incorporation of the causal relationships of their niches (Friston, 2010; Hohwy 2013).

Therefore, for any living being, its very biological inheritance, embodied and relatively stabilized through its lineage or species, can be understood, within its niche, as part of a model for predicting sensory information. And, indeed, most philosophers and scientists aligned with Active Inference tend to assume that, to facilitate their survival and development, living beings would inherit—both phylogenetically and ontogenetically—much of what they need to anticipate and reshape their ecosystems, or at least to learn how to do so (Linson et al. 2018, p.2). This insight, when reconciled with available empirical evidence, offers a new perspective on the emergence, scope, and role of possible cognitive-behavioral processes, mechanisms, and functions that, throughout evolution, assisted organisms in coordinating and navigating their niches—including what we commonly label as attention.

5.1. Active Inference and the embodied neural architecture of attention

Recall that, in order to limit the entropy of their constituent states, every living being ultimately has to deal with the fundamental issue of controlling and regulating its vital parameters. According to Active Inference, although there are several examples of organisms capable of surviving in their environment without possessing a nervous system, the need to address complex adaptive problems may have exerted strong selective pressure for the implementation of models capable of incorporating such complexity and enabling increasingly sophisticated inferences, thereby driving the development of dynamics made possible only by the brain (Pezzulo & Friston 2022). This, in turn, would allow for greater control and regulation of behavior, enabling living beings to skillfully navigate their niches.

This observation, that brains evolved to guide and control action, has been repeatedly reintroduced for over a century through the work of philosophers such as John Dewey (1859–1952), George Mead (1863–1931), Maurice Merleau-Ponty (1908–1961), and, more recently, Andy Clark. Yet, despite its long-standing tradition in philosophy—and with the notable exception of the psychologies of Jean Piaget (1896–1980), James Gibson (1904–1979), and William Powers (1926–2013)—it has, to this day, not significantly impacted the self-understanding of the evidence produced by psychologists and neuroscientists (Kelty-Stephen et al. 2022, pp.30–31).

This is a curious fact, especially given that this perspective was not only shared by the pragmatism that dominated much of Anglo-American experimental psychology during its first half-century of existence (Anderson & Chemero 2017), but also converges with the teachings of one of the pioneers of neuroscience, Santiago Ramón y Cajal (1852–1934). For both, differences between brain regions should not be taken as indicators of intrinsically distinct functions or structurally localizable "mental terms," but rather as evidence of a plurality of ways to coordinate a single task: the proactive establishment of functional couplings between an organism and its environment (Cajal, 1904, p.9). Here, the importance of the phenotypic expression of living beings cannot be overstated, since "the general functioning of the brain is achieved through the establishment of a hierarchical continuum of processes fundamentally oriented toward the embodied action [of organisms] and intended to provide them with an advantage in the struggle for survival" (Cajal 1904, p.16). The pressure for precedence of the way in which beings endowed with a nervous system actively engage with their niches would then eliminate the need for the specialization of multiple substructures to do so distinctively (Anderson & Chemero 2017, p.6).

Based on these considerations, the insistence on using broadly distinguishable "mental terms" indeed risks becoming an epistemically sterile endeavor. All evidence suggests that evolutionary pressures shaped the internal dynamics of living beings to actively deal with a vast amount of information in ways increasingly integrated with the relationships between their environment and corporeality. Thus, it would be the organism's general phenotype—rather than supposed cognitive-behavioral substructures—that primarily supports the degree of "flexibility" necessary to cope with complex and constantly changing environments—something that is far from corroborating the anthropogenic boundaries of our current psychological constructs (Pessoa et al. 2021, p.2). Here, what Active Inference allows us to clarify is that the fundamental drive to minimize prediction errors—acting from very early on and in similar ways across various contexts and distinct points in the evolutionary history of living beings—is what guided such a configuration. In other words, the gradual evolution of the organisms' embodied neural architecture would have proceeded in such a way as to continuously replicate the same predictive/anticipatory scheme, which would have enabled, at different times and in different ways, the establishment of sensorimotor contingencies capable of sustaining perception-action cycles in diverse, increasingly complex, contexts—in a process that is currently imprecisely fragmented and categorized into different "mental terms" (Pezzulo & Friston 2022).

5.2. Visual attention from bodies to brains

Here, it might be useful to take an illustrative example. An anatomical development classically considered a primary precursor—and eventual enabler—of the anticipatory engagement of organisms with their world was the emergence of the visual circuit. This originally consisted of projections from a photosensitive cell cluster located in the tectum of the midbrain—a kind of neural tube extending to the spinal cord—enabling the occurrence of visually guided locomotor reactions (Lacalli 2018). In later animals, this cluster developed into two lateral photosensitive patches, optimizing reactions to salient visual stimuli, such as the shadow of a predator. As these patches evolved into ocular lenses and the tectum expanded in parallel toward the sensory periphery, organisms became capable of performing topographic mappings of incoming stimuli, and, ultimately, of their world. This enabled them to generate a sort of guiding model for possible responses to destabilizing stimuli they eventually encountered (Hommel et al. 2019, p.2294).

However, as we have mentioned, this sort of mapping not only favored the preparation and optimization of responses to stimuli but also eventually enabled the anticipation of threats and conditions that contributed to the survival of these organisms.

Here, the anticipatory preparation of reactions to favorable stimuli and conditions would provide organisms with affordances, as it gives them the ability to select or facilitate what is homeostatically relevant and discard or inhibit what is not. Interestingly, this foundational selection process—made possible by the ancestral development of the tectum—already appears to encompass many of the processes and functions that psychology and neuroscience currently attribute to selective attention (Hommel et al. 2019, p.2296). In other words, the distributed and embodied action of the tectum would be homologous to what is now commonly attributed to the activation of the human superior colliculus, a brain region thought to be responsible for orienting the eyes and head via muscle action, as well as controlling focus through pupil constriction when our gaze is fixed on something (Basso & May 2017).

The evolution, sophistication, and diffusion of the nervous system—especially among vertebrates—would have also allowed for a significant increase in the complexity of organism-environment relationships. With the expansion of the cortex (particularly the prefrontal neocortical regions), the behavioral repertoire and regulatory capacity of living beings also expanded, allowing for the enhancement, differentiation, and specialization of reaction-guiding models into increasingly complex action maps capable of proactively favoring relevant stimuli and conditions (Andersen et al. 1997). This means that the same schema that drove the ancestral formation of a distributed and embodied system of visual orientation and reactive stimulus control would have enabled more sophisticated organisms to engage in a myriad of visually guided proactive behaviors.

Interestingly, this could help explain why, in most terrestrial mammals, the processes and functions underlying what is commonly categorized as attention share the same mechanisms responsible for promoting the visual selection of a target and the tactile discrimination of what to reach for and grasp (Corbetta et al. 1998). That is, analogously to the two distinct yet related forms of prediction error minimization, selecting targets within predictable contexts implies that organisms operate within their niches not only by exploring and optimizing their internal maps but also by imposing these maps upon the world, modifying the environments in which they are embedded and promoting the creation of increasingly favorable niches for their existence.

In short, the continuous drive for survival seems to have fostered the development of organisms with high levels of complexity that, in order to maintain their thermodynamic equilibrium, must act predictively upon their environments. The emergence of a visual circuit would have enabled living beings to do so through a structure oriented toward embodied action. Over time, such actions allowed for the exploration of new possibilities of interaction while also ensuring the establishment of regularities necessary for fulfilling the organisms' tendency to remain in favorable conditions. The later development and expansion of the cortex enabled better mappings of these conditions, as well as a broader behavioral repertoire for both responsive and proactive actions aimed at promoting them. Finally, these interrelational regularities ended up enabling organisms to optimize their prediction/anticipation mechanisms and processes, equipping them to better manage environmental fluctuations and avoid physiologically stressful and homeostatically destabilizing conditions during niche exploration. Broadly speaking, then, from a biogenic perspective, all evidence suggests that the subsequent expansion of the prefrontal neocortical regions of the vertebrate brain occurred in such a way as to equip these animals with a myriad of embodied strategies to better navigate and select these environments and conditions. In other words, a variety of policies whose common denominator would be the facilitation of visually guided interactions with objects in their complex world (Cisek 2007), which are, today, grouped under the label of visual attention.

5.3. Toward a non-reductionist neurophilosophical exploration

From this background, it can be suggested that the evolutionary history of organisms has been co-delimited both by the ecological pressures they faced and by the predictive schemas available to them, given their evolutionary trajectories. Thus, a non-reductionist neurophilosophical exploration could proceed through a logic of gradual development in the capacity to resolve increasingly complex cycles of prediction error minimization—an ability that would have allowed animals, throughout their evolution, to extend their predictive and anticipatory dynamics, from the control of their physiology to the cognitive-behavioral management of the environments they inhabit (Pezzulo & Friston 2022).

In this context, pressures favoring the development of an active architecture increasingly integrated within the relationships between embodiment and environment would have rendered unnecessary the evolutionary emergence of dissociable and distinctly specialized substructures for revisiting favorable environmental conditions. Since co-determination and Active Inference emphasize how fundamental this task is for living beings, it seems unlikely that it would have eventually been delegated to a unique and characteristically identifiable subset of interspecific processes, mechanisms, or functions.

Convergently, it would be difficult to conclude that what is centrally attributed to attention—which, by all indications, refers to the intermodal facilitation of this basic drive in complex organisms—could be located within specific neural or cognitive-behavioral subcomponents. On the contrary, if this narrative is correct, attention would not possess the fixed contours of a "mental term," but rather the volatility and multiple realizability of a family of behaviors that, in certain contexts, embodied brains enable living beings to perform (Hommel et al. 2019, p.2297–2298).

In summary, much like action, many of the processes currently attributed to attention appear to be crucial for the survival of organisms, with both being intimately connected—not only to one another but, very likely, to the broader range of embodied, multimodal strategies. Therefore, if it is true that brains evolved to guide and control action, then attention emerged to assist them. Consequently, it may refer to something far more foundational, pervasive, and complex than what its current field of study typically envisions. This is a remarkable conclusion, the detailing, empirical grounding, and primary implications of which still require adequate investigation, an endeavor that, by all indications, could be undertaken by future in-depth neurophilosophical explorations.

6. Concluding remarks

In the current article, we addressed some enduring epistemological problems involved in achieving a comprehensive and consistent understanding of attention. Beginning by tracing the historical roots of its scientific study and then critically analyzing its inherent internal inconsistencies, we argued that this worrisome scenario mostly arises from prevailing analytical approaches, dichotomous thinking, circular explanations, and conceptual reifications. Our central argument posits that such issues are rooted in the field's underlying reductive set of anthropogenic assumptions. To overcome these limitations, we proposed a significant shift toward a non-reductive, biogenic approach. Building on this, we explored how frameworks such as Active Inference allow us to reconceptualize attention less artificially, as a complex, embodied process of dynamic optimization, crucial for organisms to maintain thermodynamic equilibrium and guide adaptive behavior within their environments.

With this in mind, it is important to conclude with a brief contextualization of our proposal. Throughout the article, we recommended redirecting the focus of attention studies toward more foundational levels of analysis. To that end, we advocated the use of evolutionary thinking as an ideal guide, aligning ourselves with the current neurophilosophical preference for considering phylogenetic trajectories as the standard tool for theorizing about the cognitive-behavioral functioning and structuring of living beings (cf. Pessoa et al. 2021; Kelty-Stephen et al. 2022; Pezzulo & Friston, 2022). Thus, we strongly believe it is possible to conclude that, just like their morphology, the behaviors and overall phenotypic expressions of animals are shaped by evolution. And while this etiological reasoning is best conceived as a heuristic or provisional speculation, its instrumental use has already proven to be an effective starting point for philosophical inquiries capable of fostering experimental advances and the progress of knowledge (Hubálek 2021, p.453).

It is also undeniable that the kind of exploration outlined here echoes the broader contemporary landscape of increasingly popular biogenic proposals in comparative psychology and neuroscience. Also, a striking parallel can be drawn with the growing number of contemporary philosophers—guided by a pragmatic and radically embodied reading of the cognitive sciences—who have pointed to the "epistemic sterility" of anthropogenic approaches based on "mental categories" derived from our self-understanding of beliefs and behaviors (cf. Stewart et al., 2010; Thompson 2010; Anderson & Chemero 2017). According to this perspective, evolutionary pressures have shaped the cognition and behavior of living beings to promote survival in ways that are adaptable and strongly context-sensitive. This implies a dynamic architecture that hardly conforms to the constraints imposed by our "mental terms" (Pessoa et al. 2021, p.1). From this, a radical conclusion follows: both psychology and neuroscience should shift their focus to investigating how the coupling of widely embodied and integrated neural circuits with a constantly changing environment enables the natural realization of complex behaviors (Kelty-Stephen et al. 2022). At first sight, these all appear to be converging perspectives, given that what has been proposed by most biogenic approaches appears to be fully aligned with the dynamic holism inherent to frameworks such as Active Inference (Pezzulo & Friston 2022). Thus, a deeper neurophilosophical exploration of the topic may serve as a concrete example of the potential and limitations of relatively recent, pragmatic, and radically embodied orientations in both science and the philosophy of cognition.

Finally, it is important to highlight how endeavors like the one outlined in this article exemplify one of the key ways in which (neuro)philosophy contributes to scientific progress. Despite a few exceptions, psychologists and neuroscientists often fail to adequately recognize the role of philosophical reflection in their experimental work. Yet, as we have seen, this *modus operandi* can result in epistemological disagreements and ambiguities regarding complex topics such as attention. Here, philosophical incursions into the knowledge produced by these sciences could mitigate such detrimental effects by clarifying the true complexity and implications of the multiple scales and perspectives involved, ultimately fostering a virtuous circle between the work of philosophers and scientists. After all, the example of internal neglect within current attention studies highlights the serious consequences of ignoring the maxim once stated by Daniel Dennett: "There is no such thing as philosophy-free science; there is only science whose philosophical baggage is taken on board without examination" (1998, p.22).

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Notes

[1]The way the world appears to us in our daily lives (van Fraassen 1999).

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