The Role of Information in Consciousness

Corresponding author:

Harry H. Haladjian

ORCID: https://orcid.org/0000-0002-1784-3050

Address: Amsterdam, The Netherlands

Carlos Montemayor

ORCID: https://orcid.org/0000-0003-1786-6612

Address: Department of Philosophy, San Francisco State University, 1600 Holloway Avenue, Humanities Building, Room 388, San Francisco, CA 94132, USA

Abstract

This paper comprehensively examines how information processing relates to attention and consciousness. We argue that no current theoretical framework investigating consciousness has a satisfactory and holistic account of their informational relationship. Our key theoretical contribution is showing how the dissociation between consciousness and attention must be understood in informational terms in order to make the debate scientifically sound. No current theories clarify the *difference* between attention and consciousness in terms of information. We conclude with two proposals to advance the debate. First, neurobiological homeostatic processes need to be more explicitly associated with conscious information processing, since information processed through attention is algorithmic, rather than being homeostatic. Second, to understand subjectivity in informational terms, we must define information uniqueness in consciousness (e.g., irreproducible information, biologically encrypted information). These approaches could help cognitive scientists better understand conflicting accounts of the neural correlates of consciousness and work towards a more unified theoretical framework.

Keywords: attention, consciousness, dissociation, information theory, neural correlates of consciousness

1. Introduction: Is "consciousness without information" the same as "consciousness without attention"?

In the attempt to better understand phenomenal consciousness, the relationship between consciousness and attention has been examined more critically in the past decades. There is an ongoing debate about the nature of this relationship, with some theorists arguing that consciousness cannot exist without attention (Dehaene & Naccache, 2001; Mashour et al., 2020; Prinz, 2012; Tononi, 2012), and others arguing that attention is not sufficient or even necessary for consciousness (Koch et al., 2016; Lamme, 2018). This controversy may rely on how one defines attention (Montemayor & Haladjian, 2015). Those that argue for consciousness without attention (e.g., Block, 2014; Koch et al., 2016; Lamme, 2018; Tsuchiya & Koch, 2016) use a high-level definition of attention that does not include all types of attentional processing (Montemayor & Haladjian, 2019). This is a narrow conceptualization of attention, which should be defined to include all forms of selective information processing (see Section 3). Indeed, a central component of attention is information processing, which has been studied extensively in psychophysics and neurophysiology. While informational accounts of consciousness have also been proposed, particularly in neuroscience, the *informational relationship* between attention and consciousness has not been fully defined. The goal of this paper is to help clarify this relationship by focusing on the information that is unique to these systems. Our key claim is that conscious information processing is maintained similarly to homeostatic systems, while attention processing is goal-oriented, selective, competitive, and has a systematic input-output structure.

With the growing empirical studies of phenomenal consciousness in cognitive neuroscience, two conditions have been assumed as fundamental in this research. One of these conditions is that it is important to identify the neural correlates of consciousness (NCCs) (e.g., Koch, 2018). This assumption derives from the nature of the functional and neuroanatomical techniques that are used to localize and identify the realizers of various cognitive informational processes (e.g., attention, memory, visual cognition). Another inherent condition is that attention is necessary for consciousness but differs from consciousness with regards to the neural networks that support it, since most of attention occurs at early stages of information modulation and neural activation, mainly outside of awareness (Kentridge, 2011). In fact, this second assumption is presupposed by many scientific views of consciousness (e.g., Baars, 2005; Dehaene & Naccache, 2001; Lamme, 2006; Mashour et al., 2020; Tononi, 2012) and seemingly most philosophical theories of consciousness (e.g., Brown et al., 2019; Dennett, 2018; Lau & Rosenthal, 2011; Prinz, 2012; Rosenholtz, 2020). There is a powerful reason behind this viewpoint: If the NCCs that support information processing in consciousness were identical to the neural correlates of attention, then studying attention would tell us everything about phenomenal consciousness.

These two assumptions also present a difficulty for research on phenomenal consciousness because they entail an *informational*, rather than strictly anatomical, difference between consciousness and attention. Since it is likely that attention is necessary for consciousness (Cohen et al., 2012; Prinz, 2012), anatomical differences are only explanatory if there is a distinct type of informational processing that only NCCs can perform. We argue that such an informational difference has not been explained or described carefully by any current theory of consciousness. Addressing the informational aspects of related processes seems to be the only way of confronting the following tension in contemporary debates on consciousness: How could all theories of consciousness assume a sharp distinction from attentional correlates and yet differ so drastically about the NCCs? The goal of this paper is to present this informational challenge as clearly as possible, and propose that phenomenal consciousness crucially depends on informational processes related to neurobiological homeostasis (with interoceptive and visceral signals about this status) as well as “traditional” information processing by sensory mechanisms and all forms of attention associated with those processes.

Let's start with a seemingly simple question: What role does information[1] play in *phenomenal* consciousness (i.e., the subjective and qualitative character of conscious experience)? It seems like a question with an obvious answer: information must provide the contents of conscious experience. Consequently, the main purpose of neural structures supporting consciousness is to process this information. Could we have any sort of qualitative experience that is entirely void of some kind of information (interoceptive, sensorial, perceptual, or cognitive)? The nuance of this question lies in not only examining the informational contents of phenomenal consciousness but also defining the specific *role* that information plays in it.

Information processing occurs in all living things, ranging from signal detection in simple organisms to conscious attention in more complex organisms such as humans. This information can be processed (e.g., enhanced or suppressed) by different sensory modalities, such as auditory, visual, and proprioceptive. These different forms of information are not always at the forefront of phenomenal experience, but they exist due to systematic biological processes, namely attentional processes. Ultimately, the processing of information is crucial for interactions in any environment.

Therefore, we must frame the study of consciousness not only by defining how it relates to better-understood brain processes that support it, but also by identifying the *unique information* that it contains, beyond what can be described by attentional processes. Thus, we pose the following question: Does phenomenal consciousness possess distinct information that cannot be accounted for by attention? Assuming that phenomenal consciousness is informative, as is

[1] Provisionally, by "information" we mean the process of reducing uncertainty and the elements this process involves. A state with less uncertainty is more informative than one with more uncertainty. This definition has limitations, e.g., it assumes a particular method for determining uncertainty of an epistemic or metaphysical kind. Nevertheless, it captures the general aspect of information we will examine, which includes all forms of attentional processing, including rudimentary ones such as signal detection.

the general consensus among theorists of mind, then there must be some unique information it provides to an organism's functioning that adds to attention's fundamental informational role. Otherwise, why would we have it? Our focus here is not on the existence or dualistic aspect of consciousness *per se*, but on whether or not there is something irreducible and unique about conscious information, if any of it lies outside of attentional processes, and if so, what this is.

Anatomically, the brain areas in which various attentional systems process information are generally well understood and identified (e.g., see Carrasco, 2011; Montemayor & Haladjian, 2015; Wu, 2014). Since attention is based on information, we can start with a basic assumption:

(1) *Attention – Information* = $\varnothing$

Given that attentional processes necessarily entail information, then removing information from attention would leave "nothing". There may be some residual information within the mechanisms of attention (e.g., neural codes, cellular structures), but nothing that counts as attentional information. Attention is the capacity organisms use to select and contextualize information for decision-making and acting—without it, information could not be processed in a meaningful way. It is important to note again that we assume information processing depends on all forms of attention, including simple signal detection (which arguably is a precursor to attention with its purpose of processing information).

Now let us consider phenomenal consciousness without information. What happens when we take all information away from consciousness? We may or may not have "something" left over. We can formulate this possibility in this axiom:

(2) *Consciousness – Information* = X

Where X is essentially consciousness without informational content. Since consciousness is said to be uniquely informative, this operation should result in: $X = \varnothing$; however, this is an open question.

Another way to formulate the uniqueness of consciousness is to define what is left when all attentional processing (or simply, “attention”) is taken away from consciousness, which also holds an uncertain result:

(3) *Consciousness – Attention* = Y

If attention is necessary and sufficient for consciousness, then $Y = \varnothing$. On the other hand, arguments for consciousness without attention inherently claim that there will be an informational value for Y. If attention does not account for all of the contents of consciousness, there will be “something left over” in this operation—a “conscious informational residue” of some sort that is not accounted for by the current theories, so that: $Y \neq \varnothing$.

In essence, our challenge lies in determining if there is more to consciousness than attention, in informational terms, which would require us to explain this relationship:

(4) $X = Y$*?*

Or in other words:

(5) *Consciousness – Information = Consciousness – Attention ?*

According to present views on consciousness and attention (e.g., Cohen et al., 2012; Kentridge, 2011; Lamme, 2004; LeDoux & Lau, 2020; Tsuchiya & Koch, 2016), this equation (4) cannot be true (i.e., they are not equal). Attention is supposed to process and contain a complete set of all information computed by a conscious system, of which only a subset is conscious information. We can see how the current theoretical views on the relationship between consciousness and attention will result in an asymmetry for (4), namely: $X \neq Y$.

While we do not claim to provide an answer to these theoretical equations, we use them to clarify the challenge for addressing this asymmetry between consciousness and attention with regards to information processing. Presumably, theories that do not find consciousness and attention to be identical informationally will have an asymmetry that requires further empirical explanation. If there is something left over that is unique to consciousness when removing attention, how do we describe this remainder, as a type of "conscious information residue" or a different type of "non-algorithmic" or non-attentional information (Y)? Some theories may add a higher-order representation, others might explain it in terms of qualitative character, but these addenda need to be specified in a way that attentional information *could not play* those roles—this is what is unique about the present challenge. Establishing a better understanding of axioms (2) and (3) should help us better understand (4) and (5).

Since attention is the primary processing system for perceptual and cognitive information in humans, then removing attention from consciousness should be the same as removing information from consciousness. In other words, "consciousness *minus* attention" should equal "consciousness *minus* information". This implies attention is *necessary* for consciousness. But is it sufficient? No, because most attentional processing occurs without phenomenal experience.

And there is also that "extra something" that presumably phenomenal consciousness adds that has not been accounted for by attention (i.e., "what it is like"), based on other information-based cognitive processes that can be modelled (Jylkkä & Railo, 2019). This is where current theories of consciousness face problems. Can we conceptualize a conscious experience that lacks any information processed by attention and other information processing systems (including interoceptive and proprioceptive systems)? It may be hard to imagine, but it is important to try. Otherwise, the claim that consciousness is extremely and uniquely informative, or even plainly informative, is unjustified because its informational role would be *entirely* played by attention.

Thus the challenge we present asks whether phenomenal consciousness is informative or not—beyond attention—and what is meant by this. If it is informative, one should be able to tell what kind of information is at stake, since it presumably has a physical instantiation (Landauer, 1991, 1996). If consciousness is not informative, then one has the problem of explaining the significance of NCCs, especially those distinct from attentional systems, and how something uninformative provides us with all the *a priori* experiential knowledge, based solely on our conscious awareness. Any scientific investigation into the nature of consciousness must answer the question about the kind of information that is unique to consciousness, unless it assumes there is no unique information beyond those accounted for by attentional processes.

As we describe below, there is abundant scientific evidence confirming that attention is necessary, but insufficient, for consciousness and that the NCCs differ from the neural correlates for different types of attention. After assessing various options, we propose tentative hypotheses regarding the NCCs. The delineation between conscious and unconscious mentality suggests that informational explanations should accompany neuroanatomical ones in ways that clarify what kind of information is only present in consciousness. While there is no necessity that conscious information be processed by neurons, it is likely that conscious information will essentially involve visceral and empathic, which are the bases of subjectivity (Tallon-Baudry et al., 2018; Thompson, 2001), and are likely connected to homeostatic processes (Babo-Rebelo & Tallon-Baudry, 2019; Damasio & Carvalho, 2013) as well as emotions (Damasio, 2003, 2021; Damasio et al., 2000). Specifically, we define homeostatic processes as self-regulating and dynamic biological processes in an organism that seek stability to maintain “a life-sustaining balance”, that is, a neural and molecular equilibrium to sustain an organism’s life (Billman, 2020). From our perspective, we focus on the neural information that is transmitted between the brain and visceral systems. This favors thalamic cortical correlates as necessary, but this is still not sufficient for consciousness (Merker, 2007; Monti et al., 2015). The problem is that without a clear account of conscious information, the sufficiency claim for attention remains unverifiable. There is also the possibility that consciousness is not a unified phenomenon, with different types having different NCCs. This possibility also entails an informational difference between consciousness and attention, with consciousness regulating homeostasis in a way that cannot be modelled algorithmically like epistemic-related attentional processes. This is why we focus on this informational distinction—to better understand how information processing can unify an understanding of consciousness and attention.

An information-theoretic framework can describe perceptual or cognitive abilities, such as attention and memory, but can it also help us understand consciousness? One of the most challenging areas of research in both neuroscience and philosophy is the work trying to understand phenomenal consciousness. We believe that by understanding the role of information in consciousness, we can understand its nature more precisely, particularly in terms of the equations above. Can consciousness exist without information? Does it control information (and how is that different from conscious attention)? It is incoherent to say that something so informative as consciousness is not related at all to information processing. But where does that leave us? To begin this exploration, we first need to examine the theories and definitions of the different components that interact to produce the rich world that we experience: information, attention, and consciousness. We begin by exploring the notion of information, since it is essential for attention and consciousness.

2. Information as a fundamental component of empirical research

Intuitively, information is something that can be assessed and interpreted, which means that it can have semantic content. The successful interpreter knows more about something when it has more information about it, which implies reduced uncertainty. Information can be useful (e.g., a map guiding us to our lunch appointment) or unnecessary (e.g., a billboard advertisement trying to convince us to eat unhealthy fast food for lunch). Information can take many forms and is found organically at various levels, from the cellular level all the way up to complex physical systems. Within these different systems, signals are exchanged between specialized mechanisms that interact to encode, transmit, and decode information. These signals can be technically defined as logical states (e.g., ON/OFF) that can influence a change within the system. They can take various forms including neural impulses, molecules in DNA, or binary digital codes. The channels of transmission face capacity limitations, so these systems must optimize information in a way that allows efficient transmission, ideally free from errors or “noise”. Of course, this information need not have semantic content. Information can also be an objective component of such systems and exist independent of human interpretation.

Thus understood, information is inherently mathematical and can be formalized by probability theory, where higher probability is associated with reduced uncertainty and less probable events carry more information. Applying this framework to visual perception, we can say that more unique parts of a visual scene, such as objects occluding each other or sudden changes in the spatial relationships of object edges, carry more information than more probable visual properties, such as smooth motion or evenly textured surfaces (e.g., see Clark, 2013).

Here's where an information-theoretic framework is important for understanding the nature of our world. Information Theory was made popular by Claude Shannon in the mid-twentieth century with his description of signal processing in digital communication systems (Shannon, 1948, 1949). Since then, computing systems have advanced remarkably in their ability to process, store, and manipulate information, becoming more powerful and complex. Shannon's information-theory framework played a vital role in the development of advanced communication systems, compact computers, and artificial intelligence (see Soni & Goodman, 2017). Such systems all process and manipulate informational "bits" in organized and meaningful ways.

It is not only technology that has advanced from the formulation of an information-theoretic framework. A by-product of this Digital Revolution is its influence on the study of the human mind in the cognitive sciences. Analogies between the computer and the mind (e.g., Pylyshyn, 1984) changed the theoretical understanding of cognitive processes and have helped us model it better, influencing the neuroscientific study of perception and cognition. For example, we now have empirical descriptions of how visual attention selectively processes information in a way that enables a variety of organisms (with varying complexity) to successfully interact with their surroundings given processing constraints (Carrasco, 2011). The embodied and extended views of the mind that challenge the strictly computational and representational views also assume information processing as fundamental, both biologically and cognitively (Clark, 2013, 2017; Gallagher, 2005). Information transmission is also crucial in biochemistry and evolutionary biology (Jablonka, 2002), and supports important "transitions" in evolution, where information-processing abilities increase substantially along with a system's complexity (Jablonka & Lamb, 2006; Jablonka & Szathmáry, 1995; Szathmáry & Smith, 1995; Veit, 2022). Information theory has touched all aspects of our lives, and continues to influence theories in weighty fields such as quantum physics.

Given all the available information, it is not surprising that humans are “informavores” (Miller, 1983) and driven to constantly consume available information. This information processing can be described statistically by relating it to the amount of possible outcomes that is reduced by one bit of information, that is, “every time the number of alternatives is reduced to half, one unit of information is gained” (Miller, 1953). As with all information-processing systems, the success of human information processing depends on systematic relationships between input and output mechanisms, which inevitably face channel capacity limits in the amount of information that can be processed at once (Miller, 1956). From this perspective, attention can be measured in its ability to algorithmically process bits of information, in a reliable and computable way, but the same cannot be said about consciousness (Haladjian & Montemayor, 2016; Koch, 2019).

With respect to living organisms, information is critical for the ability to interact with the environment. This happens when external signals are processed to detect meaningful sensory information relevant to the functions of the organism (i.e., the earliest forms of attention). This in turn enables life-sustaining interactions with the environment (e.g., obtaining and eating food), which are also dependent on information processing in motor neural systems. The processing of such crucial signals for cognition and action are optimized in several ways, for example, by limiting the amount of internal states possible (i.e., reducing “free energy”) and using “active inferences” (e.g., Bayesian probability models) to predict sensory states and perception, and ultimately help maintain an equilibrium with the organism’s environment (Friston, 2010, 2012). One can argue that Shannon’s formal theory of information and Karl Friston’s predictive coding model together provide a semantics for the contents of mental states (Figdor, 2020). Yet even under this semantic interpretation of these theories, all perceptual and cognitive information is understood functionally and, therefore, best understood in terms of structured attentional routines.

Without the detection and processing of environmental information, as well as interoceptive or visceral information transmission within self-organized systems (Damasio, 2003; Park & Tallon-Baudry, 2014), living organisms would unlikely have the ability to evolve in complex environments or sustain life. Even plants process information by growing towards their energy sources of water and light, and some argue that they may do so through cognitive capacities (Segundo-Ortin & Calvo, 2019), which may describe a form of rudimentary attentional processing. And all organisms, on a cellular level, have information encoded via genetic code that evolved over time to safeguard a life-supporting transmission of information.

Because of the diverse disciplines that include information processing in their theories, the technical definition of “information” can vary greatly across these disciplines and in everyday use. In a broad theoretical sense, “information” can be defined in terms of the reduction of uncertainty within an organized system. Information, thus, can be understood as an *epistemic* term, related to the discovery of evidence and explanation. This includes data or signals that are meaningful or have the potential to convey something that is meaningful—this, of course, relies on a receiver of this information that can successfully decipher these signals or data.

There are various ways to interpret this informational framework, which can be categorized in terms of quantitative and qualitative approaches (see Adriaans, 2012). For example, Shannon’s notion of information measures it quantitatively using the physical notion of entropy, applying it to uncertainty reduction. That is, reducing signal noise will result in higher-quality transmissions and more compact information. Even quantum information, where “quantum bits” have much more complexity and capacity than bits in classical information, can be precisely measured

(Vedral, 2010). The common characteristic of these approaches to information is that physical storage, capacity, and a concrete way of identifying changes in information are all materially instantiated and mathematically modeled. Thus, these accounts of information emphasize measurement, precise quantification, and manipulability. In so far as consciousness has not yet been described in terms of precise algorithms, it is not informative in this formal way. By contrast, attention is defined functionally and can be understood from this formal approach.

From the perspective of computer science, basic units of information (binary code) can be combined in logical ways to convey information in varying complexity and forms. This makes information describable, quantifiable, compressible, and versatile. Ultimately this allows mechanical systems to not only process information but also complete a variety of goal-oriented tasks (e.g., play digital music or perform automated driving functions). Of course, describing information in this way implies that it serves a purpose for something that seeks this information, with humans being the largest consumers of information, be it perceptual, cognitive, or affective. Cognitive agents are thus intrinsically motivated to seek information and satisfy their representational needs through optimal selection processes, some of which are processes that identify important informational patterns, such as attention routines (Cavanagh, 2004; Cavanagh et al., 2001). Since attention routines are sufficient for informing cognitive agents about their environments in order to complete epistemic tasks, the role of conscious information becomes unclear (i.e., does phenomenal consciousness provide any kind of “new” information?).

Could a qualitative approach to information then account for conscious information? This approach focuses on specific types of epistemic achievements involving normative terms, such as justified belief or knowledge, or specifying differences in information from a semantic perspective (Adriaans, 2012). It is also based on quantitative transmissions of signals for their physical realization, but it fundamentally relies on a meaningful and relevant interpretation of these signals from source to recipient in order to define the reduction of uncertainty. The reduction of uncertainty is not merely measured according to a metric or formula for signal capacity, but rather according to the semantic contribution of the message to specify propositional content or a repertoire of goal-oriented behaviors. This can be modeled formally, in terms of sets of possibilities and the elimination of possibilities as a measure of gaining certainty. The more possibilities eliminated, the more informative the message is.

Thus, although the process of reducing uncertainty is central in defining information quantitatively and qualitatively, the precise way of expressing and modeling this process can vary. But here too, attention is sufficient to do all this, because it is defined in epistemic terms of elimination of possibilities according to informational goals—these are the defining parameters of attentional selection and sensitivity. In fact, attention is the best model to capture this kind of qualitative information, including knowledge and creativity (Fairweather & Montemayor, 2017).

To summarize, there are a few key points to keep in mind concerning information processing in living organisms. This involves a series of signals that are processed within a coding system that faces capacity limits in their transmission. The goal of an information system is to reduce uncertainty with regards to its signal processing in order to have relevant interactions with its environment, including maintaining homeostasis. There are different forms of signals and a multitude of ways a signal can be processed. In organisms like humans, attentional information involves intricate neurobiological signals, which can be said to have advanced the ability to optimize transmission by reducing uncertainty and becoming more efficient when facing channel-capacity limitations, especially in environments as rich and complex as that of social organisms. All related perceptual and cognitive informational functions can, and in fact are, best understood in terms of attention and can be described algorithmically. It is, therefore, unclear that conscious information could be informative without attention, or if conscious information has a role it could play on its own. We will attempt to propose how this could be possible in the next sections by differentiating the information processing in attention and other systems.

3. Perceptual and cognitive information processing relies on attention

Attention has been described as the mechanisms for selectively processing information by means of enhancing or inhibiting the neural signals in sensory and cognitive systems. Crucially, attention contextually modulates signals for decision-making, planning, and acting, which varies in complexity among organisms (e.g., simple signal detection does not have equal significance in humans as it may in ants). The information in attentional processing lies in the electrical and biochemical signals transmitted by supporting neural systems (Thiele & Bellgrove, 2018).

As mentioned above, common to all definitions of information is a commitment that information is constrained (formally or causally), algorithmic, measurably useful, and can be stored and manipulated. With regards to multicellular organisms that interact with their environment, these notions of information are sufficiently described by primitive forms of attention. This can be sensory information from external sources (e.g., visual, olfactory, auditory, haptic) or information from internal sources (e.g., proprioception, memory, visceral), all of which take the form of neurobiological signals. This attentional information processing occurs in abundance, but also faces channel capacity limitations, which is especially evident by the limited information that enters phenomenal consciousness (Haladjian & Montemayor, 2015; Kentridge, 2011; Treisman, 2006). Our brains process much more information than the bits of which we are aware.

Many have empirically and theoretically examined this important aspect of the brain, particularly within visual attention (see Carrasco, 2011), and have identified different functional roles for different forms of attention with distinct neural systems (Petersen & Posner, 2012). A classic example of attention is feature-based attention for processing specific types of basic visual information, such as color, motion, or segment orientation (see Maunsell & Treue, 2006). Another characterization of attention—spatial attention—is concerned with coordinates and involves a more distributed and integrative processing of information, which supports navigation and other goal-directed motor behaviors. A more complex form of attention is object-based attention, in which the visual system favors the selection of whole objects in a visual scene (instead of particular features), which also requires the binding of different information (features) together to ultimately construct a meaningful representation of objects (Chen, 2012; Kahneman et al., 1992; Scholl, 2001). Attended objects become the salient source of information-packaging. Ultimately, these visual representations are often linked to other information, such as those coming from other modalities (i.e., multi-sensory integration) and information from sensorimotor processing in order to help guide actions (Hommel, 2004).

What is central to all models of attention is its broad *adaptive function* of filtering information and optimally distributing resources to modulate information processing (Haladjian & Montemayor, 2015). This applies to all forms of attentional processing, from simpler “primitive” selective signal processing to highly focused attention. From an evolutionary perspective, being able to attend selectively to key aspects of the environment is crucial enough to make attention evolve across many species independently (Ward, 2013), including insects (Wiederman & O'Carroll, 2013). Most importantly, diverse species rely on the adaptive ability of attention to process contextually relevant information, which follows the complex evolutionary needs of a species. Information processing “in the wild” does not seem to be possible without the functions of attention.

While we will not get into much more detail concerning the vast literature on attention (for reviews, see Montemayor & Haladjian, 2015, pp. 25-83; Wu, 2014), there are a few theories worth noting. Christopher Mole's "cognitive unison" model of attention describes how several attentional processes can operate independently, but can only be in unison when background processes are limited (Mole, 2011). This has a reliance on inhibitory mechanisms to reduce informational demands, which may be related to the reduction of possible states (or "free energy"). Wayne Wu's view of attention as *selection for action* construes attention as an agential process (Wu, 2011). Consequently, attention is defined as guided mental action and the information that is exchanged in this guidance from input to output (or from query to solution). Other accounts emphasize the structural features of attention, such as saliency rankings in Sebastian Watzl's (2011) view. Carolyn Jennings (2015, 2020) has what is perhaps the most substantial constraint on attention, characterizing it as the basis of the self—a non-illusory, attention-based kind of self. This subjective view takes us to the other end of the spectrum, far from where we began when describing attention as a more computational selection of information. But even here, Jennings defines the attentive self in terms of neural activations and concrete information processing in attentional brain circuitry.

Regardless of how attention is defined, it is always an information-processing capacity that satisfies representational and epistemic needs. Attention selects information, makes it salient, solves problems of relevance, elicits optimal responses (e.g., behavioral), can be measured for accuracy, and can be modeled in terms of questions, answers, and background information. It also satisfies social demands through joint attention, which necessitates objective and socially determined targets and requires a "collaborative" processing of information (Campbell, 2002; Tomasello, 1999). This higher-level communication of signals relies on a shared understanding of information to succeed and it is the foundation for our linguistic capacities (Clark, 1996).

An important characteristic of attention is that it commonly operates outside of phenomenal consciousness. Many researchers have identified attentional processing without awareness through studies on attentional cueing (e.g., Schurger et al., 2008), flash-suppression (e.g., Stein & Peelen, 2021), eye movements (e.g., Haladjian et al., 2018; Lisi & Cavanagh, 2015; Spering & Carrasco, 2015), and individuals with blindsight (e.g., Kentridge, 2011). Of course this does not come without criticism, as it is difficult to claim a complete lack of awareness and identify all the brain mechanisms involved when making these claims (e.g., see Peters & Lau, 2015; Rosenholtz, 2020). Since attention is present in the animal world, we can presume that much of this attentional processing occurs without a rich phenomenal awareness (admittedly this conjecture requires testing, which is difficult enough in humans). This points to the evolutionary nature of attention and its more complex forms, including conscious attention (Haladjian & Montemayor, 2015) and aspects related to cognition (Cosmides & Tooby, 2013).

From an evolutionary perspective, it is important to understand the “transition” from purely metabolic systems to cognitive systems that have attention and consciousness (Bronfman & Ginsburg, 2016; Bronfman et al., 2016; Jablonka & Lamb, 2006). If it turns out that all the information contained in phenomenal consciousness is somehow dependent on attention, then it is difficult to justify that there was a major evolutionary transition in information processing abilities to consciousness. Attention capacities, of all kinds, would demarcate the major transition to complex cognitive systems.

Our focus here, however, is on the informational differences between attention and consciousness. Crucially, all definitions of attention appeal to the selectivity of biochemical and electrical neural signal processing, from specific inputs to outputs, in an algorithmic manner. This is fundamental for attention’s epistemic role. This selective processing includes information that remains outside of conscious experience and information that does not need to be conscious for it to perform its role in perception or behavior. The importance and ubiquity of selective attentional processing cannot be emphasized enough, and this information-based processing must have certain effects on conscious experience. In particular, consciousness seems to be an amplified, or a globally broadcast, or a highly integrated attentional signal (as we will explain below). This leads us to the next an unanswered question to address: Is consciousness anything more than amplified or integrated attention? Most likely the answer is “yes”, but we need to define what this is and if it can be characterized by informational accounts.

4. Consciousness relies on attentional information processing yet seems distinct from it

The type of consciousness that defies informational approaches concerns the qualitative “what it is like” aspect of subjective experience (Nagel, 1974). This phenomenal consciousness is core to a first-person perspective and subjective human experiences, such as appreciating beauty, feeling disgust, and introspection. The key question here is: What is the unique informational role of phenomenal consciousness that differentiates it from attention? Ned Block distinguishes *access* consciousness as one that concerns epistemic and semantic functions (Block, 1995), which can be understood in terms of attention and working memory (Montemayor & Haladjian, 2015). It is deeply associated with the types of information described in the previous section. Access consciousness is essentially the stuff of attention. In contrast, phenomenal consciousness is not reducible to standard accounts of information because it cannot be reduced to *functional* accounts (which is the core of its problematic nature). This presents a high degree of dissociation between the functions of attention and the attempt to define a functional (or informational) role for phenomenal consciousness—a dissociation crucial for understanding information in cognitive systems. The question, of course, is whether integrated attention (for thought, action, and decision-making) is equal to access or phenomenal consciousness. In other words, we must determine if the following claims are justified:

(6) *Access Consciousness = Integrated Attention*

(7) *Phenomenal Consciousness = Integrated Attention*

In terms of the equations above, the first (6) is uncontroversial (Stoljar, 2019), but the second assertion (7) is highly controversial because it presupposes that phenomenal consciousness has no additional or distinct information from that in attention.

Another way to define consciousness is that it is transitive by nature, in the sense that it is consciousness of an object or a property (this is also how one can define attention, as being object-based or feature-based attention). Consciousness can be intransitive in the sense that it merely designates an organism as having a state of conscious awareness, which is also called “creature consciousness” (Bayne, 2007; Gennaro, 1993; Van Gulick, 2012); for dissent, see (McBride, 1999). Creature consciousness is directly linked to biological information processing, also in terms of attention, and includes attending to and reacting to internal signals from viscera and other interoceptive or proprioceptive signals in a bi-directional flow of information between these internal systems and the brain. This is the basis for the signal enhancement and modulation that we postulate as the essential informational role of one type of phenomenal consciousness—a “biological” consciousness (Feinberg & Mallatt, 2016; Ginsburg & Jablonka, 2020; Graziano, 2014). This might be considered a very early or primitive form of conscious experience directly tied to simple and limited attentional processing (e.g., something very basic that is not necessarily like human conscious experience), and it is biologically grounded and in direct relation with vital bodily and cognitive functions. The difficulty is that this biologically based account identifies consciousness with an internal kind of attention, presumably through visceral reactions on the basis of arousal and other biological functions (Haladjian & Montemayor, 2016; Tallon-Baudry et al., 2018). Thus, it does not explain what is unique and irreducible about phenomenal consciousness.

So, which specific mental capacities do we gain with consciousness that we do not have with attention? Attention is varied and content-specific, with a functional role focused on selectivity. When combined with consciousness it can become highly integrative and complex (Montemayor & Haladjian, 2015). In regard to information processing, attention is generally associated with epistemic agency and knowledge, while phenomenal consciousness is hard to define in such functional terms. However, phenomenal consciousness can be characterized by visceral information that is directly related to an organism's bodily status and experiences (e.g., hunger, pain, warmth, disgust, well-being). This can point toward a more functional account, namely as a self-monitoring system to maintain homeostasis and other life-sustaining activities associated with subjective experience (Azzalini et al., 2019; Babo-Rebelo & Tallon-Baudry, 2019; Blefari et al., 2017; Tallon-Baudry et al., 2018). Consciousness also seems necessary for certain kinds of rationality (e.g., explicit inferential reasoning), as well as determining moral and aesthetic value. But rational capacities seem to be more deeply associated with access consciousness and "thoughtful reflection" rather than the visceral subjective character of phenomenal consciousness, which is likely more prevalent across various species than rational thought. So why can't attention perform these roles? Why do we even need consciousness at all?

A central qualitative description of phenomenal consciousness is the first-person subjective experience of an organism. Some theorists have proposed a close relation between this experience and core biological processes. For example, Antonio Damasio (1999) describes the "proto-self" as a continuous representation of a set of activities related to homeostasis, which signal the "state of the internal milieu, viscera, the vestibular apparatus, and the musculoskeletal system" (Parvizi & Damasio, 2001). This is thought to be the basis for emotions and first-person (subjective) experiences. Additionally, "early feelings" are differentiated from "emotional feelings" to emphasize the homeostatic nature of early feelings, which aim to help regulate an organism's life-sustaining homeostasis and may initiate regulative processes and behaviors (Damasio, 2021). These can be unconscious or conscious, but most of such processes are unlikely to depend on conscious awareness given their importance. Similarly, Catherine Tallon-Baudry's "neural subjective frame" proposal is essentially a form of "feedback loop" in a complex organism that is framed within its body, such as the musculoskeletal system in humans (Park & Tallon-Baudry, 2014; Tallon-Baudry et al., 2018). This includes the interoceptive system that involves information exchanges between viscera, neurophysiological systems, and the brain (Babo-Rebelo & Tallon-Baudry, 2019). The monitoring of visceral information, particularly from the heart and gastro-intestinal systems (to support homeostasis, such as the regulation of blood pressure or body temperature), is also proposed to be important in subjective experience by influencing brain activity and providing a continuity in the signals from different systems that operate at different time-scales (Azzalini et al., 2019). These visceral signals are not always conscious but are continuously monitored by the brain, likely the brain stem (Damasio, 2021).

We have learned a great deal about the mind and the NCCs through the experimental methods of cognitive neuroscience. This deeper knowledge, at the very least, should influence and constrain theoretical views about consciousness and attention. We now know that the brain's biochemistry and the electrical oscillations within it support a complex system of communication among cortical neurons (Thiele & Bellgrove, 2018) with dynamic connectivity (Demertzi et al., 2019). The thalamus also seems to be important for modulating levels of consciousness (Redinbaugh et al., 2020) and visual aspects of conscious experience (Purpura & Schiff, 1997). The findings that thalamic activity correlates with consciousness have important implications (e.g., coma patients) by defining what it means to be in a "minimally conscious" state (Giacino et al., 2014; Laureys et al., 2004; Schiff et al., 2005). With regards to interoceptive processing and subjective experience, "early" brain systems are likely associated with these processes (Blefari et al., 2017; Damasio, 2021; Damasio et al., 2000). While we cannot get into the details of the studies identifying these brain regions in this paper, we want to point out they are generally areas that are evolutionarily “older”. Studies have recently identified brain mechanisms that are involved with heartbeat awareness (i.e., interoceptive signals), which are thought to be tied closely to “bodily self-consciousness” and the first-person perspective (Blefari et al., 2017). The newfound understanding around these topics certainly cannot be trivial knowledge about our minds. Essentially, these insights on consciousness measure information processing in the brain and how it is related to highly integrated cognitive functions and behaviors.

There are several leading examples of empirical approaches to understanding phenomenal consciousness. Global Neuronal Workspace Theory (GNWT) posits a broad network of neural activation (with inputs from various modality-specific neural systems) as necessary for attentional information to become conscious (Baars, 2005; Dehaene & Naccache, 2001; Mashour et al., 2020). This approach also inherently relies on attentional and memory systems to make this content accessible to metacognition (Shea & Frith, 2019). Another theory, Recurrent Processing Theory (RPT), specifically focuses on the causal presence of recursive signals as markers of consciousness, but denies that a broad network of activation is necessary (Lamme, 2003, 2006). This approach indicates a reliance on working memory systems, which also inherently require attentional processing (i.e., to process information that enters working memory). A radically different approach is described by the Information Integration Theory (IIT), which models different levels of consciousness based on the amount of information that a system has integrated regardless of how it is physically instantiated (i.e., not necessarily neural or brain-based), leading to an intrinsic irreducibility of components to produce phenomenal experience (Toker & Sommer, 2019; Tononi, 2004, 2012; Tononi & Koch, 2015). In other words, consciousness depends on a system with rich information that is also highly integrated (i.e., with high levels of interconnectivity). It must be noted that such theories of consciousness are criticized because they are difficult to be proven experimentally (e.g., see Doerig et al., 2019) or have unclear conclusions (Merker et al., 2021).

From a more classical philosophical approach to consciousness, Higher-Order Theories (HOT) of consciousness require activation from areas that involve embedded representations to achieve conscious awareness, rather than merely local or global activations (Brown et al., 2019; Gennaro, 2004; Lau & Rosenthal, 2011; Rosenthal, 1997, 2008). These neural-based representations must achieve a higher level of stability or quality (e.g., being able to report awareness with a level of confidence) in order to be conscious (Cleeremans, 2014). This approach has also been described as relying on working memory (LeDoux & Lau, 2020). Thus, even philosophical views are now grounded empirically from recent studies in neuroscience.

One current debate in consciousness research questions whether measures of consciousness require verbal report and behavioral assessment or if they should be define strictly in neural terms. Advocates of GNWT favor the former while advocates of RPT favor the latter. Some have tried to reconcile differences between these two theories by focusing on the dissociation between attention and consciousness (Pitts et al., 2018), but this requires a careful scrutiny of all the different forms of attention present in order to understand how they are related—not just high-level focused attention (Montemayor & Haladjian, 2019). It is even debated if the issue is indeterminate and impossible to answer (Chalmers, 2013). We believe that stalemates in consciousness research (e.g., Dennett, 2018; Lamme, 2018) will benefit greatly from a focus on *information processing* and a careful analysis of the dissociation between consciousness and attention, as well as their evolutionary accounts (Haladjian & Montemayor, 2015). In fact, while there are fundamental contradictions among these different theories of consciousness, all these empirically-grounded approaches emphasize information processing and the dependence of consciousness on attention. Ultimately, it is important to have a consistent definition of attention as an information processing system, which can operate at various levels.

With respect to the NCCs, each of the leading theories predict activations of distinct brain areas. There is considerable discussion about which areas should be privileged (Koch et al., 2016), and there is no consensus, even at the methodological level, about how to exactly identify and measure them (Fink, 2020). There are also debates about whether the cortex is necessary for consciousness (Merker, 2007) and the role of the thalamus in supporting consciousness (Monti et al., 2013; Monti et al., 2015; Schmitt et al., 2017). Some even question whether the entire nervous system and its functions for action control in skeletal muscle should be taken into consideration for conscious information processing (Morsella et al., 2016; Park & Tallon-Baudry, 2014). It could be that these accounts concern a more fundamental kind of consciousness than those in the prevailing theories of the NCCs. Since none of them explain what makes consciousness distinct from attention, we remain with the same difficulty.

For our purposes, this distinction entails that access consciousness can be functionally defined as attention, and thus it already corresponds to information. So it is more crucial to focus on phenomenal consciousness since there is no consensus on its informative nature. Actually, the only shared assumption among all theories of consciousness is that it must depend on attention at some level, whether explicitly stated or not. It is this common assumption that requires clarification, especially in the informational difference between consciousness and attention.

Is it acceptable to say that the subjective experience of qualia (and the associated hard problem) are somehow illusory (Dennett, 1996, 2018; Frankish, 2016; Humphrey, 2011), but still argue that there is something informative in the qualitative nature of consciousness? The problem lies in determining how consciousness is informative in a different way than attention, even if its qualitative nature is “illusory” (this “illusion” being that the qualitative aspect provides information that does not capture objective aspects of attended contents). Suppose that, per the hard problem, all the information we gain immediately through phenomenal consciousness is primitive and distinct—it is not the kind of information we can measure and test through standard scientific accounts of information. There are two ways to respond to this claim. The first one is to present a *model* of this type of information processing—IIT is such an attempt (Toker & Sommer, 2019; Tononi, 2004, 2012).[2] The second option is to assert the irreducibility of such information to any type of measurable, functional, or structural account of information. This would lead to anti-physicalism (Chalmers, 2010), which is not an ideal outcome as it is inherently unfalsifiable and untestable. Only the first alternative is scientifically testable (although for criticism, see de Barros et al., 2016; Montemayor et al., 2019).

Since IIT takes phenomenal information to be distinct from other cognitive information that does not pass the Φ threshold of integration, which includes attention, IIT is incompatible with (7). According to IIT:

(8) *Phenomenal Consciousness ≠ Access Consciousness*

And this would lead to:

(9) *Consciousness – Attention* = +*Φ* (a positive residue of Φ)

The question, again, is what could this “residue” be? Is it measurable? One way to appreciate the difficulties in approaches that take phenomenal consciousness to be maximally informative

[2] The other major scientific theories of consciousness—GNWT, HOT, and RPT—do not differentiate conscious information from other cognitive information in terms of irreducibility and primitiveness, but rather in terms of representational structure.

concerns the problematic claim that phenomenal consciousness is not reducible to cognitive function. Consider an asymmetry entailed by the "hard problem" of consciousness (Chalmers, 1995). Why should any cognitive function be associated with the extremely unique and rich qualitative character of subjective experience? Is there something additional given by phenomenal consciousness beyond the functional explanation of information processing models? This problem has been a central topic in consciousness research during the last few decades, although not without criticism (including Dennett's (2018) assertion that we should focus on the question of "what does consciousness do?"). Less consideration has been given to the *inverse formulation* of Chalmers' hard problem, namely, is it possible to consciously experience a mental content without any informational or functional relation to the physical world? Can someone experience a vivid red color without having a visual system, or experience it subjectively without gaining very specific information about objects or surfaces?

How is this issue related to the "what it is like" aspect of subjective experience (Nagel, 1974)? The radical and allegedly irreducible subjectivity that lies behind the explanatory gap between experience and functional scientific explanation must be accounted for somehow. For example, Jylkkä & Railo (2019) have proposed that the explanatory gap in phenomenal experience is best understood as being a physical phenomenon that is distinct from the *model* of the phenomenon, but has physical instantiations with observable causal interactions. Essentially, this proposal indicates that subjective experience is a physical event that is structured by elements within neurobiology, even though we cannot yet systematically define it.

The proposal we would like to put forth is that *homeostatic uniqueness* will explain the phenomenology of subjective experience. This provides a foundation for an explanatory gap between internal and self-sustaining *experiences* that cannot be explained from a third-person perspective. Some have pointed out that being alive—with its metabolic functions and its evolution—is necessary for the kind of mind we have (Boden, 2009; Jonas, 1966; Maturana & Varela, 1980; Smit & Hacker, 2020). On this view, life is defined in terms of a unique "visceral perspective" from which an organism autonomously satisfies its needs through homeostasis—not merely by reproducing biological processes, but fundamentally by self-sustaining itself.

We differentiate our perspective from the theories described above by emphasizing the essential role of information for consciousness. While previous theories inherently include the processing of information, they neither address this extensively nor do they contrast it with attention. Without an ability to process information (be it from internal or external sources), we would not have conscious experience. It is a first and crucial step that leads to consciousness. In other words, information about the environment (e.g., sensations, perceptions), information from memory, and information about the bodily self (e.g., proprioceptive or visceral signals) are key components to conscious experience. Homeostatic processes are included in this, and could be the differentiator of what makes a conscious organism (e.g., by the complexity of homeostatic needs). Yet this is only part of the story. For artificial intelligence systems, which can emulate human intelligence and reasoning but not possess the experience of these abilities, they may get closer to human intelligence by adding the "need for survival" and an ability to monitor and influence system homeostasis in artificial agents, although this would not be the still not the same as human emotional and conscious intelligence (Man & Damasio, 2019).

Therefore, the explanatory gap in informational terms can be stated as: consciousness is more fundamentally related to visceral information than is attention. The informational asymmetry between consciousness and attention might depend on the unique and visceral character of homeostatic processes. And yet, attention still may be the most important source of cognitive information that sometimes allows us to be aware of homeostatic needs via conscious attention.

5. Using informational terms to understand how attention and consciousness are related

Now we face the task of determining how much information is shared between attention and consciousness. If there is an asymmetry between them, as explained above, how should we understand the necessary dependence of consciousness on attention? On one hand, the explanatory gap suggests a deep (and according to some philosophers, a necessary and metaphysical) distinction between conscious and unconscious information. No information described from the “third-person perspective” can fully capture the experience of subjective conscious information. This gap is an a priori, or an in-principle, obstacle for the science of consciousness (e.g., Chalmers, 1995; Nagel, 1974). On the other hand, everyone with empirically-grounded theories of consciousness agrees that some form of attentional information processing is necessary for consciousness. But how could this be, given the explanatory gap plus the fact that attention can be described empirically, from a third-person perspective? If attention is *necessary* for consciousness, how is an informational gap between them possible? A closer look at information processing should be helpful here.

Without information, attention would be unnecessary. Information processing is essential in defining attention’s functional. Is this functional role of attention essential to consciousness? If one accepts the explanatory gap, then the answer is negative. If one claims that attention is necessary for consciousness, then the answer is affirmative. Even theorists that argue in favor of the explanatory gap, including those postulating it is a necessity of our universe (Chalmers, 1995), would agree that consciousness is highly informative. If attention explains the rich informative content of consciousness, then there is another necessity that must be taken into consideration—one that appeals to attention rather than “what it is like” to be an organism. This is a paradoxical situation that leads to an asymmetry based on the dependence of consciousness on attention and the explanatory gap. There is no resolution yet about what information is uniquely conscious since it can all be ascribed to information processing systems.

Consider the visceral aspect of consciousness, which provides a physical experience of internal states. If this is unique to phenomenal consciousness, what is the specific informational role of a visceral experience? If attention on its own does not necessarily entail the phenomenal experience associated with the information it is conveying, and yet can perform functions well, what do (phenomenal) visceral signals add? One proposal is that a visceral-related component may unify experiences in a unique way (Solms, 2019; Tallon-Baudry et al., 2018), perhaps by allowing the monitoring of different life-sustaining systems that operate at different time scales (Azzalini et al., 2019). While this may provide an important information-integration role, emphasized particularly by IIT, it is unclear how to understand this informational role without attention. Moreover, attention also integrates contents, cross-modally, and at times involuntarily. How then can we understand the unique “unity of consciousness” in terms of information?

If consciousness and attention were considered identical processes, this question would be easier to answer. That is not the case, however, as we know that there are some different neural processes that support attention and consciousness (Lamme, 2004; Maier & Tsuchiya, 2021), and we know confidently that their relationship entails at least a single dissociation—attentional processing can occur outside of consciousness. Recall the simple “equation” from the introduction that we would like to assess:

(5) *Consciousness – Information = Consciousness – Attention ?*

The underlying question here is: What is left if we removed all information from consciousness, or X (2)? When all attention is removed from consciousness, will it equal Y (3)? The reverse is easier to consider, where consciousness is removed from attention. Many attentional processes do not enter phenomenal experience, and this has been empirically confirmed (e.g., Cohen et al., 2012; Lu et al., 2012; Oriet et al., 2017). From the other direction, some argue that you can have consciousness without attention (e.g., Block, 2014; Meuwese et al., 2013; Pitts et al., 2018), but this argument relies on *how* attention is defined, and in most cases (if not all) these studies consider only the more deliberate form of focused “top-down” attention. That is, they typically ignore the more basic kinds of attention, where information is processed primarily in the “background” (Montemayor & Haladjian, 2019). Also ignored are the effortless forms of attention, where we do not necessarily need to be conscious of the information that is processed to influence our behaviors (Haladjian & Montemayor, 2015). In other words, it is never clear what is meant by “consciousness without attention”, either in informational terms or thorough a perspective that includes all types of attention.

What would be left if we removed *all* the different types of attentional processes from consciousness? How might we then scrutinize the role of information in consciousness without the constraint of attention? Perhaps it would help to examine the distinction between quantitative and qualitative approaches to information that we mentioned previously. This distinction allows us to define informational systems as follows. The quantitative approach claims that two systems are *extensionally* equivalent if they have the same measure of information in performing a computation (according to a mathematically understood model that provides a precise measurement). They are extensionally equivalent because the same inputs will yield the same outputs with an identical process of uncertainty reduction or precision in signal detection (i.e., they will be measured reliably). This is the basis for computations in our brain’s neurons and in our digital technologies (but perhaps with differences in precision).

By contrast, a qualitative approach claims that two systems that have information concerning the same semantic contents, or arrive at a conclusion with the same degree of epistemic justification, will be *intensionally* identical because the processes involved will be *about* the same contents, reasons, and inferences. Intensional equivalence does not correspond to extensional equivalence because of the contextual opacity of intensional contexts—the same way of storing information may differ with respect to the semantic content, or equivalently, the reduction of extensional possibilities is not sufficient to eliminate all the intensional ones. Attention, however, can easily be distinguished along those lines. Call extensional attention "algorithmic" attention, and intensional attention "agential" attention. The first captures the input-output structural relations of information processing. The second focuses on the capacities of attentive agents. There is no need to mention consciousness to make sense of this distinction. Therefore, it is not unique to the distinction between consciousness and attention because it is important to categorize attention itself.

Our goal is to emphasize a discrepancy between consciousness and attention with regard to any definition of information. This inconsistency is twofold. First, the realization conditions, material and formal characteristics, and the evolution of different informational systems (biological and artificial) can all be defined functionally. In perception and cognition, they can be typified in terms of different kinds of attention routines involved in various aspects of information processing and types of pattern recognition (Cavanagh, 2004), explained functionally in computational terms. As discussed extensively in the literature, largely in response to the "hard problem", phenomenal consciousness is not reducible to functional analysis or computational terms. Second, attention as a type of epistemic agency may satisfy normative standards for justification, knowledge, and even epistemically constrained curiosity (Fairweather & Montemayor, 2017), all without consciousness. Hence, there is a discrepancy between standard notions of information with respect to how they could instantiate attention versus consciousness, starting with the fundamental relationship between the input and output of a function.

These are substantial challenges for defining consciousness in terms of information. Some theorists have attempted to address this by appealing to uniquely rich types of information integration as the basis for consciousness in humans (Tegmark, 2016; Tononi, 2004, 2012) and even artificial systems (Bringsjord & Sundar, 2020)—but these are likely functional accounts that concern access consciousness (i.e., attentional systems). In any case, it is not clear that these integration theories differ from standard accounts of quantitative information, such as Shannon's theory. If information has a functional role in cognition, behavior, evolution, and so on, then it fundamentally satisfies at least a quantitative criterion (and even a semantic one when you consider agency and purpose). This already limits what kind of information we can consider meaningful or even categorize with some degree of precision. In fact, IIT describes integration functionally and even provides a functional *metric* for it: the degree of maximal integration (or Φ_{max}) within an informational system (Tononi, 2012).

How do the current empirical theories of consciousness treat information processing? Since GNWT requires neural inputs from different sensory modalities and activation of the prefrontal cortex to provide the contents of experience, it clearly relies on information processing and attentional neural networks, including the thalamus, which act as gatekeepers of information (Moustafa et al., 2017; Schmitt et al., 2017). Even when you introduce the requirement of metacognition in GNWT to assess subjective confidence about inputs and decisions (Shea & Frith, 2019), a dissociation from information is not obvious as it also relies on neural processing within the prefrontal cortex as well as the parietal lobes to support these abilities (a clear NCC approach). The other theories described above also require information as a necessity, either in the form of recursive signals (RPT) or in the integration of signals (IIT). Such neural signals, as mentioned, can be understood as attention routines. HOT also requires a representation and activation of signals for consciousness, and thus is another theory reliant on information processing, in particular, by defining conscious information in terms of contents embedded in a higher-order representation (contents that are also best understood as attended to at the first-order level). “Older” brain regions related to self-monitoring systems (including interoception) rely on the insular cortex, brain stem, and other subcortical regions (Babo-Rebelo & Tallon-Baudry, 2019; Blefari et al., 2017; Damasio et al., 2000), which do not clearly correlate with top-down attention. We could go on (e.g., creature consciousness, etc.) and we would not find a single theory of consciousness that does not rely on information or that could deny the dependence of consciousness on the neural networks of attentional processes on some level.

6. Confronting the informational problem of consciousness

The discrepancies explained above confront consciousness theorists with the question we have been highlighting: Are there distinct types of information found in consciousness that are not found in attention? If no informational approach to consciousness is possible, that would lead to a radically strong kind of epiphenomenalism according to which phenomenal consciousness is not only non-physical but utterly uninformative—a result that no theorist would favor.

Our proposal is that attention suffices to capture any available notion of information, and that a new approach to *conscious information* must make explicit its specific biological basis and its relation to attentional information. Thus, we propose to make the notion of “integration” less dependent on conceptual contents (as in IIT), epistemic norms (as in primitivist theories of phenomenal content), or causal relations (as in standard externalism about content), and instead define it in terms of biological signals and their intensification based on homeostatic engagement. Signals related to homeostatic abilities would rely on “older” brain regions, such as the brainstem and cerebellum (Damasio et al., 2000; Park & Tallon-Baudry, 2014; Solms, 2021). This differs from other approaches (i.e., GNWT and RPT) because the emphasis is on a kind of *affective or visceral homeostasis*, rather than simply the anatomical areas associated with the NCCs. This claim is compatible with proposals from Mark Solms (2021) and Damasio (2021) that the homeostatic nature of basic consciousness provides the valence structure of consciousness through basic feelings, that is, this form of consciousness is more affective in nature, relying on the reticular brainstem.

Let’s go back to what can perhaps be considered a precursor to selective attention: simple signal detection. Signal detection theory is used to determine if a signal (processed by a physical mechanism) provides information to the system that is better than guessing. In perceptual science, signal detection theory essentially captures the ability to detect the difference between meaningful patterns in data and random noise. While an “ideal observer” can perform this ability in an optimal manner (see Geisler, 2011), it is rarely the case that information is processed and detected optimally, hence the reliance on predictive uncertainty reduction. Here we can think of the entropy that physical systems are prone to have (i.e., as in the Second Law of Thermodynamics) and the drive to minimize entropy, which helps achieve some level of equilibrium in dynamic environments (Friston, 2010). This is an example of the homeostasis that living organisms strive to achieve.

From an information-theoretic approach to perception, probability computations are important and there are several probabilistic accounts of neural processing (e.g., see Clark, 2013; Ma, 2012); for dissent, see (Block, 2018). The main idea behind these accounts is that the brain has evolved to optimize information processing by using past experiences to predict the “meaning” of the signals (sensory or cognitive). This allows for the “filling in” of probable information from memory, facilitating interactions with the environment. One can argue that this ability to predict probable information was an adaptation in information-processing systems with channel capacity limitations—an adaptation that facilitated complex interactions with the environment. Such predictive abilities are possible because of the systematic and organized nature of perceptual information processing and the neural systems supporting it. This predictive processing is in line with the idea of "active inference" and a reduction of prediction errors by combining perceptual and intentional representations (Friston, 2010; Friston et al., 2011).

Another relation to information theory to consider is the brain's ability to optimally compress information (Maguire & Maguire, 2010). From this perspective, the brain's ability to process information from different sources relies on its ability to compress a vast amount of information and improve its predictive abilities, which can be modeled via an algorithmic information theory. This would effectively serve the evolutionary drive to propagate a species (i.e., successful reproduction and transmission of genetic material). The question, again, is why should consciousness be responsible for either compression or probabilistic predictions, when the neural processes of attention describes these functions sufficiently?

The empirical evidence, unsurprisingly, strongly favors attention as the main mechanism in prediction, compression, signal detection, and signal interpretation. For instance, the processing of information for higher-level functions depends on the strength of the signal and also on how the information is processed by the receiver. The more basic forms of attention, such as feature detection or spatial attention, rely on simpler processing of signals, as measured in signal detection studies. Signal processing becomes more intricate for more complex attentional processes, for example, when actively tracking multiple moving objects (Pylyshyn & Storm, 1988) or in an object-based attention that holistically identifies what is being perceived and its many features (Treisman, 1998). Attention also integrates information from different modalities (e.g., visual, auditory, haptic) to form rich and meaningful representations of our world (Driver & Spence, 2000), which support the ability to act within this world (Hommel, 2019). The success of these different processes can be modeled in terms of the amplification or suppression of neural signals. These signals influence what enters awareness (Jimenez et al., 2020), especially if it requires performing actions or motor movements (Lau et al., 2004). This may rely ultimately on neural systems also associated with working memory (LeDoux, 2020). Clearly these processes are connected to how information is processed and stored, which attention is meant to optimize (i.e., its functional purpose). The processing of relevant information really seems identical to attention, in accordance with the equation (1) above.

Thus, it is still unclear if consciousness plays an integrative or compressive role with information that attention cannot fulfill. Phenomenal experience must be then a different kind of information, for example, a highly integrated form of information (Tegmark, 2016), or one with visceral properties (Azzalini et al., 2019; Tallon-Baudry et al., 2018), or one that is purely sensorial and lacking any sort of intentionality (Farkas, 2013). This aspect of homeostatic-like visceral responses may be the foundation of the human ability for empathy, as it provides a first-person window into how others might feel when experiencing certain sensations, such as when enjoying a sunset or an opera. By experiencing first-hand such sensations and perceptions, eventually the understanding that others may experience similar things entered the repertoire of cognitive functions, likely due to evolutionary demands of complex social species.

Indeed, the first-person perspective and empathy might be crucial parts of this equation concerning the “conscious information residue”, at least in humans. Empathy arguably relies on phenomenal consciousness and may be explained by active inference (Friston, 2010) and the affective nature of basic consciousness (Solms & Friston, 2018). From this view, being able to perform and understand actions requires specific neural mechanisms (e.g., mirror neurons) and the predictive encoding of intentions in others or in the self, which can be modelled by the free-energy formulation of active inference (Friston et al., 2011). Could we even have empathy if we did not have some ability to reflect on our phenomenal experiences and imagine ourselves operating from another's perspective? This is especially crucial for the kind of empathy called "experienced empathy" and "motivated empathy" versus recognitional empathy or empathic care (Zaki, 2014, 2017). The formulation of artificial consciousness is thought to be limited by a lack of such "spontaneous empathy" in machines (Haladjian & Montemayor, 2016; Turkle, 2005/1984). In addition to the neural processing involved, empathy seems to also rely on visceral information that supplies or enriches the phenomenal aspect of our experience (Tallon-Baudry et al., 2018). We cannot rule out the possibility that empathy can occur outside of conscious awareness, but this needs to be investigated empirically (another hard problem).

The homeostatic approach may best elucidate the general distinction between consciousness and attention in informational terms. Consciousness is generally dependent on valence and equilibria, which is deeply tied to an inherent "neediness" of a living system to maintain homeostasis (Man & Damasio, 2019). Attention, by contrast, is algorithmic in the sense that it seeks and processes information. The key aspect of the consciousness-attention dissociation is the information processing role of attention that does not rely on consciousness, but it may require a "primitive" form of consciousness in assessing homeostasis—a conscious form of attention. This is a theoretical possibility that needs to be studied empirically in more detail. The brainstem plays an important role to support valence judgments and visceral responses (Azzalini et al., 2019), which help regulate homeostasis in more unpredictable contexts (Solms, 2019). The homeostatic role of consciousness is particularly important when a brain's predictive functions are lacking (which can negatively impact learning). While the information processing by attention provides the contents for consciousness, this homeostatic function is likely an area where attention and consciousness are dissociated.

The feeling of “flow” is another interesting phenomenal experience to consider. Flow is a conscious experience related to effortless attention, where one experiences an “order in consciousness” that minimizes any conflicts or struggles that may be associated with learning the rules of a new task (Bruya, 2010; Csikszentmihalyi, 1997). When first learning to play a piano, for example, one expends a great deal of effort in the various information-heavy tasks associated with achieving goals—understanding the notes, using both hands to independently and precisely press the keys, and operating the foot pedals. This initial attention-demanding state suffers from errors that produce a not-so-nice musical experience, and this informational conflict between the goals of attention and what is perceived produces an effortful feeling (or in terms of the Free Energy Principle, it is a discordance between expected states and experienced states, producing “surprise” or entropy). When one has mastered the piano and can play it with uninterrupted elegance, the conscious flow experience that comes with this is often described as calm and pleasant, where one can be engrossed in the experience and lose a sense of time. This level of expertise allows the pianist to enjoy the congruent flow of information between attentional processes and conscious experience, perhaps even hinting at the recursive yet stabilizing nature of consciousness. This seems to correspond to the idea that consciousness signals a desired state of homeostasis—in this example, the congruence between the information used to perform an action on the piano and the matching feedback signals from performing that action (i.e., music).

The notion of creature consciousness may further clarify its unique role. Simply put, the biochemical nature of the brain has properties inherent to it that are the basis for the non-reproducibility of a conscious perspective, and has a unique information processing ability that is physical in nature (Tegmark, 2015). Since information is physical as well (Landauer, 1991, 1996), this could be a correspondence between conscious experience and the physical, self-organizing biological systems that aim to achieve homeostasis. Of course, this creates many open questions that must be addressed through scientific inquiry. If anything, this perspective could help allay some fears around the emergence of machine consciousness, among other arguments against it (Dehaene et al., 2017; Haladjian & Montemayor, 2016; Man et al., 2022).

Ultimately, when it comes to consciousness, what matters is not the just reduction of uncertainty and the reception of signals, but the creation of a type of saliency from visceral inputs that may be the origin of the first-person perspective (Tallon-Baudry et al., 2018). Its *content* can be determined by attention and information processing, thereby confirming the non-intentional view of consciousness (Farkas, 2013); but what subjective experience is must be determined independently of those contents. Currently, the commonly accepted view on consciousness is that it cannot be reproduced by algorithms or artificial mechanisms, at least not in a simple computational manner (see the issue of irreproducibility emphasized by (Aaronson, 2016). Understanding why consciousness is not reproducible or capable of being "cloned" presents an intriguing problem for information theory in this context, which we will now briefly touch on.

7. A path forward to a better understanding of consciousness

Regardless of which methodologies and theories one favors, it is not ideal to be stuck in a stalemate regarding the informational nature of consciousness based on challenges created by the explanatory gap and the dependence of consciousness on attention. Is this problem irresolvable? One option is to deny consciousness any privileged informational status (e.g., Prinz, 2012). But since most would agree that consciousness is uniquely informative, we can also agree that it would be better to provide an explanation about what makes consciousness *seem* so informative, at the very least. Therefore, the only available path to move the debate forward is to critically examine the dependence of consciousness on all forms of attention and signal processing and see where we can go from there.

There is substantial empirical support for a dissociation between consciousness and attention—more information is processed by attention than what reaches phenomenal consciousness (e.g., Haladjian & Montemayor, 2015; Montemayor & Haladjian, 2015; Pitts et al., 2018; van Boxtel et al., 2010; Velmans, 1991). In addition to the psychophysical evidence, this dissociation has also been shown in neural studies (Lamme, 2004; Maier & Tsuchiya, 2021; Tallon-Baudry, 2012). It remains unclear, however, if all forms of consciousness require a form of selective information processing. The *feeling* associated with phenomenal consciousness, for example, may require both interoceptive and exteroceptive signals to be processed (e.g., homeostatic states, ambient temperature, sounds, touch) but not in a selective way (i.e., without selective attention). But even this seems to entail that some form of information must be processed—in this case, neural signals that convey interoceptive and proprioceptive information within the context of the "self".

Information is ultimately central to the functions of attention, providing content for cognitive abilities in and outside of conscious experience. It is unclear if consciousness relies on information in the same way, but it certainly seems to play an informational role. Consciousness may even play some crucial functional roles, such as in the integration of information from different modalities (Palmer & Ramsey, 2012) and supporting some types of learning (Meuwese et al., 2013; Overgaard & Kirkeby-Hinrup, 2021); however, this is not likely to be the unique role of consciousness given the semantic and epistemic roles that are central to attention.

As discussed, consciousness seems to indicate a state of homeostasis in the brain, and certain "unbalanced" states can trigger actions for the organism to regain homeostasis. Since complex metabolic systems follow general laws of physics (e.g., thermodynamics), such systems strive to maintain an equilibrium at a macroscopic level, even with varying levels of entropy in terms of the microscopic flows of energy (or information), which requires a multi-stage account of information in physics (Rovelli, 2017; Tegmark, 2015; Vedral, 2010). When interpreting consciousness through Friston's Free Energy Principle, it is the reduction of possible informational states (via inference and actions) that helps reduce the entropy within a system so that a steady-state equilibrium can be maintained, upon which phenomenal consciousness seems to depend. If maintaining homeostasis is common in all living organisms, why must homeostatic-related consciousness be special? Is it a distinct system for seeking homeostasis?

Now we are faced with other interesting questions. Can we say that consciousness *maintains* neurobiological informational equilibrium or is simply *an indication* that such an equilibrium is present? Is homeostatic equilibrium in itself a type of information that is distinct from attentional information (e.g., in a complex algorithmic way)? What happens when consciousness is in a robust equilibrium? Is this related to the expert pianist's "flow experience" described above? What happens when consciousness is not at equilibrium? Could this explain certain forms of neurological disorders, such as schizophrenia or Parkinson's (Friston, 2010) or disorders of consciousness (Giacino et al., 2014)? While we cannot give direct answers to these questions here, it is possible that theoretical models such as the Free Energy Principle (Friston, 2010; Williford et al., 2018) and quantum information theory in physics may play a role in solving these questions (Vedral, 2010). The key may lie in carefully examining the self-organizing properties of such systems and how that may be neurologically instantiated.

Another point to consider is that consciousness may be a mechanism for *further limiting* information. That is, the first-person cohesive narrative of selective information provided by consciousness is a way to limit the awareness of all information processing, which would be an inherently high-entropy state for complex information-processing organisms like humans. On the other hand, consciousness may be considered a *result of a limited processing of information by attention*, or an equilibrium of information processing between action-planning and perceptual feedback. These views point towards an understanding of consciousness in terms of limiting and filtering functions, similar to those of attention—but as a form of meta-attentional process (Webb & Graziano, 2015). An advantage of this approach is that modeling consciousness on attention would be compatible with the equation that all information is attentional information (1). A disadvantage of this account is that consciousness cannot be truly unique, maximally specific, or irreproducible—or at least it is not obvious what would ground such irreproducibility.

One possible way to think about the irreproducibility problem of consciousness is in terms of it being like an encryption mechanism, rather than merely an information filtering or integrating mechanism. Conscious information seems to be "doubly encrypted", to use a loose expression. First, it is a kind of "master key" code for intentional contents, but only through the functions of cross-modal attention, which can also be unconscious. This suggests that the essence of conscious awareness is a biological kind of interface with attention that cannot be reduced to algorithmic functions and might be either purely sensorial (Farkas, 2013) or empathic (Haladjian & Montemayor, 2016; Mackes et al., 2018; Williams, 2012). This biologically-based, homeostatic aspect of consciousness is "encrypted" in the sense that the master codes of cross-modal attention cannot "decrypt" consciousness' informational essence. If anything along these lines were confirmed, it would at least explain the puzzling asymmetry mentioned above—cognitive functions and structures do not always entail conscious information, but conscious information seems to entail contents that require functions and structure.

Another way in which consciousness is "encrypted" is that only one individual is aware of this internal information at any point in time—outside "decoders" cannot evade this uniqueness and privileged access, or reproduce it in any way (Aaronson, 2016). This is the essence of a first-person subjective experience central to phenomenal consciousness. This includes homeostatic feelings, which correspond to internal states, have direct access to the nervous system, and are unique to an individual's interoception and sense of self (Damasio, 2021; Damasio & Carvalho, 2013). The feelings associated with interoceptive signals cannot be experienced by another, while exteroceptive systems process external information that can be experienced by others (yet, we cannot be sure if such information will produce identical subjective experiences among different interpreters). The consciousness and attention dissociation explains this in terms of the dissociation between internal homeostatic information and functional algorithmic-like information, which correspond to phenomenal consciousness and attention, respectively.

A way to extend this encryption proposal is to distinguish conscious and attentional information in terms of a *boundary condition*: a limit at which there is a significant change in how information is processed. In other words, it may be a *phase transition* between one type of information processing and another (Szathmáry & Smith, 1995). This transition resembles encryption in the sense that this information becomes inaccessible to external processing, but it is more profound than encryption because it is a unique and irreproducible informational structure only available to the organism experiencing it. Attention is replicable, functional, and informationally tractable. Consciousness, then, is a boundary condition in which attention changes because it stops being reproducible and "algorithmic". Where does this transition come from? Our proposal is that it originates in the visceral elements of a unique neurobiological and complex perspective (Haladjian & Montemayor, 2015). Consciousness, on this account, is a biologically determined boundary condition on types of integrated information processed by attention.

Another possibility is that there is information in the *relationship* between bits of information—a relationship that consciousness may crucially shape. That is, consciousness connects different bits of information and in doing so delivers new information (i.e., this relationship). As there are always some forms of neural signals occurring (i.e., information processing) in living organisms, a level of consciousness may be associated with the complexity of the connections. If you consider your current phenomenal experience, it is unlikely to be comprised of isolated bits of information that disregard the context or relation to other bits of information present, including the subjective frame that together constitutes a sense of self and “ownership”. True you can focus on one aspect of this experience, but it still typically belongs to an overall unified experience. This could be what some consciousness theories are trying to say (e.g., IIT, GNWT). The relationship between processed information can be better explained by advancing such theories and identifying how conscious information differs from attentional information.

These examples illustrate the possible informational differences between attention and consciousness. Summarized simply, attention is epistemically valuable while phenomenal consciousness is viscerally and empathically valuable. Phenomenal consciousness, in itself (based on its neural activations or state of connections), may also provide a type of information related to homeostatic equilibrium. The unique type of information that consciousness provides, if such a distinction truly exists, is something that current theories of consciousness have not directly addressed. Where does this information fit among the neural processes described by current theories? Is there conscious information that is not provided by attention, and if so, how is it processed? At the very least, this is a research direction that should be investigated because it could produce new and useful insights about the functional role of consciousness.

8. Conclusion

Humans have evolved to process a large amount of information in a world where information is ubiquitous. It would be overwhelming if it was not processed selectively by our perceptual and cognitive systems. Attention plays the important role of selectively processing and modulating a vast amount of information obtained from environmental and internal processes. This is the case regardless whether the information is experienced consciously or not. Without such information processing, most living organisms would be unable to function.

Information-processing mechanisms have evolved to process environmental information in a way that supports the survival of organisms. This is uncontroversial. Attentional systems demonstrate the selectivity of signal processing that allowed more complex organisms to successfully navigate and manipulate their environment. From detecting features to recognizing objects to using tools, these perceptual and cognitive processes are seen in the animal world with increasing complexity (Haladjian & Montemayor, 2015). Attention optimizes the processing of relevant information to support these functions and can be described computationally or algorithmically. Consequently, attention crucially depends on information. If there was no need for an organism to process complex information, attention would have never evolved in the way that it has.

The role of consciousness within such information-processing systems is still debated. There is little consensus on its functional purpose and whether or not it can be described in evolutionary terms. Nevertheless, there are some aspects of survival that consciousness seems to promote. Namely, the ability to empathize with other organisms (e.g., for social interactions, which is also seen in non-humans) and the possible amplification of signals to fully engage the organism in life-sustaining tasks (e.g., conscious attention), which can include visceral experiences. Attention seeks and processes information from internal and external sources, which often are nonessential. In other words we can say that attention can function in arbitrary ways while consciousness is more foundational since it is closely tied to life-sustaining homeostatic processes. Information is essential to both processes, and better defining the neural processing of conscious information may help further explain the relationship between attention and consciousness and how they interact to benefit an organism. While attention clearly describes information processing, it has not been explicitly defined whether or not all forms of consciousness require information processing as well, and if so, whether or not all this information is provided by attention. These are the key questions that must be addressed.

To solve the equation (5) we proposed, which assesses whether or not "consciousness without information" is the same as "consciousness without attention", we need to delve deeper into how information is defined. Can a system's state count as information? For example, if the mechanisms of attention did not process any information, is there still information inherent to the physical properties of these biological mechanisms that are in themselves a type of information? What would this imply for consciousness? Is this related to the requirement of sentience in living organisms (e.g., see Ginsburg & Jablonka, 2020)? Or does conscious information come from the processing and organizing of attentional information in a way that creates new relationships, or encrypts information, or encourages homeostasis?

The main question that we ask the scientific community to address is what kind of information is left in consciousness, if any, when we take away all the information from attentional processes, including simple signal detection processes (3)? This would require a deeper understanding of what the neural signals (NCCs) associated with consciousness actually entail. Is there information different from that processed by attention? Is it contingent on interoceptive or proprioceptive information? Is it information from all these sources combined in a unique way? What mechanism does this "combining"? Perhaps we currently cannot understand the information in consciousness because it is at a level that is beyond our abilities to measure scientifically (e.g., quantum level). Similar to our understanding in physics, advances in measurement tools and methods may be required. Nevertheless, we first need to address the question about what information remains if all attention is taken away from consciousness.

To support our perspective, we need more focused research on how the information that we claim to be unique to consciousness (related to subjective experience and feelings) is different from information processed by sensory systems (e.g., visual, auditory, haptic). This necessarily requires that current theories of consciousness include a quantifiable and meaningful designation of the information received from internal monitoring systems, such as proprioceptive and interoceptive systems, including visceral information. The role of maintaining homeostasis could be a way to functionally define the purpose of consciousness, but before this can be claimed we need to understand if consciousness has an *active* role in such homeostatic processes. That is, does consciousness perform something distinct from attentional and signal processing systems to promote homeostasis? Another unique role of consciousness could be related to assigning valence to representational states that are related to homeostasis (e.g., “out of balance = “bad”). This could help explain why many processes occur outside of awareness but are experienced in phenomenal consciousness when there is a critical intrinsic value for the self (Cleeremans & Tallon-Baudry, 2021). Finally, phenomenal consciousness may serve the purpose of providing a continual and unified homeostatic representation. In complex organisms, interoceptive information can come from many sources and thus needs to be managed and prioritized. Perhaps this is the purpose of consciousness, and the status of this system is a bit of information distinct from the information processes we have described—the challenge is quantifying the informational structure of this “conscious residue”. This is what we think is missing from current theories on consciousness.

Would we have attention if we did not interact with the information present in our environment? It does seem that without information, attention and even simple signal detection would be unnecessary and nonexistent. Is consciousness also based on information in a similar way? If so, it should quantifiable as it is in attentional systems. The general outlook, however, has been that consciousness is not computable or reproducible—it cannot be reduced to information processing or modeled by complex algorithms. So if it cannot be reduced to computations of information, then what is it? This unanswered question is the dilemma that continues to fuel debates in this field, particularly because consciousness in itself is considered to be informative. By better understanding the informational role of homeostasis and valence judgments in consciousness, and how diverse informational processes support these, we may find a way to move forward in our understanding of consciousness and its functional purpose.

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Conflicts of Interest

None.

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