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A Physical and Evolutionary Perspective of Consciousness and Self-Awareness

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Dissertação de Mestrado

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Advisor: Prof. Daniel Mograbi

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Abstract

Lage, Caio; Mograbi, Daniel (Advisor); Soutif, Ludovic (Co-Advisor). **A Physical and Evolutionary Perspective of Consciousness and Self-Awareness**. Rio de Janeiro, 2020. 81p. Dissertação de Mestrado - Departamento de Psicologia, Pontifícia Universidade Católica do Rio de Janeiro.

The following work addresses issues pertaining to the study of consciousness and self-awareness. Regarding consciousness, this study addresses the hard problem from a reductive physicalist perspective, considering consciousness as one of many other phenomena in the physical world. As for self-awareness, this work addresses, in an evolutionary and neurocognitive perspective, the methods to study self-awareness, which animals are self-aware and what are the adaptive advantages of self-awareness.

Keywords

Consciousness; Quantity; Supervenience; Self-Awareness; Evolution.

Resumo

Lage, Caio; Mograbi, Daniel (Orientador); Soutif, Ludovic (Co-orientador). **A Physical and Evolutionary Perspective of Consciousness and Self-Awareness**. Rio de Janeiro, 2020. 81p. Dissertação de Mestrado - Departamento de Psicologia, Pontifícia Universidade Católica do Rio de Janeiro.

O trabalho a seguir aborda questões relativas ao estudo da consciência e da autoconsciência. Em relação à consciência, este estudo aborda o problema difícil ("*hard problem*") a partir de uma perspectiva física reducionista, considerando a consciência como um entre muitos outros fenômenos no mundo. Quanto à autoconsciência, este trabalho aborda, numa perspectiva evolutiva e neurocognitiva, os métodos para estudar a autoconsciência, quais animais são autoconscientes e quais são as vantagens adaptativas da autoconsciência.

Palavras-chave

Consciência; Quantidade; Superveniência; Autoconsciência; Evolução.

Riassunto

Lage, Caio; Mograbi, Daniel (Tutor); Soutif, Ludovic (Co-Tutor). **A Physical and Evolutionary Perspective of Consciousness and Self-Awareness**. Rio de Janeiro, 2020. 81p. Dissertação de Mestrado - Departamento de Psicologia, Pontifícia Universidade Católica do Rio de Janeiro.

Il seguente lavoro affronta questioni relative allo studio della coscienza e dell'autocoscienza. Per quanto riguarda la coscienza, questo studio affronta il problema difficile ("*hard problem*") dal punto di vista del riduzionismo fisico, considerando la coscienza come uno dei tanti altri fenomeni nel mondo. Per quanto riguarda l'autocoscienza, questo lavoro affronta, da un punto di vista evolutivo e neurocognitivo, i metodi per studiare l'autocoscienza, quali animali sono autocoscienti e quali sono i vantaggi adattivi dell'autocoscienza.

Parole chiave

Coscienza; Quantità; Sopravvenienza; Autocoscienza; Evoluzione.

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ARTICLE 1

I. THEORETICAL BACKGROUND

The following work consists of two papers. In the first one, we discuss the relationship between consciousness and the brain – assuming there must be some relationship. We argue that consciousness arises out of a transition from quantity to quality, i.e., from an increase in the number of neurons and connections, leading to different dynamics that eventually gain different qualities, such as consciousness.

In this paper, we treat consciousness as being reducible to physical processes. To understand why we chose this approach among all the others, we will outline the pros and cons of monism and dualism, and then support the idea that reductionism is a well-suited approach to the mind, and more specifically, to consciousness.

Among the approaches to the mind, there are two main options: dualism and monism. Dualism, whose main proponent was Descartes (1641/1973), suggests that the mind and the body are ontologically distinct. For Descartes, the mind is a thinking, inextensive, and indivisible thing, while the body is thoughtless, extensive, and divisible. Another type of dualism, property dualism, defended by Huxley (1873/2011) and Chalmers (2016), argues that there is only one physical substance. This substance, however, bears two kinds of properties: physical property and non-physical. Mental phenomena are understood, in this context, as non-physical properties of a physical substance (namely, the brain and its components).

The biggest problem dualism faces is explaining the causal relationship between the mind and the body in both directions, that is, how it is that the mind can have causal influence over the body or, more generally, the physical universe (so-called problem of *mental causation*) and how it is that the body can influence the mind? Or, in Princess Elisabeth's (1643/2007) terms, how something immaterial and extensionless (the mind) can determine the movements of the body and vice versa, if contact and extension are required for this to happen? (Shapiro, 2007). This is known as the mind-body problem. Note that this is also a problem for property dualism, given that the causal closure thesis (i.e. the thesis that only physical causes can have physical effects) is widely accepted today. Besides, neuroscience and neurobiology studies have shown that mental events brain states and functions are strongly correlated (Gazzaniga, Ivry & Mangun, 2014), and the more the brain is studied, the more correlations are found with different cognitive phenomena. In addition, physics tell us that the universe is composed of a single physical substance (Strawson, 1998, 2006). For these and other reasons, physicalism is the approach with more followers in the academic environment (Bourget & Chalmers, 2014).

Physicalism, a type of monism, suggests that only the physical exists, in such a way that mental properties are ultimately understood as the results of material relationships (Dennett, 2015). There is nothing over and above physical phenomena. Physicalism deals with the mind-body problem by approaching the mind in a physical way.

However, physicalism has issues too, such as the problem of qualia (Lewis, 1988/2004). This problem occurs from a first-person ontological point of view (Searle, 1987): subjectivity, sensations, feelings seem to be something completely different from the physical world, since they have a phenomenological (non-physical) character for those who experience them.

Chalmers (1995) draws a distinction that helps us understand the problems of consciousness and the difference between what is already known about the brain and the nature of consciousness. According to him, there are two types of problems regarding consciousness: the so-called easy problems pertaining to the explanation of how we integrate information in the brain, what are the functions of consciousness, how we interpret data from the senses, how we store memories, etc.; and the hard problem pertaining to the explanation of *how* conscious experience, with its qualitative features, can occur, having explained the functional properties, dynamics, and structure of the brain; in short, how subjective experiences, with all its qualities, arise out of brain processes subjective experience.

Our proposal is that consciousness is one of many worldly phenomena that takes on a new quality by an interplay between the quantity of the system's elements and its dynamics. Consciousness cannot derive from ten neurons only. More is needed. When there is a certain quantity of neurons, they will make certain connections that will lead to different brain dynamics. When the threshold between quantity and dynamics is met, a new quality is gained: consciousness. In this view, consciousness is reduced to physical processes and each different qualitative experience is determined and ultimately explained by the different dynamics of neurons. A great way to see and study this is through the administration of drugs with psychoactive effects, since they change brain dynamics, causing different conscious experiences.

The brand of physicalism defended here is often labelled by contemporary philosophers, *supervenience physicalism*. Supervenience physicalism is the view that *prima facie* non-physical items supervene on physical ones and are, therefore, also physical "at the bottom". More specifically, supervenience states a non-symmetrical relationship between A and B in such a way that there cannot be a difference in A without a difference in B (McLaughlin & Bennett, 2018). When it comes to mental items like consciousness and qualia, it is the view that there are no mental differences without physical differences, i.e. if two systems are physically identical, then they must be mentally identical (Papineau, 1993). In our view, consciousness and qualia supervene on brain processes as a result of a transition from quantity to quality. This, we believe, dismantles the hard problem, since consciousness is just one of many worldly phenomena that changes quality through quantity, and which is completely explained by physical processes. If there is a hard-problem of consciousness, there should also be a hard-problem for all the other qualitative changes that happen in the world, such as with chemical compounds, group formations etc.

One interesting aspect of our proposal is that it opens a possibility for consciousness to have levels. There are lower-levels of consciousness and higher-levels of consciousness, which vary according to the number of neurons and their dynamics. That is why many animals seem to have consciousness, but not like we do. They manifest lower levels of consciousness.

As a consequence of a reductive physicalist approach, we understand that consciousness must be treated in an evolutionary perspective, since consciousness has its roots in the physical world, and if it has levels, it is reasonable to suppose that it developed gradually throughout the course of evolution[1]. That is what we did

[1] An embracing reductive physicalist theory assumes that every other science field can be reduced to the physical. Here we reduce biology to the physical.

in the second paper. In this paper, though, our focus was in a higher aspect of consciousness, known as self-awareness or self-consciousness[2] (Morin, 2006). We discuss what is self-awareness, how it is studied experimentally, and what are its adaptive advantages. We relied on a lot of recent scientific evidence to understand the components of self-awareness and which animals are self-aware. From that we give an evolutionary reason for why self-awareness could have been naturally selected.

Evidence suggests that self-awareness has many components, and we worked with three of them that are well studied: self-recognition, metacognition, and theory of mind. To recognize oneself means also to be aware that one has a body; that the body is part of me. The connection between self and body has been the topic of different studies and theories. Damasio, for example, suggests that the self-process requires the representation of the ongoing state of the organism (Damasio, 2003). Another theory that has received much attention in the last few years is so-called embodied cognition, where the main thesis is that cognition depends on the characteristics of the physical body (Chemero, 2009). For Pereira Jr. (2013) consciousness involves not just the brain, but the interaction between brain, the whole living body, and environment. Indeed, a large amount of evidence supports the idea that the body is a central feature of self-awareness. Self-recognition is studied empirically through the recognition of oneself in the mirror.

Besides this more concrete aspect of self-awareness, there are two other more abstract ones: metacognition, which is the cognition about cognition, studied through confident behaviors, and theory of mind, which is the ability to attribute mental states to others and predict their behavior, studied through the false-belief task or distinctive inferential behaviors such as deceptive behaviors.

In the second paper, we review the literature and gather together many studies suggesting that some animals have at least one of these components. Since a unified theory for a large amount of evidence is still needed, we provide a theoretical background to account for the evidence in the light of evolution, incorporating all

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[2] Self-awareness and self-consciousness can be used interchangeably. However, we adopted the term self-awareness because it is the most used term in this literature.

the evidence found about self-awareness, without disregarding the evidence because of its “weakness” or because of the method.

Self-awareness, just like consciousness, comes in different levels. There are animals who are self-aware in a lower-level, and animals who are self-aware in a higher level; it all depends on which self-awareness components they have and how developed they are. We believe that this explanation is good because it gives a more naturalistic explanation of self-awareness and it can account without contradiction for all the evidence of self-awareness available in animals. We did not exclude evidence by arguing that the methods were not good enough, or the evidence was not clear enough.

We proceed by discussing the adaptive advantages of these components. Working in the light of evidence, we give an evolutionary account of why these components were naturally selected. Even though this part is a post-hoc discussion, we believe we have good reasons for supporting the idea that they were naturally selected for their adaptive advantages, because we could think of important reproduction and survival advantages for each component.

This work approaches consciousness and self-awareness from a neuroscientific, physical and evolutionary perspective, gathering arguments from different scientific research fields. We hope that this work will provide new insights for the study of consciousness and self-awareness.

II. OBJECTIVES

According to the theoretical background presented, this dissertation is composed of two studies with the following objectives:

- To propose an answer to the hard problem of consciousness from a physical perspective;
    - To argue that consciousness has levels;
    - To argue that experimental studies with psychoactive drugs are useful to understand the nature of consciousness.
- To address and give a theoretical foundation to the study of self-awareness;
    - To understand the methods to study self-awareness;
    - To analyze which animals are self-aware;
    - To discuss the adaptive advantages of self-awareness.

III. ARTICLES SECTION

ARTICLE 1

Lage, C; Soutif, L; Mograbi, D. Consciousness in the Physical World: The Transition from Quantity to Quality (Manuscript in preparation).

Consciousness in the Physical World:

The Transition from Quantity to Quality

Abstract

How does the brain create the experience of consciousness with all its qualities? It has been suggested that even though we can explain many functions of the brain, it is not possible to explain how a physical brain can create the subjective experience of consciousness, also known as the hard problem of consciousness. In this paper, we argue, through a reductionistic view, that this problem is an illusion. Different phenomena in the world, from chemical substances to human formations, are explained by transitions from quantity – and new dynamics between elements – to quality. We point to examples from these fields, suggesting that, since consciousness can be reduced to physical processes, the same happens in relation to consciousness and the brain; a certain number of neural networks and a specific dynamic between them are needed, with a new quality being gained when a threshold is met. On this view, consciousness and each different qualitative experience is determined and ultimately explained by the different dynamics of neurons, as can be best seen in the example of psychoactive substances.

Keywords

consciousness; quantity; quality; qualia; supervenience.

Introduction

We, as humans, get to understand many aspects of the universe, from the gravitational forces governing the movement of stars and planets to the structure of our brain cells. Yet, we still fail to fathom the only phenomenon we have immediate access to: consciousness. Neuroscience unveils some functions of consciousness and how the brain performs them, such as how it integrates sensory information, focuses attention and controls behavior. However, these are the so-called easy problems of consciousness (Chalmers, 1995). By contrast, scientific theories and methods leave a gap in explaining *how* conscious experience, with its qualitative features, can occur having explained the functional properties, dynamics, and structure of the brain; how, for instance, when we see the color red we have the subjective experience of red, or when we hurt ourselves we feel the subjective sensation of pain; more generally, how matter creates first-person experience with all its phenomenal qualities. This is the hard problem of consciousness (Chalmers, 1995).

The problem arises not only because of ontological and methodological disagreements, but also because of conceptual confusion (Velmans, 2009). The discussion involves two concepts — consciousness and qualia — that are controversial, hazy, and often used carelessly as if they were interchangeable. *Consciousness* designates different concepts (Block, 1995; Dehaene, Lau and Kouider, 2017) with four meanings associated to it (Lormand, 1998): knowledge in general, intentionality, introspection, and phenomenal experience. The latter is, arguably, key to definitions of consciousness. Velmans (2009) goes so far as to suggest that consciousness necessarily involves phenomenal content and that, when the latter is absent, consciousness is absent too.

Although religions, such as Buddhism and Hinduism, suggest that contentless conscious states, *i.e.* pure states of consciousness, can occur (Shear and Jevning, 1999; Travis and Pearson, 2000), conscious states, whether experienced by humans or by other animals, are usually endowed with content and phenomenal qualities. Each conscious experience has a subjective feel or *quale*, a "what-it-is-like" to have it (Nagel, 1974). According to Block (1994), these subjective feels, termed *qualia*, are the experiential properties of sensations, feelings, perceptions, thoughts, and desires. In this paper, we use *consciousness* as a term standing for the first-person phenomenal experience caused by dynamic interactions in the brain —assuming that the brain is responsible for the subjective feel of conscious states. Since these experiences have (subjective) qualitative properties, we use the term *qualia* to refer to them.

To solve the hard problem, one must answer the following question: how consciousness and qualia can occur through physical (i.e. brain) processes; *how material causes within a physically closed causal chain can generate first-person experience with its qualitative properties?* Levine (1983) suggests that, no matter how much we know about the brain and its physical properties, there will always be a gap between the brain and the qualitative properties of consciousness. In this paper, we argue that the hard problem is not a real problem, since consciousness, similar to many other phenomena in the world, can be explained by transitions caused by quantitative changes and different dynamics. If this is true, the gap between the physical world and consciousness is not, so we argue, as unbridgeable as it may sound, because conscious properties, are a worldly phenomenon and ultimately realizable in physical terms, i.e., they supervene neural processes and can be explained by this transition, the same way we can explain the different phases of water or the formation of societies. Section 1 explains how the transition occurs in chemistry. Section 2 tracks the phenomenon in human relationships and dynamics. The remaining sections of the paper (3-5) explain the transition with respect to consciousness, thought of as supervening on brain states, and being ultimately explained through transitions from quantity to quality and the establishment of new dynamics

1. From quantity to quality: the case for chemical elements and substances

Matter is continuously changing. Throughout our lives, we gain and lose cells. Our tissues grow and degenerate. At which point, it may be asked, these small changes lead to a different state? How many hairs, for instance, one must lose to become bald? This puzzle, called by the Ancient Greeks *The Sorites Paradox,* was first posed with respect to physical changes in the world: one grain of wheat does not make a heap, neither do two, but eventually, the addition of just one grain of wheat will make a heap (Hyde, 2011).

The Ancient Greeks tried to explain how changes occur and suggested some of them happen through a transition from quantity to quality (Grant and Woods, 2002). For the Greek philosopher Democritus, the world was ultimately made up of atoms (indivisible particles that are colorless, soundless, tasteless, etc.) and void. The different shapes, sizes, orders, and positions of the atoms spread throughout the void would account for the quantitative and qualitative different aspects of bodies (Hooykaas, 1949; Pasnau, 2007). Later, after Aristotle's critique of Democritus' theory (O'Brien, 1977), Epicurus refined the atomic theory, which remained influential for many centuries (Partington, 1939) until Dalton elaborated a new theory based on empirical evidence (Harrison and Treagust, 2003).

Dalton's theory expanded on notions entertained a few decades earlier by Lavoisier, who concluded that water was not one element, but composed of hydrogen and oxygen. Water is a substance (H_2O) and, at different temperatures, the elements alter their coalition and synergy, changing phases: gas, solid or liquid water (see Figure 1). Thus, a change in quantity (heat) leads to different interactions among elements, altering the substance's qualitative state. According to Lavoisier (1789):

> *Water [...] whilst below Zero of the French thermometer, or 32° of Fahrenheit, it remains solid, and is called ice. Above that degree of temperature, its particles being no longer held together by reciprocal attraction, it becomes liquid; and, when we raise its temperature above 80°, (212°) its particles, giving way to the repulsion caused by the heat, assume the state of vapour or gas, and the water is changed into an aëriform fluid. (p. 3-4)*

Figure 1. Phases of water as a result of quantitative changes and different dynamics between elements.

These changes also entail the occurrence of different qualitative properties. For example, during the transition from liquid to solid state, water increases in volume. These qualitative states, as different as they are, involve the same elements: two atoms of hydrogen and one of oxygen. The changes happen because of the different dynamics and interactions among the physical elements, leading to the occurrence of different qualitative states (gas, solid, liquid) and properties (volume changes, “hardness” etc.).

Even though water is not yet solid at 1° Celsius (sea-level pressure), the interaction among its physical elements is not the same as the one involved in higher temperatures, e.g. when water heats up to 99° Celsius (at sea-level). At any point between 99° C. and 1° C., water is commonly understood as being in the same (liquid) phase. However, this is not *exactly* the same state since the interactions and dynamics among its particles at both points (99° and 1°) are different. This is visible to the naked eye: water is more agitated at 99° C and steadier at 1° C. This holds true for even smaller differences: water at 49°C is in a different state than water at 51°C (even though the difference may not be visible to the naked eye). Yet, from 99°C to 101°C, not only a change occurs in interaction among the particles but also a phase change. The substance change qualities and properties by virtue of this specific change in interaction among its elements. A new phase is ascribed as a result of this change: water is now (said to be) in a gaseous phase. A quantitative change has led to a new qualitative state. Nonetheless, the new qualities and properties are all accounted for by the physical properties, i.e., all these different qualitative states and properties are, ultimately, accounted by the water elements and their dynamics.

The same chemical element can exist in different forms simply through the occurrence of a new set of interactions among its atoms within the same phase. This phenomenon is known as *allotropy*. For example, carbon has different allotropes (graphite, diamond or graphene) depending on how its atoms are bound together (Hirsch, 2010). These three allotropes, even though made of the same element, possess different qualitative properties: graphite is black, diamond is transparent, and graphene is the hardest material ever tested. Thus, an element, through structural modifications, acquires new properties and gains, so to speak, a new identity.

Chemical reactions are another common phenomenon, involving changes in substances that occur when one or more atoms are added or lost, creating a new chemical substance (Greenwood and Earnshaw, 1997). For example, formic acid (HCOOH), when one carbon atom and two hydrogen atoms are added, becomes a new substance termed *acetic acid* (CH_3COOH), gaining new properties such as different boiling and melting points (Brown *et al.*, 2012).

According to the Law of Conservation of Mass, nothing is lost or created, i.e., elements and their quantity are conserved. "[…] [W]hat happens are only changes, modifications" (Lavoisier, 1789/1965). These modifications can eventually lead to a new qualitative state and properties, which are explainable in terms of the quantitative changes and new dynamics within the physical system. Later, with the vast dissemination and impact of chemistry, other thinkers, such as Marx and Engels, adhered to this idea and used it to explain abstract social relations.

2. The case for people: war and society

Marx and Engels used the transition from quantity to quality to explain mechanisms of social transformations (Carneiro, 2000). Based on Hegel's dialectical way of thinking, Marx and Engels' writings culminate in the idea of dialectical materialism, characterized by the continuous transformation of men and the world through their relations and dynamics (Swyngedouw, 2009).

For Engels, new qualities may emerge out of people interactions, just like new properties may emerge when water is boiled or frozen. One of his favorite examples involves Napoleon's soldiers losing their battle with Mamelukes one-to-one yet overcoming the Mamelukes strength as an organized and disciplined whole (Napoleon's army), even if outnumbered (Pawly, 2006). This war-related phenomenon was well known to Romans, who took advantage of military organization in their battles. The famous Testudo formation (Rance, 2004) involved grouping soldiers and using their shields to create a unified solid formation protecting their torsos and heads, thereby providing better defense against distant attacks (such as arrows and spears) and offering a safer way to advance towards enemies. When grouped, the individual soldiers form a platoon, thereby reaching a new qualitative state and gaining properties not possessed by its individual members. Nevertheless, the new qualitative state and properties are all accounted by the basic elements that compose it (i.e., humans and its dynamics).

Changes in people interactions can be the key for understanding social phenomena. Any social group comprises a number of individuals. This is a necessary, yet not a sufficient condition for a social group to be a group since social groups are also determined by the relations between their members. Individuals can only turn into a society if they interact (organize, define rules, get in contact with one another etc.) Society is the process of interaction between people and the world; the interactive dynamics among people that share similar customs and organizations. In other words, society is accounted for by its basic elements, which are the individuals and their dynamics. There is nothing over and above the individuals and their dynamics.

3. The case for consciousness and qualia

Could a similar process be involved in the occurrence of consciousness? For example, do consciousness and qualia result from the interaction between a certain number of nerve cells? Here we assume, as many authors do, that the brain somehow provides the support for consciousness with its qualities. Few authors, however, have tried to give a systematic account of the dynamics of the brain and its relation to consciousness and qualia (Thompson and Varela, 2001; Edelman, 1990, 2003; Tononi, 2004, 2008).

For Tononi (2004, 2008), consciousness involves the capacity to integrate information. Information is the discrimination of alternatives, reducing uncertainty, and integration is the unity of a system that shares the information. With higher integration of information, consciousness increases. For him, consciousness is measurable within a system through the φ value, which is the "amount of causally effective information that can be integrated across the informational weakest link of a subset of elements" (2004, p. 1). The different relations and states of the system entail the qualities of this phenomenal experience. Tononi coins these states of the system *qualia spaces* (Q-space), and each different state is a different Q-space. Thus, different arrangements in Q-space lead to different qualitative experiences.

Tononi's theory entails that: (1) consciousness is not an all-or-nothing phenomenon; it has levels; (2) consciousness can be measured; (3) qualia are determined by the dynamics of a system; (4) since consciousness is the integration of information, there can be conscious artifacts. (1)-(3) are in line with our view to the effect that consciousness supervenes on brain states through transitions from quantity to quality. (4), however, expresses that consciousness is a functional state irrespective of its material support. By contrast, just like graphene cannot be made of oxygen, consciousness (first-person experience with distinctive qualitative properties) cannot supervene on metal, i.e. the material support for consciousness (nerve cells) is crucial.

Edelman (2003) warns against reifying consciousness, suggesting that it should be thought of as a process that emerges from interactions between the brain, the body, and the environment. He emphasizes the material basis that allows the existence of consciousness and argues that consciousness results from dynamic interactions among widely distributed groups of neurons (2003). Evolution naturally selected certain neural systems, within which consciousness emerged, through the interaction of neuronal assemblies.

He draws a distinction between primary and higher-order consciousness. The former arose through evolution and was maintained because it allows animals to integrate perceptual and motor events in memory, creating a scene of the present (termed “remembered present”), giving them an adaptive advantage. For Edelman, the emergence of primary consciousness involves brain activity in thalamocortical loops. It also involves structures such as the basal ganglia and the brainstem. On his view, a key process for the emergence of consciousness is reentry – when information is sent to an area of the brain, and makes the way back, (e.g. from the thalamus to the cortex, and then from the cortex to the thalamus), making a simultaneous exchange of signals (Edelman and Gally, 2013).

Higher-order consciousness can be observed, potentially, in chimpanzees and, in a more complex form, in human beings. It appeared later in evolution, through more complex interactions among neural systems including language processing, allowing breaking free from the present – creating notions of past and future selves (Edelman, 2003).

Edelman and Tononi propose that both a certain quantity and the interaction between constituent parts are necessary for the appearance of consciousness. What we are suggesting is that consciousness is entirely accounted for the more basic physical elements that it constitutes; i.e., a neuronal ensemble of a certain size (i.e. a minimal number of neurons) and a specific dynamic (for example, thalamocortical loops). When the threshold for these conditions are met, consciousness arises; but consciousness is described through these conditions. Just like the phases of water and its qualities can be explained in terms of the dynamics between its elements; and just like society can be explained in terms of the dynamics between a certain number of individuals, consciousness can be explained in terms of a certain neuronal quantity, and their relations. Consciousness, then, can be reduced to more basic physical elements.

4. Elaborating on the idea

The hard-problem presupposes that there is something which sets consciousness and qualia apart from the chemical and human formation examples above. Chemical elements (such as Hydrogen, Carbon, Aluminum), chemical substances (such as formic or acetic acid), platoons, and society can be ultimately accounted for in physical terms, since the elements that constitute them are also physical. Consciousness, on the contrary, seems to be different from the brain process on which it supervenes. However, what we are proposing is that consciousness can also be ultimately explained physically. Consciousness is simply one of many cases in which a new qualitative property emerges from a different quantitative process. In this sense, consciousness is not very different from other organic processes, such as digestion, because digestion is entirely accounted for by the biological processes within the human body, the same way consciousness is accounted for by the neuronal processes in the brain.

Consciousness, the way I experience, is reduced to the brain processes I have. This means that to experience consciousness the way another person does, it would be necessary to have that particular nervous system with the exact same configuration. If two people would have the exact same brain configuration (same number of neurons, same connections, same neurotransmitters, same interaction between brain and other bodily processes, same interaction between brain and the physical world, etc.), then they would be experiencing the same thing.

Similar to water and other chemical compounds, brain processes alter their interactions and dynamics, leading to the formation of different brain circuits. So, what is the difference between blue and green, anger and happiness, pain and pleasure? They all have distinctive phenomenal qualities, for they all supervene on different brain processes, but they are all ultimately accounted for by these processes. In the same way that distinct qualities are observed in carbon depending on its structure and dynamics, consciousness (first-person experience) and its qualities (the subjective sensations of blue, green, anger, pain, etc.) supervene on the brain (being physical) because of its dynamics and structures.

Our proposal that consciousness and qualia supervene on brain processes as a result of a transition from quantity to quality has advantages. First, it locates consciousness and qualia in a physically closed world without losing phenomenality. Second, it gives a naturalistic account of the rise of consciousness through evolution, understanding that consciousness is not an all-or-nothing experience. Observing the behavior of other living beings may lead us to infer that consciousness has levels. Chimpanzees, who are close to us on the evolutionary scale and have similar brain processes, even show some evidence for higher-order consciousness behavior, such as planning for future needs (Osvath and Osvath, 2008), lying, deceiving etc. (Jolly, 1991). It is possible that consciousness itself provides adaptation, for example by allowing increased memory capacity and correlation between cognitive processes (Block, 1995; Weiskrantz, 1997).

If we suppose that consciousness, as we know it, came into existence without an evolutionary process, the hard problem becomes even harder. It is probably wrong to suppose that a single species, through evolution, developed a neural circuitry that allowed it, from one moment to another, to gain consciousness *such as we experience it*. Rather, it is more consistent with evolutionary theory that consciousness came to existence gradually (Feinberg and Mallatt, 2013), with the evolution of neural systems, reaching more complex capacities in human beings. As indicated, we can infer primary consciousness in many other animals (Edelman, 2001), although this process is probably vaguer and cruder than ours. In the same way that water is in different qualitative states in each degree Celsius, consciousness is in different states according to the quantity and dynamics of brain process.

5. Testing the hypothesis through experimental approaches

One alternative to measure the transition from quantity to quality with respect to consciousness is to investigate its altered states. In particular, neurotransmitter availability seems to be a privileged way to consider how quantitative material changes lead to distinct qualitative mental states. Drugs with psychoactive effects allow to experimentally manipulate, in a reversible manner, the concentration of certain molecules in our nervous system, with measurable effects on conscious experience.

Serotonin, for example, one of the main monoamine neurotransmitters, has been involved in a number of relevant organic processes, including, but not being limited to, effects on mood, motility, sleep, sexual behavior and appetite (Mohammad-Zadeh, Moses and Gwaltney-Brant, 2008; Pytliak, Vargová and M, 2011). It is well established how different quantities of serotonin in the central nervous system lead to distinct mental states. For instance, selective serotonin reuptake inhibitors (SSRIs) are the most common prescription medications used in the treatment of depression and anxiety disorders (Sheehan *et al.*, 2005). They act by preventing serotonin transporters from removing (reuptaking) serotonin from the synaptic cleft. The increased quantity of serotonin in synapses facilitate neurotransmission, leading to enhanced communication between neurons and excitatory effects, establishing different brain dynamics. SSRIs are linked to increased psychomotor activity (Schrijvers, Hulstijn and Sabbe, 2008), more positive mood (Flory *et al.*, 2004) and decreased anxiety (Homberg, Schubert and Gaspar, 2010).

Is a mere change in quantities of serotonin sufficient to generate different mental states? Increasing serotonin only leads to these mental phenomena depending on the specific class of serotoninergic neurotransmitter affected. Serotonin increases can lead to changes in organic processes that are not mental in nature (e.g. digestion), depending on the site of action. For instance, tryptophan, a serotonin precursor, when ingested in fruits such as bananas, does not cross the blood-brain barrier or alters the brain levels of serotonin (Wurtman and Melamed, 1981). Increases in serotonin only lead to changes in mental states if specific serotoninergic pathways, on which processes such as mood supervene, are affected.

Similarly, when examining the affinity of fluoxetine (a SSRI commonly known by the brand name “Prozac”), it becomes clear that its effects on mood and motility are linked to its action on the sodium-dependent serotonin transporter (SERT; Owens, Knight and Nemeroff, 2001). A substance with a different profile of receptor and transporter binding affinity, such as psilocybin (the active component of magic mushrooms, with high affinity for 5HT2a receptors), entails markedly distinct mental states, with hallucinations being a hallmark of its effect. Again, it is plain here that not only changes in quantity (amount of neurotransmitter in the synaptic cleft) and dynamics (increased excitatory transmission among neuronal ensembles) are needed in the transition from the physical to the mental, but also alterations within specific systems. Changes in the quantity of dopamine in the nigrostriatal pathway lead primarily to movement alterations (as in Parkinson's disease and its treatment; Cools, 2006; Olanow, Obeso and Stocchi, 2006), whilst changes in the mesolimbic pathway lead primarily to feelings of pleasure and anticipation (as in substance abuse disorders; Sinha, 2008).

This highlights the importance of the specific material support in which psychoactive substances exert their effect. Although a certain number of elements and the interaction between them may constitute a necessary condition for the transition from physical (brain) to mental states, this may not be a sufficient condition. A specific material support, in the end, may be crucial to establish which qualities, including consciousness, matter may display.

In this paper, we proposed that the hard problem of consciousness is not a real problem. Conscious properties supervenes on the matter and are perfectly explainable through the transitions from quantity to quality and the establishment of new dynamics between constituting elements. Consciousness is just one of the many phenomena in which a qualitative process supervenes on different quantitative processes. If there was a problem to explain this transition, then there would also be a hard problem in explaining how water changes phases or how humans create societies. However, we do not know, yet, the specific parts or processes of the brain needed for the emergence of consciousness, how many neurons are necessary, nor when, in the course of evolution, this transition took place. Nevertheless, we believe the notion of the transition from quantity to quality, considering the need for a specific material support (i.e. nervous systems), dismantles the hard problem.

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ARTICLE 2

Lage, C; Mograbi, D. An Evolutionary View of Self-Awareness (Manuscript in preparation).

An Evolutionary View of Self-Awareness

Abstract

The capacity of self-awareness has been taken as one of the differences between humans and other animals. A growing amount of evidence is challenging this notion, proposing that many animals are self-aware too. In this paper we discuss, through a neurocognitive view, different questions regarding self-awareness, such as what is self-awareness, how it has been studied experimentally, which animals are self-aware, and what are the adaptive advantages of self-awareness.

Keywords

self-awareness; self-recognition; metacognition; theory of mind; levels; adaptive advantages.

Introduction

Every experience we have is a first-person experience, and the subject that lives such an experience is the self. Having a sense of self allows the creation of a protagonist for the objects and events that permeates our mental life (Damasio, 2003b). The self, the I in every experience (such as “I am hungry” or “I want freedom”), has been an old-time subject of interest, and recently a great interest is in its the neurobiology and neuroscience (Feinberg & Keenan, 2005). For Damasio, every organism, even the simplest ones, have a minimal self process (Damasio, 2010), and he highlights the importance of the body to understand the self (Damasio, 2003a). Feinberg , instead, proposes that a neural nested hierarchy of three systems creates the self, where lower level processes are nested within higher level processes (Feinberg, 2011).

Even though the debate about what is the self is still a puzzle (Gillihan & Farah, 2005; Searle, 2005; Strawson, 1999), it is becoming clear, through a neurocognitive view, that the self is not an unitary concept, but divided in many components (Klein, 2010). Generally, self-awareness is the process where one becomes the object of one’s own attention (Gallup, 1982; Morin, 2006), and where one is aware of themselves as themselves (Smith, 2017), but, since self-awareness is divided into components, it can be thought of as awareness of these components. This division provides an advantage for defining and hypothesizing when self-awareness is lacking or impaired, which animals are self-aware, and when self-awareness emerged in the evolutionary scale.

The study of self-awareness allows a better understanding of humans and animals conditions. Research in this field has important implications: theoretically, it may provide a clear ground for integrated interdisciplinary models to better understand the dynamics of self-awareness; clinically, it may provide new approaches for treatments of psychological and medical disorders; and ethically, it may provide a better background to infer if and to what extent infants, neurocompromised patients, and animals are self-aware.

This paper will discuss some issues about self-awareness. Section 1 will discuss the idea that self-awareness has levels. Section 2 will address the components of self-awareness. Section 3 will discuss the methodological challenges and techniques to access self-awareness and its components. Section 4 will discuss why animals developed self-awareness, i.e., what are the adaptive advantages of self-awareness. Finally, the last section will give our final considerations.

1. Levels of Self-Awareness Across the Evolutionary Spectrum

Gradualism is a general principle of evolution. According to it, evolution occurs gradually, through small steps; i.e., through small incremental changes accumulated in a long scale of time (Laland et al., 2015; Mayr, 1982). Consequently, the traits follow a continuum in the course of evolution since progress does not happen in jumps, but step by step. In this sense, traces of cognitive abilities are expected to be found in other species, since they do not follow a binary (have it or not) rule, but they gradually emerged over a long period. This means that some of these processes are more subtle, varied and with different types and levels. Indeed, rudimentary beings are expected to have these processes more rudimentarily, while more complex beings are expected to have them more developed. Accordingly, self-awareness has gradations (or levels), and it varies in virtue of the availability or not of the components, and their development.

Different authors addressed the idea that self-awareness has levels (Bermúdez, 2000; de Waal, 2019; Legrain, Cleeremans, & Destrebecqz, 2011; Morin, 2006; Rochat, 2003). For de Waal (2019), some animals (such as fish and smaller brained animals) have low levels of self-awareness, while hominids and other animals have high levels of self-awareness. Bermúdez (2000) also proposes that there are primitive forms of non-conceptual self-awareness, such as somatic proprioception. What these authors are suggesting (and so are we) is that self-awareness is not a binary trait, but a gradual one.

Morin (2006) compared and discussed nine neurocognitive models of consciousness consistent with levels of consciousness and self-awareness. In his paper, he argues that all nine have similarities that can be divided into four levels. The first level is unconsciousness, where there is no response to the world or the self. The second one is consciousness, where an external stimulus is being processed. The third level is self-awareness, which is categorized in two (Fenigstein, Scheier, Buss, & Buss, 1975): a lower form of self-awareness, called public self-awareness (aspects of the self that are public to others, such as our body and behavior); and a higher form of self-awareness, called private self-awareness (aspects of the self that are private to the person; that have first-person ontology, such as our thoughts, emotions etc.). Finally, the highest aspect of self-awareness is the meta-self-awareness (awareness that one is self-aware). It is important to highlight that evolution is a process of differentiation, and not perfecting. There are different processes that vary according to the demands in play, making individuals adapt to them.

The gradualist perspective of self-awareness divided in components explains why healthy humans can diverge from some animals, children and people with neurological and neuropsychological disorders, even though some of them are capable of complex behaviors: because they may not have some of these components, or, if they do, they might be underdeveloped or impaired. Thus, self-awareness can range from low-level processes to high-level processes.

2. Self-Awareness Components

The recent debate about what is the self focuses on understanding it not as a single process, but as composed of many components and processes (Klein & Lax, 2010). The challenge is to establish what they are, and understand how they interact to create the unitary experience of the self (Feinberg & Keenan, 2005; Klein, Rozendal, & Cosmides, 2002). From a neurocognitive view, self-awareness is composed by interoception, the sense of internal body with the perception and integration of autonomic, hormonal, visceral and immunological signals (Seth & Friston, 2016), proprioception, the sense of body position in space (Han, Waddington, Adams, Anson, & Liu, 2016), sense of agency, the sense of being the agent who originates an action (Hur, Kwon, Lee, & Park, 2014), and many others.

Since these and other concepts are hard to study empirically in humans and especially in other animals, we will focus on three components of self-awareness that are more studied in humans and other animals. The first is self-recognition. Despite the complex relationship between the body and the self (De Vignemont, 2011), studies highlight the importance of body-recognition (or self-recognition) as a component of self-awareness (Anderson & Gallup, 2011; Aspell et al., 2013; Gillihan & Farah, 2005), since our body is part of us. Damasio (2003) even emphatically proposes that to understand the neural basis of the self, one should search at the neural mappings of the body. Self-recognition has been studied trough the recognition of one's own body in the mirror.

The second one is metacognition, which is the "knowledge and cognition about cognitive phenomena" (Flavell, 1979). This is a second order cognitive capacity, such as thoughts about thoughts or knowledge about knowledge (Papaleontiou-Louca, 2008). Metacognition involves knowledge, monitoring and regulation of cognitive processes (Pintrich, Wolters, & Baxter, 2000), as well as emotions and motivations (Papaleontiou-Louca, 2003).

Finally, the third component is theory of mind, which involves attributing mental states (desires, beliefs, knowledge etc.) not only to oneself, but to others (Goldman, 2012). Being able to attribute mental states to others first involves being able to attribute mental states to oneself (although this is controversial, see Carruthers, 2009). With it, one can infer the behavior of others and even manipulate it (Frith & Frith, 2005). Theory of mind allows awareness that others may be self-aware too.

3. Methods to Assess Self-Awareness in Animals

How can we know if animals, children and neurocompromised patients are self-aware? Even if we have good evidence to suppose that they are self-aware, how can we know to what extent they are self-aware? With healthy human adults it is easier to test, since we can express our private states and answer scales of self-awareness (Sherer, Bergloff, Boake, High, & Levin, 1998). But animals, children and severe neurocompromised patients cannot talk about their private states and answer questionnaires. How to do it, then? The first researchers to study this empirically were Amsterdam (1968, 1972) and Gallup (1970).

3.1. Mirror Self-Recognition Test

The first experimental evidence of self-awareness in non-human animals was from Gallup (1970), who studied the public aspects of self-awareness in chimpanzees. In his study (G. G. J. Gallup, 1970), he put a mirror in the chimpanzees cage so they could get used to their reflection. After some time, he marked the chimpanzee's face with a red dye while they were unconscious. When they woke up and faced the mirror, they tried to clean their faces, rubbing the mark. This, Gallup argued (1998), was evidence that they were self-aware, since they could recognize themselves in the mirror and realize that the mark was not on their faces before; it was not part of them. Two years later, Amsterdam (1972) used the same method to access self-awareness in infants under two years old. Today there is plenty of evidence showing that children are capable of mirror self-recognition at around 18 to 24 months old (Amsterdam, 1972; Nielsen, Suddendorf, & Slaughter, 2006; Suddendorf, Simcock, & Nielsen, 2007).

Since Gallup's and Amsterdam's studies, the mirror self-recognition (MSR) test, also known as mirror test, became a widely used method to access self-awareness. Different studies using this method suggest robust evidence of spontaneous mirror self-recognition in others animals, such as elephants (Plotnik, de Waal, & Reiss, 2006), Eurasian magpies (Prior, Schwarz, & Güntürkün, 2008), and dolphins, who even though they cannot reach the mark, show clear and repetitive behaviors of recognizing themselves in the mirror (Morrison & Reiss, 2018; Reiss & Marino, 2001) and they can pass the MSR test at a younger age than children and chimpanzees (Morrison & Reiss, 2018),

Other animals do not pass the mirror test spontaneously, but pass it when trained, such as rhesus monkeys (Chang, Fang, Zhang, Poo, & Gong, 2015; Chang, Zhang, Poo, & Gong, 2017) and pigeons (Epstein, Lanza, & Skinner, 1981; Uchino & Watanabe, 2014). Pigeons can also discriminate video images of themselves when trained (Toda & Watanabe, 2008). However, pigeons could not use the mirror as monkeys did, because monkeys started to use the mirror spontaneously for other behaviors, such as checking unseen body parts, while pigeons did not (Güntürkün, Ströckens, Scarf, & Colombo, 2017).

For other animals, even though they did not pass the MSR test, they show different behavior in front of a mirror, such as contingency checking (moving body parts to check if the same movement is also happening in the mirror), frequent observation of the reflection, and others. This happened with killer whales, false killer whales (Delfour & Marten, 2001), manta-rays (Ari & D'Agostino, 2016), rats (Yakura et al., 2018) and jackdaws (Soler, Pérez-Contreras, & Peralta-Sánchez, 2014). Additionally, a pilot study with horses showed that some of them could at least recognize that the mirror image was not a real animal (Baragli, Demuru, Scopa, & Palagi, 2017).

Other evidence is less consistent. For example, some studies suggest that gorillas pass the MSR test (Parker, 1994; Patterson & Cohn, 1994; Posada & Colell, 2007), while others suggest that they do not pass is (G. G. J. Gallup & Suarez, 1981; Shillito, Gallup, & Beck, 1999; Swartz & Evans, 1994).

Just as there is evidence suggesting that some animals pass the MSR test, there is also evidence suggesting that other animals do not pass the test, and show little evidence of contingency behavior in front of mirrors, such as gibbons (Hyatt, 1998; Suddendorf & Collier-Baker, 2009), giant pandas (Ma et al., 2015), California sea lions (Delfour & Marten, 2001), small passerine (Kraft, Forštová, Utku Urhan, Exnerová, & Brodin, 2017), jungle crows (Kusayama, Bischof, & Watanabe, 2000), New Caledonian crows (Medina, Taylor, Hunt, & Gray, 2011), keas, Goffin's cockatoos (van Buuren, Auersperg, Gajdon, Tebbich, & Bayern, 2019), and Tanganyikan cichlid fish (Hotta, Komiyama, & Kohda, 2018).

Additionally, there is some enigmatic evidence. For example, one study showed that cleaner wrasse fish passed the MSR test, showing behaviors consonant with self-recognition, such as trying to remove the mark by scraping its body and reacting differently when exposed to a conspecific behind a glass (Kohda et al., 2018, 2019). The authors proposed that even though the cleaner wrasse pass the

MSR test, they are not self-aware. Another example is the study that showed that even if African cichlid fish do not pass the MSR test, they have different brain area activations between fighting against a real fish and fighting against the mirror image, suggesting that they recognize something unusual about it (Desjardins & Fernald, 2010). Even ants passed the MSR test, but the authors were cautious and did not take it as an evidence for self-awareness (Cammaerts & Cammaerts, 2015).

Indeed, the mirror test may display larger age differences depending on the context (Kartner, Keller, Chaudhary, & Yovsi, 2012), and it has been criticized as not being an universal (Broesch, Callaghan, Henrich, Murphy, & Rochat, 2011), and reliable method to access self-awareness (Heyes, 1994, 1995; Rochat & Zahavi, 2011). For example, many animals cannot reach the physical marks made on its body because they do not have limbs for this, such as aquatic animals, leaving the evidence harder to interpret. It is so controversial that it has been suggested that there is no evidence for mirror self-recognition in other primates other than great apes (Anderson & Gallup, 2011).

Suddendorf and Butler (2013) suggested that the only robust evidence for mirror self-recognition was with great apes and humans, and, consequently, body-recognition must have evolved at around 18 to 14 million years ago, when the phylogenetic tree line split off from small apes to great apes. However, for Prior and colleagues (2008), since magpies also pass the mirror self-recognition test, self-recognition must have evolved independently in primates and corvids (when they diverged 300 million years ago), suggesting that evolution can solve similar problems in similar ways, and that the neocortex is not essential for it. One study showed that self-face recognition is associated with complex bilateral network involving frontal, parietal and occipital areas (Devue & Brédart, 2011).

The amount of evidence of mirror self-recognition in different animal suggests that self-awareness has levels, and that it began to develop millions of years ago. However, how can we explain such disparities in the evidence? Why do some animals who are expected to show this trait not show it, while others who are expected not to show it, show it? Why do fish pass the test, while some monkeys and young children do not? We can think of some explanations for such enigmatic evidence.

First is that the mirror is not a natural object in many human cultures and in the animal world, so some of them must get used to it before they can be able to recognize themselves, such as the case with monkeys and, forcefully, pigeons. Another example is the study that showed that nutcrackers could recognize themselves in a blurry mirror, but in front of a regular mirror they acted as it was a conspecific (Clary & Kelly, 2016). The authors suggested that this was probably because the blurry mirror represents better situations in the bird's natural experience, such as the blurry reflection of water.

The second explanation is that body-recognition also has levels *within it*. Some animals do not pass the MSR test because they do not have this ability fully developed yet, but they can show unusual behaviors in front of a mirror, suggesting that they have some kind of self-recognition, but it is still incipient (in a low level). It would be wrong to assume that these animals do not recognize themselves whatsoever, and that they are not self-aware because they did not pass the test. In the framework that self-awareness has levels, and that the components of self-awareness also have levels, this evidence is much easier to understand. They do not have a high-level of self-recognition, but they do have a low level of self-recognition and, consequently, a low-level of self-awareness.

The third reason is that the MSR test may not be a perfect method to study self-recognition. Since monkeys do not pass the MSR test spontaneously and fish–apparently–do, it is not unreasonable to suppose that the test is flawed and not applicable to every animal. Indeed, the MSR test also has limitations. As we discussed, some animals cannot touch the mark because they do not have limbs, and other animals do not have vision as the main or the most developed sense to detect the world. Accordingly, even though the mirror test provides evidence of animals' self-awareness, it cannot be thought of as an applicable method for every animal. Considering this, two studies (Cazzolla Gatti, 2016; Horowitz, 2017) used the concept of the mirror test, but they adapted it to dogs, whose olfaction is the main sense apparatus. Both studies provided evidence that dogs could recognize themselves through their smell. Consequently, there is a necessity for a larger battery test to study self-awareness (de Waal, 2019), since the MSR test is far from being the only and perfect method. Nonetheless, for Gallup (2018), olfactory mirror recognition is not a rigorous method and there is no compelling evidence for dogs self-recognition.

It could also be argued, as a result of the third explanation, that the evidence is so hard to interpret that any judgment is risky, i.e., that even though some animals seem to pass the test, it is so hard to interpret their behavior; thus, assuming that they passed would be premature (specially with the evidence of fish and ants). Although we agree that some evidence is harder to interpret, we cannot blind ourselves to it just because it does not fit our conceptual scheme of animals who are self-aware and animals who are not. We emphasize this point because some authors are being more skeptical towards evidence with animals who supposedly do not have self-awareness. For example, in the cleaner wrasse fish study (Kohda et al., 2018), and the ants study (Cammaerts & Cammaerts, 2015), the authors were cautious to assume that the animals were self-aware. However, if the study were to be made with a mammal, maybe there would be less skepticism towards the evidence, even though the only change was the animal, and not the evidence. In another paper, de Waal (2019) argues that the cleaner wrasse did not pass the MSR test, even though, for us, the video shows clear signs of contingency behaviors. We think most of the skepticism towards the evidence comes from our incapacity to think such tiny and simple beings could be self-aware, and this incapacity reflects a misguided conception of self-awareness as being an all-or-nothing attribute. Once we understand that self-awareness is divided in components and that these components have levels (accounting for different levels of self-awareness), evidence becomes more digestible.

Finally, if self-recognition has developed gradually, it means that it is possible that an animal of one taxa can recognize itself, while other animals of the same taxa cannot. That is why it is possible that some fish can recognize themselves, while others cannot; or that some gorillas can recognize themselves, while others cannot. It follows that in some cases we cannot attribute self-recognition to all animals of the taxa, but only to some. This also means that there are different levels among the taxa, some will have a more developed ability to recognize itself, while others will have the ability less developed.

So, can we trace self-recognition in the evolutionary scale? When did it first appear? As evidence shows, the fully acknowledgement of the body in the mirror appears to be a recent trait, but this may be because of the reasons explained above. However, we must think of self-recognition as a continuum, having levels. Evidence shows that even though many animals do not pass the MSR test, some of them pass when trained, and others show idiosyncratic behavior in front of a mirror, suggesting that they acknowledge something different with it. We propose and interpret these data as evidence for a low level of self-recognition. In this sense, there is evidence of a low level of self-recognition even in fish, suggesting that self-recognition dates from millions of years ago. In contrast, a high level of self-recognition would be complete acknowledgement of itself in the mirror or in similar reflective surfaces. To date, evidence suggest that only a few animals have high levels of self-recognition, such as chimpanzees, elephants, dolphins and magpies.

3.1.1. The Toy Shopping Cart

The mirror test is the most popular method to access body self-recognition, but it is not the only one. One study investigated if infants could move a toy shopping cart that had a little mat attached to it (Moore, Mealiea, Garon, & Povinelli, 2007). To move the shopping cart, the infants had to step outside the mat so that their body would not prevent the motion. The researchers also applied the mirror test to the infants. They found a significant correlation between the two tests, independent of the infant’s age. A similar method was used with elephants, where they had to step outside a mat to finish a task, and they did it much more often than the control group (without the mat), which did not have to step outside the mat to finish the task (Dale & Plotnik, 2017).

The mirror test and the toy shopping cart are methods to access lower/public components of self-awareness, i.e., to access bodily awareness, and the evidence suggests that many animals have it. But what are the methods to investigate higher/private components of self-awareness?

3.2. Metacognition

Metacognition is the awareness of one's mental states or cognitive processes (knowing, doubting, remembering, etc.) that can regulate behavior adaptively (Smith, Zakrzewski, & Church, 2016), and it involves knowledge, monitoring and regulation of cognitive processes (Pintrich et al., 2000). Differently from mirror self-recognition, metacognition is a high-order component of self-awareness, because it involves private aspects of awareness, and consequently, more abstraction. Metacognition is studied through confident behaviors. If one is not confident with the amount of knowledge or ability to perform a task, one can (1) engage in information-seeking behaviors, gaining more knowledge to perform the task, or (2) decline to do the task and/or escape to an easier one, even if the reward is minor.

In one study (Call & Carpenter, 2001), researchers studied information-seeking behaviors in infants (2½-year-old), chimpanzees and orangutans. They placed food (for the apes) and stickers (for the children) in two or three tubes. When the subjects did not see in which of the tubes the bait was hidden, they searched in all of them before choosing, i.e., they engaged in information-seeking behaviors. This behavior happened more often than when they saw where the bait was hidden, suggesting that they somewhat knew their knowledge and confidence regarding the task. Other studies using a similar method proposed that gorillas, bonobos, orangutans (Call, 2010), and chimpanzees (Call, 2010; Perdue, Evans, & Beran, 2018) have metacognition. In the information-seeking paradigm, other studies shows evidence in rhesus monkeys (Michael J. Beran & Smith, 2011; Rosati & Santos, 2016), western scrub-jays (Watanabe & Clayton, 2016), pigeons (Castro & Wasserman, 2013; Roberts, McMillan, Musolino, & Cole, 2012), and rats (Kirk, McMillan, & Roberts, 2014).

Besides information seeking, the option to decline a task and escape to an easier one is another common behavior when uncertain. Humans and dolphins (Smith et al., 1995), as well as rhesus monkeys (Smith, Shields, Schull, & Washburn, 1997), when faced a difficult task at which they are uncertain of the response, choose easier tasks, which they have higher chances of getting the right response. Rats also decline to do a task in which they are not confident, and do an easier one, even if the reward is reduced (Yuki & Okanoya, 2017).

Could metacognition also have levels? Two studies proposed that capuchin monkeys, even though not showing clear metacognitive behaviors, have a rudimentary capacity of metacognition, because, despite showing less uncertain behaviors (information seeking, escaping) than rhesus monkeys, they showed some of these strategies on some trials and conditions (Michael J. Beran, Perdue, & David Smith, 2014; Vining & Marsh, 2015). Additionally, even though dogs could not engage in information-seeking behaviors *per se* to find the location of the reward, they chose more often human informants, who would point a location, than human non-informants, who would not point a location (Mcmahon, Macpherson, & Roberts, 2010). The dogs preferred the informant choice than the non-informant even if it would not lead to a greater chance of reward. They were not reinforced by choosing the informant, but they were choosing them based on inferential processes. This suggest they have metacognitive processes, but at a lower level.

It could be suggested that because of the amount of evidence of different animals presenting metacognitive process, maybe there is some yet to discover behavior trick that allows animals to perform uncertainty behaviors without having access to their mental states (Couchman, Beran, Coutinho, Boomer, & Smith, 2012), i.e., these behaviors can be explained by first-order processes (Carruthers, 2008; Crystal & Foote, 2009). Some even criticized the tasks as being so simple that any animal could solve, making it impossible to know if they have metacognition (Insabato, Pannunzi, & Deco, 2016). What we propose is that metacognition has levels, and some animals have it more developed (such as humans, rhesus monkeys and dolphins), while others have it more rudimentary (such as capuchin monkeys and dogs). This explains the evidence without excluding mental states. If we disregard the idea of levels of self-awareness and cognitive processes, it may well be some behavior to discover. But we can understand this evidence as the initial development of metacognition.

3.3. Theory of Mind

Another high-level cognitive component of self-awareness is the theory of mind, the ability to attribute mental states to others; to understand that others feel, see and know. Theory of mind, similar to metacognition, cannot be directly observable since it is a private aspect of self-awareness. It also engages more abstraction, and for this it is another high-level component of self-awareness.

In children, theory of mind is assessed trough the false-belief task, which tests the ability of attributing lack of knowledge (belief in something false) to another person, and it was first developed by Wimmer and Perner (1983). In their study, they found out that children could represent wrong beliefs at between 4-6 years old. The false belief task was implemented (Baron-Cohen, Leslie, & Frith, 1985), and became known as the Sally-Anne task, which is used to access theory of mind.

In this task, there are two puppets, Sally, who has a basket, and Anne, who has a box. Sally gets a ball, puts it in her basket and leaves the scene. While she is away, Anne gets Sally's ball and hides in her own box. After that, Sally comes back to the scene. The researcher, then, asks the child: where will Sally search for her ball? Kids that have a theory of mind will usually say that Sally will look at her own basket, since it was where she left before, and she did not see Anne changing the ball's place. But children who do not have a theory of mind will say that Sally will look for the ball in Anne's box. This is because they cannot attribute false beliefs to others, i.e., they do not understand that others might have different knowledge, opinions and beliefs different from theirs, a condition also seen in autistic children (Baron-Cohen et al., 1985; Leslie & Frith, 1988). Recent studies show that children develop a theory of mind at age two (Carlson, Koenig, & Harms, 2013), although they might even show signs of implicit theory of mind abilities before (Slaughter, 2015). One study found that 2-year-olds can understand not only false-beliefs, but understands actions of others who want to implant false-beliefs (Scott, Richman, & Baillargeon, 2015).

For non-human animals, the first experimental study of theory of mind was from Premack and Woodruff (1978), who studied it in chimpanzees. In their study, chimpanzees had to see videos from humans struggling to do a task. After, the researchers presented several photos to the chimpanzees, and they had to choose the one that represented the correct solution to the problems that humans were dealing with. Since the chimpanzees consistently chose the correct photo, it was argued that they could attribute non-observable states to others (such as want, think and believe), suggesting they have a theory of mind. Later, the studies of Hare and colleagues (2000, 2001) provided more robust evidence for theory of mind in chimpanzees, and they were crucial for developing related studies even for other animals (Andrew Whiten, 2013).

The Premack and Woodruff study was controversial, and 30 years later, Call and Tomasello (2008) reviewed several other studies that investigated theory of mind in chimpanzees and children. Their study suggests that chimpanzees understand that others see, hear and know things; understand goals and intentions of others, and, in a broad sense, they have a theory of mind. What chimpanzees cannot do is attribute false-beliefs (something that children can do) and, in a narrow sense, they do not have a theory of mind.

We can translate narrow and broad sense to our terminology of low and high level. Some animals may have a theory of mind but not fully developed, since they lack some processes, while others have a more developed theory of mind. It is not just a question of whether or not they have it, but whether they are fully developed or partly developed; i.e., whether they are low-level or high-level. Indeed, this idea is not new. Many studies treat theory of mind in at least two categories, rudimentary or minimal theory of mind, and full-blown theory of mind. The idea of levels of theory of mind was better exposed in the paper by Butterfill and Apperly (2013).

Besides the evidence of theory of mind in great apes (Krupenye, Kano, Hirata, Call, & Tomasello, 2016; Tomasello, Call, & Hare, 2003), other studies support evidence of animals' theory of mind, even if in a rudimentary form (or, in a lower level). For example, joint attention, when two or more individuals share focus on something, has been observed in dogs (Horowitz, 2011; Maginnity & Grace, 2014), wolfs (Udell, Dorey, & Wynne, 2011), and ravens (Bugnyar, Reber, & Buckner, 2016).

Another behavior associated with a theory of mind is deception. Tactical deception is the ability to act "honestly" to mislead or manipulate others (A. Whiten & Byrne, 1988). To deceive, one must attribute certain beliefs and intentions to others, and also suppose that they will act according to them. Three-year-old children, for example, can conceal emotional expressions to deceive others (Lewis, Stanger, & Sullivan, 1989). Besides, compared to three-year-olds, two-year-olds are less likely to lie if they transgressed in their behavior (Evans & Lee, 2013), and their deceptive abilities may develop through pragmatic needs, rather than from conceptual developments (Newton, Reddy, & Bull, 2000). Interestingly, with adults, one study found that people who scored higher in self-awareness scales were more effective deceivers (Johnson et al., 2005). That means that there is a positive correlation between deception and levels of self-awareness, congruent with what we are proposing.

In animals, Whiten and Byrne (1988, 1985) give the example of a baboon who suddenly adopted an alert posture and looked at the horizon (a behavior usually done when a neighboring group or predator is in sight), while being chased by another baboon, who got wary and stopped chasing him. The deception occurred because there was nothing in sight, so the baboon that was getting chased pretended that there was something there in order to deceive the other.

Tactical deception is also seen in monkeys, when they go far away from the alpha male to have sex (Le Roux, Snyder-Mackler, Roberts, Beehner, & Bergman, 2013; Overduin-de Vries, Spruijt, de Vries, & Sterck, 2015). A variety of examples and anecdotical cases of primate deception can be found in Byrne's and Whiten's (A. Whiten & Byrne, 1988), and in de Waal's papers (de Waal, 1992). Interestingly, in primates, tactics of deception are corelated with the size of the neocortex (Richard W. Byrne & Corp, 2004).

The Mantis Shrimp also provides a great example of tactical deception. When they molt, they lose their hard exoskeleton and become vulnerable. But, when faced with a rival that wants to get it home, the mantis shrimp is more prone to produce meral spread threats to frighten the opponent, even though the mantis shrimp couldn't engage in a fair battle since the exoskeleton is not hard yet (Caldwell & Steger, 1983). Moreover, they were more likely to bluff and less likely to escape if the rival was smaller than them, and more likely to escape and not bluff If the rival was bigger (Adams & Caldwell, 1990), also suggesting a sufficient level of self-awareness to know how strong they are compared to the opponent.

Another complex example of tactical deception is the cuttlefish. The courtship ritual of cuttlefish involves altering their shape and color. A male cuttlefish, in the presence of a female and another male and potential rival, displays receptive patterns on one side of the body to the female, while simultaneously displaying female patterns on the other side of the body to the other male, preventing the rival from disturbing the courtship (Brown, Garwood, & Williamson, 2012).

4. Adaptative Advantages of Self-Awareness

As we have seen, different animals have different self-awareness processes and at different levels (see table 1). Although evidence suggests that many animals are self-aware, it is debatable what the adaptive advantages of self-awareness are. Why are we, and other animals, self-aware? Does it provide any evolutionary advantage? What are the adaptive advantages of self-recognition, metacognition and theory of mind?

Table 1. Evidences of self-awareness components and its levels.

Animals/Components	Self-Recognition	Metacognition[1]	Theory of Mind
2-year-old Children	✓	✓	✓
Chimpanzees	✓	✓	±
Gorillas	?	✓	
Orangutan		✓	
Gibbon	-		
Baboon			±
Bonobos		✓	
Rhesus Monkeys	✓̶	✓	
Capuchin Monkeys		±	
Elephants	✓		
Giant Pandas	-		
Dolphins	✓	✓	
Killer Whales	±		
False Killer Whales	±		
California Sea Lions	-		
Manta-rays	±		
Horses	±		

Dogs	✓	±	±
Wolfs			±
Eurasian Magpies	✓		
Jungle Crows	-		
New Caledonian Crows	-		
Ravens			±
Jackdaws	±		
Small Passerine	-		
Keas	-		
Goffin’s Cockatoos	-		
Nutcrackers	✓		
Western Scrub-Jays		✓	
Pigeons	✓̸	✓	
Rats	±	✓	
Ants	✓		
Mantis Shrimp			±
Cuttlefish			±
Tanganyikan Cichild Fish	-		
Cleaner Wrasse Fish	✓		
African Cichild Fish	±		

Subtitle: ✓ = Evidence of having the component; ✓̸ = Evidence of having the component if trained; ± Evidence of having the components in a lower level; - = Evidence of not having the component; ? = evidence is contradictory and not conclusive; If the block is not filled, we did not find studies or we did not search for them; [1]either information seeking or option to decline were considered evidence

First, we will address the idea that self-awareness may have been an epiphenomenon of brain complexity and has not been selected because it has an advantage, but it has only been so because it was a by-product of brain complexity, the latter having adaptive advantages. One argument against the adaptationist view is that adaptationists think every trait, behavior and skill exists or existed because it has or had a function, providing an advantage (Gould & Lewontin, 1979). Gould and Lewontin (1979) gives the example of the Spandrels of San Marco, who were an epiphenomenon of the architectural structure, and later, since it was there, became a place for religious art design. Spandrels were not designed as a place for art, but they just happened to be as a secondary effect of the architectural structure. This secondary adaptation of the space does not mean that spandrels have a primary function for the church; they were an epiphenomenon of the architectural structure. The same may apply to self-awareness: maybe self-awareness has no adaptive or functional advantages, and it exists just because it is an epiphenomenon of brain complexity. Hence, we must find good arguments to propose that self-awareness was naturally selected because of its importance for survival or reproduction.

Perhaps the strongest argument in favor of self-awareness and its components is that different animals have it. These components independently appeared in the course of evolution, and the convergent evolution of these traits suggests that they were adaptive to the pressures that animals were dealing with. If fish, birds and mammals, who have very different brain circuitry, developed self-awareness, it must be because it has an adaptive advantage.

Self-awareness could have been selected by social factors and communication (Weiskrantz, 1997). Regarding social factors, one reason self-awareness could have been selected is because knowing yourself and others, and knowing about your own desires, thoughts, and intentions, as well as the desires, thoughts, and intentions of others, has a great positive impact in dealing with the world and with each other, providing greater reproductive and survival advantages. In the competitive environment to find food and protection against a predator, social habitat was crucial, and the ability to differentiate yourself from others, as well as the ability to think abstractly about yourself, optimize social life (Skowronski & Sedikides, 2019). In this sense, self-awareness is a product of the complex set of relationships among individuals. Not surprisingly, most of the animals we have evidence of self-awareness for live in complex social environments. As for communication, for a better way to express yourself, and understand what others want to communicate and express, it is crucial to understand what you think and what others are thinking. If you can access your internal states and the internal states of others, communication becomes easier and more efficient.

Self-awareness gives a general sense of what I am and what I want, and what others are and what they want. Since self-awareness is composed by different components, each component of self-awareness also has its own adaptive advantage. For example, self-recognition has important survival advantages, because knowing that you have a body, and knowing what it looks like, can help you deal with anything abnormal about it that could be dangerous (e.g., a deadly insect or a bruise). Self-recognition also allows us to evaluate our fitness potential, and compare it with others, enabling judgments about who is stronger and if one can stand a fight, or if it is better to flight. Furthermore, some animals need to know if a branch can carry their weight when they land on it (de Waal, 2019), and knowing your body may be a enhance the acuity of this estimation.

As for metacognition, it enables individuals to know if they are capable or not to perform a task which could be the line between life and death. For example, metacognition allows an animal to know if they are capable or not of jumping to the other branch. Suppose a primate is starving, and he sees some beautiful big fruits in a neighboring tree. To get there, he must jump from one branch to another. If the branch is high and far away, and if the animal does not know whether he can jump it, he may put his life at risk for such a succulent lunch. On the other hand, if he knows that he cannot jump, he may plan other strategies to reach for the food (e.g., using a large stick, and if that doesn't work it, he may change and try another strategy), or he may prefer not to risk it and stay in the tree he is in, eating the fruits of this tree, even if they are not that succulent or even if he still ends up hungry. Metacognition allows individuals the knowledge of whether they can get food and sex safely.

The most notorious advantages of self-awareness for social interaction comes from a theory of mind. Complex social living requires complex cognitive capacities, and theory of mind allows individuals to access their own mental states and infer the mental states of others, predicting and adapting behaviors. For example, theory of mind allows an individual to infer what their partner is thinking and what they desire, and, through that inference, decide if and how to help it. As a result, the individual may gain the other's appraisal, which can lead to alliances (good for survival) or sex (reproduction). Additionally, since theory of mind allows individuals to infer the internal states of others and act based on this inference, one can infer if someone is feeling good or bad and adjust our behavior towards them to maximize the interaction. For example, if an animal sees that its allied conspecific is angry, he may choose not to interact with him because it may result in a pointless fight, or he may choose to cheer him up. Theory of mind facilitates communication and exchanges between individuals, allowing a group to grow bigger, and giving them more power to fight against other groups.

One great survival advantage of theory of mind is deception. The example of the baboon from Whiten and Byrne (1988, 1985), or the example of the mantis shrimp, who pretend they can engage in a fair fight, when they actually cannot (Caldwell & Steger, 1983), show precisely how deception can have an important survival advantage. Besides survival advantages, deception also allows reproductive advantages, as seen with monkeys who go far away from the alpha male to have sex (Le Roux et al., 2013; Overduin-de Vries et al., 2015), or the cuttlefish who can deceive the male competitor and court the female at the same time (Brown et al., 2012).

Weiskrantz, however, suggested that many other species that do not have theory of mind can deal with their social demands (Weiskrantz, 1997). Maybe theory of mind is unnecessary for dealing with general and simple social demands, but theory of mind may have adaptive advantages regarding more complex social factors, such as more acute guesses of others' intentions and emotions (which could prevent or start attacks, and open ways to emphatic behavior, which could create more bounding in the community, strengthening it), and the manipulation of others' thoughts and behaviors by deceptive behaviors. A great example comes from ravens, who pretend to hide food in one place when another raven is seeing, just to detract the other's attention from the principal place where the food is hidden (Bugnyar & Kotrschal, 2002), and from Eurasian jays that prefer to hide their food behind opaque barriers, rather than transparent barriers, when another conspecific is watching (Legg & Clayton, 2014).

Thus, it is not because one social species does not have theory of mind that it has adaptive advantages. They can be social and not have theory of mind because 1) it is still incipient, and they are yet to develop it, 2) the social demands are not so hard to pressure this new ability, or 3) because they can handle social demands in different ways. None of these take away the adaptive advantage of theory of mind for survival and reproduction in complex social habitats.

Weiskrantz, however, makes a good observation: humans are the only species to have serious social problems (Weiskrantz, 1997). Even though theory of mind may have its benefits, it brings problems. We overthink problems and situations regarding us and others, and this, instead of creating an adaptive repertoire for future encounters and dangers, can lead to deleterious behaviors propelled by stress, anxiety, prejudice, paranoia etc. We must remember, though, that evolution is not interested in individual welfare; it is only interest in survival and reproduction. Whether humans or animals suffer is ok as long as they survive and spread their genes.

5. Final Remarks

In this paper we have discussed the importance of understanding self-awareness as the product of a gradual process throughout evolution. Self-awareness is not a binary concept, but a process varying in a continuum. In this framework, self-awareness has levels, varying from low levels to higher levels. The variation occurs in virtue of 1) the availability or not of the components and 2) the levels of development of the components themselves. This explains much of the evidence of whether animals pass or not some self-awareness tests. Some of them passed because they have the components in a high level, while others do not pass because they lack the component or because they were still incipient. Most importantly, however, is that this explains cases of animals who do not pass the tests but show different behaviors or brain activation. This shows they are in the middle of the continuum. We can understand them as having the component in a low-level stage. This shows that the difference between us and them is not qualitative, but quantitative, as Darwin had already pointed out (Darwin, 1874). We are more self-aware, so to say. Interestingly, animals who show more high-order self-awareness capacities have a great number of neurons in the cortex, such as elephants (Herculano-Houzel et al., 2014), dolphins (Roth & Dicke, 2005), and great-apes (Herculano-Houzel, 2017). This is another suggestion that the difference is only quantitative, and not qualitative.

We cannot discard, however, some problems with the methods to access self-awareness. Most of them are biased by the way we, humans, understand and make sense of the world, and some of them do not have ecological validity. Since different animals have different ways to guide themselves in and to make sense of the world, we propose, for future research, that the methods can be suited for the way each animal makes sense of themselves and the world around them. One example is the MSR test that, since many animals never seen a mirror (and never seen themselves in the mirror), a better way to access self-recognition is using reflective surfaces common in the animal's world, such as water. Not only water differs from a mirror because of its distorted image, but when an animal tries to touch it, it finds no opposite force, and the limb enters the water; while in the mirror, the reflection is perfect and when the animal tries to touch it, it finds resistance. No wonder so many of them could not make sense of the mirror self-reflection. This is supported by the nutcracker's study (Clary & Kelly, 2016), which used more ecological ways to test self-recognition, and found that animals could recognize themselves in reflective surfaces that were more natural to what they were used to.

The ideas we discussed in this paper have different implications. For example, if animals are self-aware, if only minimally so, is it unethical to eat them? Can we use them for scientific research? Can we treat them as senseless beings? Evidence is suggesting that animal's cognitive abilities and inner world are not very different from ours, differing more in quantity than in quality. The understanding of self-awareness still requires more studies, and we hope that future evidence can clarify the gaps.

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IV. GENERAL DISCUSSION

Our work proposed to treat consciousness and self-awareness from a physicalist and an evolutionary standpoint. We treated consciousness as one of many worldly phenomena that take on new qualities by undergoing changes in quantity as well as dynamical changes. We believe that a reductive physicalist view of consciousness fits the bill, and, at the same time, preserves the essential characteristic of consciousness, that is, quale.

This approach to consciousness led us to treat self-awareness, a higher aspect of consciousness, in an evolutionary perspective, assuming the reducibility of biology to physics. We gathered empirical studies to understand the methods used to access self-awareness. We found numerous evidence of self-awareness components in animals; some of the evidence, however, was not perfect as some animals did not pass the tests and tasks as they should, but nevertheless showed behavior that could suggest that they do not completely lack the component in question. We explained this by the idea that self-awareness comes in different levels and that some animals have lower-levels of self-awareness, while others have high levels. Finally, we discussed the adaptive advantages of self-awareness and why these components were naturally select.

This work has two notable features. The first one is related to our first paper about consciousness. We believe that this work has provided a fresh approach to the study of consciousness, gathering arguments from different points of view. In addition, to support our argument, we proposed an experimental way to test our hypothesis through the study of psychoactive drugs and its effects on the brain. This opens a possibility to empirically test and support our argument.

The second notable feature has to do with the second paper, where, as far as we are concerned, we are one of the few who have gathered together a great number of studies of self-awareness and incorporated all the evidence into a single framework. The studies on self-awareness still lack a unifying theory, and we proposed a way to unify the evidence and make sense of it in a theoretical background.

This work has some implications. The first one is that, if we are right, the so-called hard problem is an illusion, and consciousness is not something over and above the physical world. The hard problem is not a problem, and consciousness and qualia can be reduced to the physical. Consciousness is part of the physical world, and it follows the same rules of all other worldly phenomena.

The second one is that it allows the possibility for consciousness and self-awareness to be measured, since consciousness levels vary according to the number of neurons and the dynamics of brain structures, and self-awareness levels vary according to the availability or not of its components and its development. This has important impact for the cognitive study of children, brain-damaged patients, and animals in general. It would be possible to say when a child becomes aware of him(her)self, when a brain-damaged patient has lost consciousness and the ability to self-recognize, which non-human animals are conscious and self-aware, and maybe it could even be possible to track which was the first non-human animal and the first human that became conscious and self-aware.

The third implication, as a consequence of the second one, is that assuming that we can measure consciousness levels, this would entail ethical implications, especially regarding animal's right. For a long time, humans have been trying to find the distinguishing characteristic of us from other animals. The capacity for self-awareness or the increased development of consciousness have been considered as one of these characteristics. However, evidence shows that many other animals are self-aware too, and that we can reasonably suppose that many have conscious experiences very similar to ours. Apparently, the difference between us and them is, as Darwin (1874/2013) puts it, more of degree than of kind.

Finally, we would like to present potential study directions. For future research, it is important to investigate more about the neural correlates of consciousness in order to precisely track the brain processes of consciousness and self-awareness. We know that we have approximately 86 billion neurons (Azevedo et al. 2009), we know that the number of neurons in the cerebral cortex is correlated with superior cognitive abilities (Herculano-Houzel, 2017), and we also know that the ingestion of psychoactive drugs that changes the brain processes dynamics alters the quality of subjective experience. However, we still do not know exactly how many neurons are needed and what dynamics they must have for consciousness, with its qualities, to arise.

One way to approach this is by studying as many animals as possible. If we know how many neurons each animal has and what their brain dynamics are, it would be possible to make a correlation between the number of neurons and the brain's dynamics with superior cognitive skills. This is particularly interesting for the study of self-awareness, since one can make a correlation between the number of neurons and the brain's dynamics with the ability to pass or fail the tests of self-awareness components. We believe that, with more research, it will be possible to say that in order to pass the MSR test, that approximately X number of neurons and a cerebral dynamics Y is necessary; or that lower-levels of self-awareness require X number of neurons and brain dynamics, and higher levels of self-awareness require Y number of neurons and brain dynamics.

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