



## Review article

# Missing piece of the puzzle in the science of consciousness: Resting state and endogenous correlates of consciousness



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## ABSTRACT

Consciousness still stands as one of the most interesting and the most elusive problems of neuroscience. Finding its correlates is the first step toward its satisfactory explanation. Several theories have proposed its correlates but none of them seem to be generally accepted even though most of them share some very similar elements. These elements are the activity of the thalamus, which is considered by some as the central region for consciousness, and gamma synchronization, which should be the general principal for the emergence of conscious experience. However, all of these proposed theories share one characteristic and that is that they do not take into consideration the recently discovered endogenous activity of the brain, which is generally associated with the default mode network. Although the activity of this large scale brain network is in correlation with various levels of consciousness it is still missing in discussions of consciousness. This review recognizes the importance of endogenous activity and points out the important discoveries of endogenous activity that could be an important step toward a satisfactory explanation of consciousness.

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## 1. Introduction

Consciousness represents the most enigmatic issue in current theories of the mind. There are at least three positions that can be taken regarding consciousness. The first is the position taken by radical reductionists, eliminativists and some orthodox neuroscientists. These claim that consciousness should not be even considered as an issue because it does not exist and therefore any move we make explaining it is automatically a waste of time. The second position is the classical philosophy of consciousness, which claims that consciousness exists but it is something fascinating with such a mysterious nature that it cannot be fully explained by empirical science. These interpretations of consciousness were bound together by the concept of the *Hard Problem of Consciousness*, which roughly claims that empirical science especially neuroscience will never be able to give a satisfactory answer to how and why conscious phenomenal qualities arise from physical processes of the brain (Chalmers, 1996, 1998). The last position is “neurophilosophy” or “empirically oriented philosophy”. Adherents of this new position consider consciousness to be a cognitive or neural process of the brain without any mysterious or intractable nature.

From this open minded basis and without any fundamental restrictions we constantly strive to explain issues of the philosophy of the mind using actual empirical data, measurements, observations and neuroscientific conclusions. From this combination we can expect valid empirical answers to questions about the nature of consciousness. What are the main questions of the science of consciousness? We can name the basic ones: *What are we conscious of? How do we become conscious? Why are we conscious? and Who is conscious?* (Prinz, 2005). All of the answers to these questions are related to the *neural correlates of consciousness* that are considered by Chalmers to be “arguably the cornerstone of the recent resurgence of the science of consciousness” (Chalmers, 2000, pp. 17).

In this review we will swiftly go through the proposed theories of consciousness. We will highlight which neural correlates they offer, what these theories are based on, and what their common features are. This review will also show that the science of consciousness based solely on these theories is missing a very important piece of the puzzle. This missing piece is *conscious resting states* that are currently widely associated with the *default mode network* (DMN) and its *endogenous brain activity* (Gusnard, Akbudak, Shulman, & Raichle, 2001; Raichle & Snyder, 2007; Raichle et al., 2001). This large-scale resting network is associated with a wide range of cognitive states but it is seldom considered from the perspective of the neural correlate of conscious experience.

The organization of this review is following. At first we will introduce three types of consciousness – *Background States of Consciousness*; *General Stream of Consciousness* and *Specific States of Consciousness*. Then we will show their correlates, first in evoked brain activity. Evoked brain activity represents so called reactive states of brain which are induced by stimulation. These states are also associated with active attention which is necessary for immediate responding to the environment. After that this review extensively describes DMN and shows its neglected correlates of three types of consciousness. Evoked brain activity is in anti-correlated position with activity of DMN which is most active during the absence of external stimulation and is responsible for spontaneous internally oriented mental states (Gusnard & Raichle, 2001; Gusnard et al., 2001; Raichle & Snyder, 2007; Raichle et al., 2001). And finally this review discusses and proposes precuneus as a new cerebral celebrity of consciousness.

## 2. Three types of consciousness whose correlates we will seek

Studying consciousness is anything but easy, not only because it is a very difficult scientific theme but also because there are many meanings of this concept. So the first thing we have to do is make it very clear what we do and do not mean by the term consciousness. We will not in any case be defending the *Hard Problem of Consciousness*. Even though we believe that the Hard Problem should not be entirely avoided it can be left alone for a while so it does not pollute every discussion about consciousness and subjective experience. John Bickle summed it up pretty nicely: “Zealous guardians of ‘the hard problem’ in the philosophy of consciousness should loosen up. Philosophers aren’t only ones respectful or in pursuit of the full glory of Mind” (Bickle, 2003, pp. 213). So we take the liberty to think about consciousness as being something very similar to the “representational property of representations or a cognitive property of the system that processes representations” (Brooks, 2005, pp. 401).

I believe that we have cleared up our position about consciousness pretty quickly and I also believe that we can skip most of the other connotations of consciousness and restrict ourselves here to just three: *Background States of Consciousness*; *General Stream of Consciousness*; *Specific States of Consciousness*.

*Background States of Consciousness* are states of being awake, being asleep, states of dreaming, and being in a coma or in a vegetative state. These states are not part of conscious experience but some of them are crucial for its emergence. This includes states of being awake or arousal which is a key factor for the occurrence of conscious experience. On the other hand being in a state of dreamless sleep or coma makes it impossible to have ongoing conscious experience (Searle, 1990) even though this state is accompanied by cortical information processing (Daltrozzo et al., 2009).

By *General Stream of Consciousness* we mean a general stream of mental states and ongoing subjective experience. Finding correlates of *General Stream of Consciousness* means finding specific regions that are involved in the neural representations of mental states and also finding specific principles, conditions or mechanisms (e.g. specific neural oscillations or neural synchrony) that must be met to make this specific mental state conscious. Stream of consciousness therefore has to be distin-

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