Available online at www.sciencedirect.com
SCIENCE DIRECT®
Epilepsy & Behavior 7 (2005) 150–160
Epilepsy & Behavior
www.elsevier.com/locate/yebeh

Review

Consciousness, epilepsy, and emotional qualia

Francesco Monaco [a], Marco Mula [a], Andrea E. Cavanna [a,b,*]

[a] Department of Neurology, Amedeo Avogadro University, Novara, Italy
[b] Raymond Way Neuropsychiatry Research Group, Institute of Neurology, Queen Square, London, UK

Received 17 March 2005; revised 23 May 2005; accepted 25 May 2005
Available online 25 July 2005

Abstract

The last decade has seen a renaissance of consciousness studies, witnessed by the growing number of scientific investigations on this topic. The concept of consciousness is central in epileptology, despite the methodological difficulties concerning its application to the multifaced ictal phenomenology. The authors provide an up-to-date review of the neurological literature on the relationship between epilepsy and consciousness and propose a bidimensional model (level vs contents of consciousness) for the description of seizure-induced alterations of conscious states, according to the findings of recent neuroimaging studies. The neurophysiological correlates of ictal loss and impairment of consciousness are also reviewed. Special attention is paid to the subjective experiential states associated with medial temporal lobe epilepsy. Such ictal phenomenal experiences are suggested as a paradigm for a neuroscientific approach to the apparently elusive philosophical concept of qualia. Epilepsy is confirmed to represent a privileged window over basic neurobiological mechanisms of consciousness.

Keywords: Consciousness; Epilepsy; Experiential phenomena; Qualia

1. Introduction

Over the last decade there has been a heightened interest in attacking the problem of consciousness through scientific investigation [1–5]. A growing literature now tackles the issue of consciousness from a neuroscientific perspective, as it has seemingly been transferred from philosophical debate to empirical scrutiny. Nevertheless, it has been advocated that neuroscientists should take advantage of the conceptual tools provided by philosophers of mind (e.g., the concepts of mental representations and phenomenal states), because at least part of the difficulty hampering the progress of the scientific understanding of consciousness flows from the ambiguities of the term [6–8]. The main issue is generally thought to be the explanation of how brain processes cause consciousness and how consciousness is realized in the brain [9,10].

Despite the remarkably different perspectives of empirical and theoretical research, most of the disciplines involved in the contemporary "quest for consciousness" found a common agreement about some kind of psychophysical correlation between mental and brain states: every mental state (state of consciousness) is associated with a neural state; it is impossible for there be a change in mental state without a corresponding change in neural state [11,12]. Sometimes this assumption is referred to as the "supervenience thesis" of the mental on the physical [13]. Precise experimental settings and functional neuroimaging techniques allow us to place conscious properties within a biological framework [14,15]. This led to the formulation of sophisticated theories about the neural correlates of visual consciousness and other conscious phenomena [16,17]. The neural correlates of consciousness can be defined as the minimal set of neuronal events that gives rise to

* Corresponding author. Fax: +39 0321 373 3298.
E-mail address: A.Cavanna@ion.ucl.ac.uk (A.E. Cavanna).

1525-5050/$ - see front matter © 2005 Elsevier Inc. All rights reserved.
doi:10.1016/j.yebeh.2005.05.018

a specific aspect of a conscious percept [18,19]. However, correlations between neural processes and features of conscious experience are far from providing a definitive explanation of the causal relationship between them [20]. Despite the remarkable progress and anticipated advances in the neurosciences in elucidating the neuronal mechanisms underlying mental states and cognitive functions, the identification of consciousness with these mechanisms avoids the subjective experience and fails to advance our understanding of consciousness [21]. Therefore, the actual essence of the problem concerning consciousness is how any physical description can be synonymous with subjective experience. Or, in other words, how the subjective, first-person account of consciousness can be objectified in a somewhat reductive explanatory account [6,22].

In this context, clinical neurosciences offer unique avenues for the understanding of the relationship between pathological brain function and altered conscious states. In the present article, the different epileptic ictal semiologies are demonstrated to illuminate certain neuroanatomical and neurophysiological facets of consciousness.

2. A bidimensional model of consciousness

Described as "the most obvious and the most mysterious feature of our mind" [23], consciousness has always defied any unequivocal definition. Attempts to define consciousness have yielded fairly different results over time, as this concept cuts across the domains of clinical medicine, neurosciences, psychology, and philosophy [24–28]. In a recent and comprehensive review, Zeman [29] stressed the distinction between consciousness and self-consciousness, and expanded both concepts: the former can be intended as "wakefulness," "experience," or "mind," while self-consciousness can convey five different meanings, encompassing "proneness to embarrassment," "self-detection," "self-recognition," "self-knowledge," and "awareness of awareness." As a matter of fact, the use of such terms varies according to the practical purpose of the investigation being conducted. In everyday clinical practice, consciousness is generally equated with the waking state, and the abilities to perceive, interact, and communicate with the environment and with others in the integrated manner that wakefulness normally implies. The clinicians commonly use such terms as *clouding*, *dwindling*, *waning*, and *lapsing* of consciousness, meaning a reduced level of wakefulness and awareness. Epileptologists introduced the concept of "loss of contact" with the surrounding environment for a better description of the ictal conscious state [30]. Overall, these terms are arguably useful in communicating the patient's responsiveness, but do little to further scientific understanding of conscious states as subjectively experienced by the patient.

In this respect, although a unified model seems hard to develop, a useful distinction can be made between the quantitative (level) and qualitative (content) features of consciousness [12,31]. What follows is a bidimensional model for the description of physiological and pathological conscious states, as it has been suggested by traditional electroencephalographic (EEG) studies [32] and recent neuroimaging findings on patients affected by ictal impairment of consciousness [33].

The level of consciousness is a matter of degree: a range of conscious and unconscious states extends from alert wakefulness through sleep into coma [34,35]. To be conscious in this sense means to be awake, aroused, or vigilant. The shift between the different levels of consciousness can easily be induced by exogenous substances, such as several drug classes acting on the central nervous system (Table 1). The level of consciousness can be quantified by analyzing the behavioral responses that are constituent functions of consciousness as awareness. For example, the Glasgow Coma Scale (GCS) adopted three objective parameters, namely, motor responsiveness, speech, and eye opening, as measures to assess consciousness [36]. Interestingly enough, none of these faculties is either necessary or sufficient for consciousness [37]. The level of consciousness is what clinical neurologists usually refer to when reporting "impairment" or "loss" of consciousness in the phenomenological description of epileptic seizures. Video monitoring has long been employed to document the full extent of ictal unresponsiveness as a testable measure of the level of awareness.

The ascending activating pontomesodiencephalic reticular formation, together with its thalamic targets, has been recognized as the principal substratum of vigilance since the pioneering works of Moruzzi and Magoun [38]. More recently, influential authors such as Crick [39] and Llinás et al. [40], among others, have hypothesized that the neurological basis of awareness lies in the reverberating activity of thalamocortical neural loops, the so-called 40-Hz thalamocortical oscillations [41]. Circumscribed brain lesions involving the reticular formation and/or the nonspecific thalamic nuclei (nucleus reticularis and intralaminar nuclei) are associated with bilateral cortical impairment and, therefore, severe restrictions in the level of consciousness, such as coma and persistent vegetative state [42,43].

Table 1
Main pathophysiological levels of consciousness and drugs affecting them

Level of consciousness	Drug class
Excitement	Psychostimulants
Wakefulness	(normal state)
Drowsiness	Anxiolytics
Sleep	Hypnotics
Coma/vegetative states/anesthesia	Anesthetics