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# Intention and Attention in Consciousness Dynamics and Evolution

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**Abstract**

All through the history of the universe there is an apparent tendency for increasing complexity, with the organization of matter in evermore elaborate and interactive systems. The living world in general, and the human brain in particular, provides the highest complexity known. Presumably, the neural system with its complex dynamics has evolved to cope with the complex dynamics of the environment, where it is embedded. The evolution of a nervous system constitutes a major transition in biological evolution and allows for an increasing capacity for information storage and processing. Neural knowledge processing, cognition, shows the same principal features as non-neural adaptive processes. Similarly, consciousness might appear, to various degree, at different stages in evolution. Both cognition and consciousness seem to depend critically on the organization and complexity of the organism. Different states of consciousness can apparently be associated with different levels of neural activity, in particular with different oscillatory modes at the mesoscopic level of cortical networks. Transitions between such modes could also be related to transitions between different states of consciousness. For example, a transition from an awake to an anaesthetized state, or sleep, is accompanied by a transition from high frequency oscillations to low frequency oscillations in the cortical neurodynamics. In this article, I will briefly discuss some general aspects on the evolution of the nervous system and its complex neurodynamics, which provides organisms with ever increasing capacity for complex behaviour, cognition and consciousness. Consciousness and cognition apparently evolve through interaction with the environment, involving both attention and intention. I will discuss these dual and complementary aspects of consciousness, and their effects as perception and action. Finally, I will speculate on consciousness related to life, and how it may be regarded as a driving force in the exploration of our world.

**KEY WORDS:** Attention, intention, free will, neurodynamics, cortical networks, EEG, evolution and

## 1. Introduction

When we open our eyes after a good night's sleep, we again become conscious of the world around us. A few moments before, we had closed our senses to the external world, resting in an inner world, which only in the dreaming state had some degree of consciousness. We were unable to attend to our physical environment, or move voluntarily in it. When we wake up, we make a transition into a state, where we suddenly can perceive and act intentionally. Also in our wake conscious state we may shift between several sub-states, corresponding to different levels of alertness or wakefulness.

During sleep, our cognitive activity is mostly unconscious. We may wake up from this state spontaneously (by some internal "clock" or other internal event), or as a result of a sounding alarm clock, or the whispering of our name, or a weak smell of smoke, or any other significant signal, that may be below threshold for any insignificant sensory input. Obviously, there is a certain level of "awareness" also in the so-called unconscious state.

Even in our wake state, most of our cognitive activity can be unconscious. While it is important to distinguish between cognition and consciousness, (which is often mixed up in the literature), both seem to be linked to system and process complexity. In fact, the cognitive and conscious capacity seems to increase with an increasing level of complexity, or interconnectedness (Århem & Liljenström, 2007; Tononi, 2008; Koch, 2011).

The brain, like other biological systems, has presumably evolved to efficiently increase the probability of survival in a constantly changing environment. This would imply, among other things, a rapid and appropriate response to external (and internal) events. We may assume that the neural system with its complex dynamics has evolved to cope with the complex dynamics of the environment, by constantly interacting with it.

In the following, I attempt to relate the neurodynamics of the brain with our cognitive and conscious activity, and also set it in an evolutionary context. Specifically, I will consider the dual aspects of consciousness, intention and attention, and its effective counterparts in the sensory-motor system as perception and action. Finally, I will speculate on these aspects as universal to all life, and on consciousness as a driving force in nature.

## 2. Neural Dynamics

Brain structures are characterized by their complexity in terms of organization and dynamics. This complexity appears at many different spatial and temporal scales, which in relative terms can be considered as *micro, meso,* and *macro* scales. The corresponding dynamics may range from ion channel kinetics, to spike trains of single neurons, to the neurodynamics of cortical networks and areas. The high complexity of this neurodynamics is partly a result of the web of non-linear interrelations between levels and parts, including positive and negative feedback loops. (Freeman, 2000; Århem & Liljenström, 2001; Århem et al, 2005).

Still very little is known about the functional significance of the neural dynamics at the various organizational levels, and even less about the relation between activities at these levels. However, different neurodynamical states seem to correlate with different functional or conscious states. Transitions within the brain dynamics at some level apparently correlate with transitions in the "consciousness dynamics", involving various conscious states, e.g. when going from sleep to awake states, or from drowsiness to alertness, etc. Supposedly, there is a spectrum of states, each one with its own characteristic neurodynamical (oscillatory) mode.

It seems that phase transitions at the *mesoscopic* level of neural systems, i.e. at levels between neurons and the entire brain, are of special relevance to mental state transitions. The mesoscopic neurodynamics of cortical neural networks typically occurs at the spatial order of a few millimetres to centimetres, and temporally on the order of milliseconds to seconds. This type of dynamics can be measured by methods, such as electrocorticography (ECoG), electroencephalography (EEG), or magnetoencephalography (MEG) (Freeman, 2000).

*Mesoscopic* brain dynamics with its transitions is partly depending on thresholds and the summed activity of a large number of *microscopic elements* (molecules and cells) interconnected with positive and negative feedback. Some of this activity is spontaneous and can be considered as noise (which may have a functional significance, see e.g. Århem et al., 2005). In addition, the mesoscopic dynamics is influenced and regulated by various hormones and neuromodulators, such as acetylcholine and serotonin, as well as by the state of arousal or motivation, relating to more *macroscopic* processes of the brain.

Hence, mesoscopic neurodynamics can be seen as resulting from the dynamic balance between opposing processes at several scales, from the influx and efflux of ions, inhibition and excitation etc. Such interplay between opposing processes often results in (transient or continuous) oscillatory and chaotic-like behaviour (Skarda & Freeman, 1987; Freeman, 2000; Liljenström, 2010). Clearly, the brain activity is constantly changing, due to neuronal information processing, intrinsic fluctuations, neuromodulation, sensory input, and internal state shifts.

An essential feature of the mesoscopic brain dynamics is spatio-temporal patterns of activity, appearing at the collective level of a large number of neurons. Waves of activity move across the surface of sensory cortices, with oscillations at various frequency bands (Freeman, 1975, 2000). In general, low frequencies correspond to low mental activity, drowsiness or sleep, whereas higher frequencies are associated with alertness and higher conscious activity. Fig. 1 shows the simulated effect of certain anaesthetics, which are presumed to cause a transition from high frequency (gamma) to low frequency (theta) oscillations, mimicking a transition from an awake to an anaesthetized state (Halnes et al., 2007).

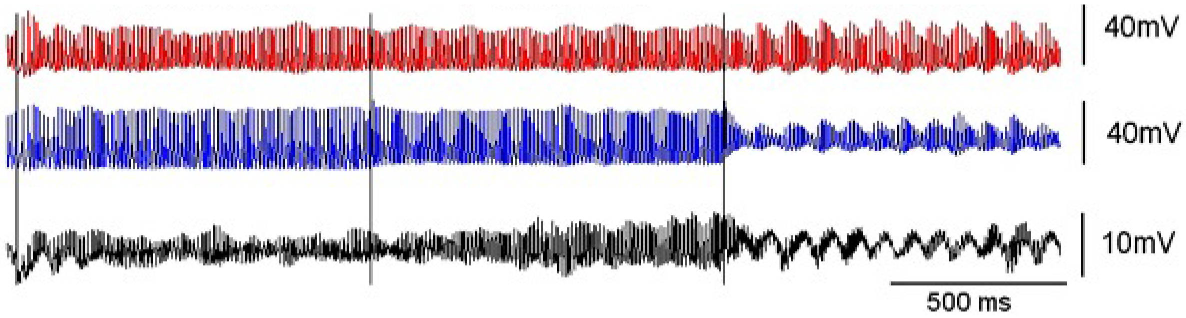


Fig. 1. Simulated effect of certain anaesthetics, which may shift the mesoscopic neurodynamics from high frequency (gamma) oscillations to low frequency (theta) oscillations for three different concentration levels of potassium ion channel blocking, increasing from left to right. These shifts in neurodynamics would presumably correspond to shifts in conscious states, going from alert (left) to anaestetized/ sleep (right). The two upper time series show the activity of a single excitatory and inhibitory neuron, respectively, while the lower time series is the network mean. (Adopted from Halnes et al, 2007).

In particular, oscillations in the gamma frequency band, around 40 Hz, has been associated with (visual) attention, based on experiments on cats about two decades ago (Eckhorn et al., 1988; Gray & Singer, 1989). It was this phenomenon that triggered the boost of studies on neural correlates of consciousness, as e.g. suggested by Crick and Koch (1990; Koch, 2004) and contributed to opening the field of neuroscience to consciousness studies. This experimental and theoretical research on neural oscillations has been complemented by computational models, which attempt to relate structure to dynamics and function. (I have dealt with these issues in more detail elsewhere, e.g. in Liljenström 1991, 1995, 1997, 2010).

## 3. Consciousness Dynamics

The complex neurodynamics at a mesoscopic level of the brain seem significant for cognitive functions and conscious activity. It has been related to perception, attention and associative memory, but also to volition and activity in the sensory and motor areas of the brain. Even though many details are still unknown, it is obvious that there is an interplay between the neurodynamics of the sensory and motor pathways, essential for the interaction with our environment (Cotterill, 1998; Merker 2010).

We explore our world in a perception-action cycle (Freeman, 2000). The development of our cognitive and conscious abilities depend on an appropriate interaction with the complex and changing environment, in which we are embedded. Our perceptions and actions develop and are refined to effectively deal with our external (and internal) world.

However, prior to perception is attention, and prior to action is intention. It has even been suggested that attention and intention are at the core of our experience of existence (Popper et al., 1993). Yet, while attention has been shown to correlate with certain neural oscillations, intention has not been demonstrated to the same extent. Attention is primarily related to the sensory/perceptual pathways and brain areas, whereas intention would be more related to the motor areas and pathways. In particular, the supplementary motor area (SMA), but also the parietal cortex, show early signs of intentional motor activity (Eccles, 1982; Libet 1985; Desmurget et al., 2009).

Attention could be general and extended, but could also be focused to some specific part of our internal or external worlds. Our attention may be drawn to some specific memory, thought, or sensory experience, while neglecting or inhibiting the rest. Perhaps more commonly, our attention is drawn to some object or event in our environment, something that is of special relevance or interest to us, for our survival or for our curiosity. We may also *intentionally* turn our attention to some area of interest.

Intention can be viewed as a precursor to volition and will, as an "urge" or "desire" to act in a certain direction, to attain a certain goal. Voluntary movement, or more generally, behavior, is based on perception and past experience (memory), which are required for prediction of internal and external interactions. Attention may provide information about the internal and external worlds, but intention guides our actions. We can attend to our intentions, but we can also intentionally guide our attention.

While attention and intention would be most effective in the wake conscious state, they could also be present, to lesser degree, in "unconscious" states (e.g. visual attention in the original 40 Hz experiments were observed in anesthetized cats (Eckhorn et al., 1988; Gray & Singer, 1989)). They could be present at different levels of intensity, where we become conscious awake above a certain threshold.

*Attention* and *intention* could be seen as complementary aspects of consciousness, with their effective neural counterparts of perception and action, respectively, when implemented through the interactions within sensory and motor hierarchies of the nervous system. They correspond to an "inward" and an "outward" going activity of consciousness (see Fig. 2). Both of these aspects seem essential for *exploring* our external (and internal) world. In other words, we play the *dual role of actor and observer* in the drama of existence (Joseph, 1982, 2011).

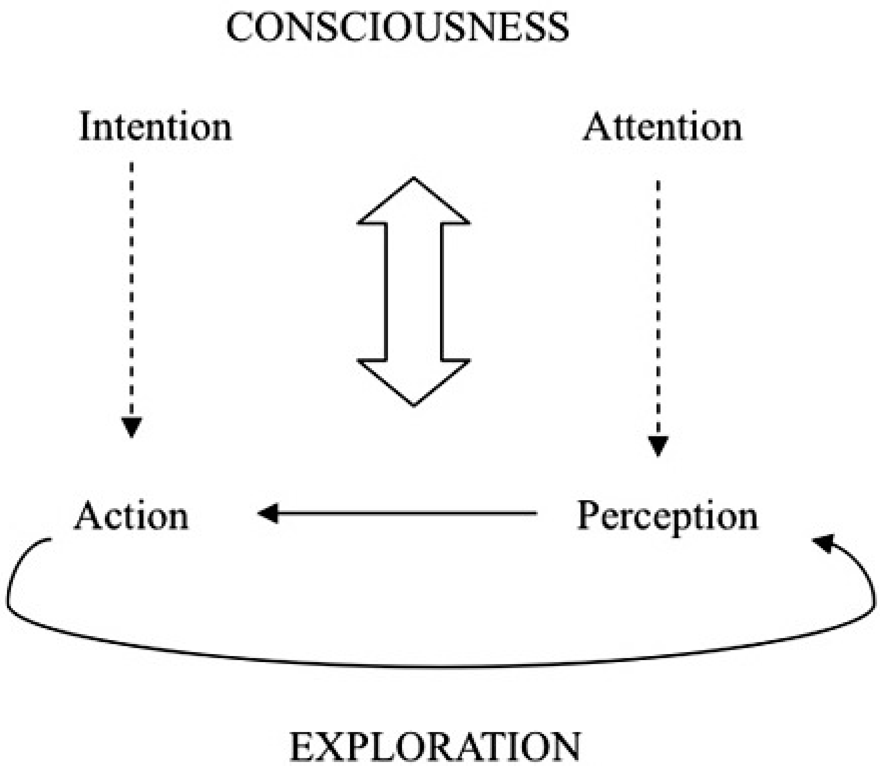


Fig. 2. The relation between the "implicate" order of consciousness, as in the dual aspect of attention and intention, and the "explicate order" of exploration, as in the perception-action cycle.

**4. Consciousness and Life**

Attention and intention, as complementary aspects of consciousness are presumably not only part of the human experience, but could be much more universal. For example, (visual) attention has been studied in insects, such as fruit-flies (van Swinderen, 2008) and honey bees (Srinavasan 2009), and can be expected to be found also in other invertebrates. Likewise, intentional behaviour can be attributed to many types of (in particular social) animals, including crustaceans (Hauser & Nelson, 1991; Mather 2011; Nani et al., 2011).

Indeed, these aspects of consciousness might be intimately linked to life at all levels, albeit not in the same sense as we use the terms for humans (or other mammals). Naturally, in organisms without a nervous system, attention and intention could never be implemented through any sensory or motor hierarchy of such a system, but would rather have to be implemented through other molecular or cellular structures.

This view is akin to that of Delbrück (1986), who considers consciousness to include all types of "awareness" of external and internal events, from a crude form of perception in the simplest organisms to self-consciousness in Man. The more complex the cellular organization of an organism is the more this organism can be aware, or conscious, of the external and internal world. In this sense, consciousness has evolved together with other properties of life. In his book, "Mind from Matter?" (1986), Delbrück regards perception as the basic form of consciousness and he claims (p. 43) that,

> "The unity and continuity of life is equally manifest in its psychic aspects. Perception in plants and animals is a familiar phenomenon, but the beginnings of perception are also clearly present in microorganisms, in which adaptive behavior demonstrates that they can detect and evaluate signals from the environment and respond appropriately".

This is not a dominating view today, but it is appealing in the sense that it relates processes in simple organisms with those in higher. It avoids the difficult task of finding a possible origin of consciousness in evolution, and points to a continuity in the living world. In fact, a similar view is shared by Margulis and Sagan (1995), who suggest that also intentionality may be attributed to simple organisms, including bacteria.

The electro-chemical (or other) processes that take place in the intricate neural networks of the brain can be assumed to be associated with various internal states and "mental" processes of an animal. In lower animals, the nervous system may allow only for "primitive mental" processes, such as perception, learning, recalling, drives, and emotions (Mather 2011; Nani et al., 2011). To a large extent the animal is presumably unconscious of these internal processes, and it is only aware (conscious, in the Delbrück sense) of the *external environment*. As the nervous system evolves and attains a higher degree of complexity and organization, its processes become more advanced and sophisticated, including cognition, as an act of knowing, thinking, reasoning, believing, and willing. Eventually, (symbolic) language becomes an important and integrated part of the cognitive functions (Joseph 2000), facilitating reflection and communication.

In birds and mammals, and most articulate in man, there is an advanced ability to "internalize" the world through the formation of spatial and temporal patterns. In particular, *temporal binding* allows us to understand the relation between cause and effect and to experience "the arrow of time". For humans, the internal model of the world also includes other individuals and their minds. Models of other individuals are important for determining the significance of their behavior, and for predicting the "next step" in that behavior.

Self-consciousness, a sense of an "I", may develop when experienced events are given a sequential context in the internal model of the world. It is obvious that many cognitive functions (but not consciousness in general) depend upon memory, but the "I" needs memories well structured in time, in order to be perceived. Obviously, also planning for the future, involving attention as well as intention, is an essential component in the making of an "I" (Ingvar 1994). Our subjective experience of a decision to act, as well as of a sensory stimulation, seems to require a time span of a few to several hundred milliseconds (Libet 1985, Crick 1994, Soon et al., 2008).

Thus, the capacity to predict future events have been extended to the anticipation and expectation of a continuous individual life. Also, if one has a (good) model of oneself one can infer ones own thinking, feelings and behaviors also to others, thus allowing for a more efficient interaction with other individuals, and better prediction of their behavior. The ultimate pattern in our understanding of the world results in an experience of *meaning*, where our interrelationships can be set in a context (attention), and be seen as purposeful (intention). Fig. 3 shows an attempt to link the evolution of cognitive and conscious interaction with the external environment to an increasing complexity of living organisms.

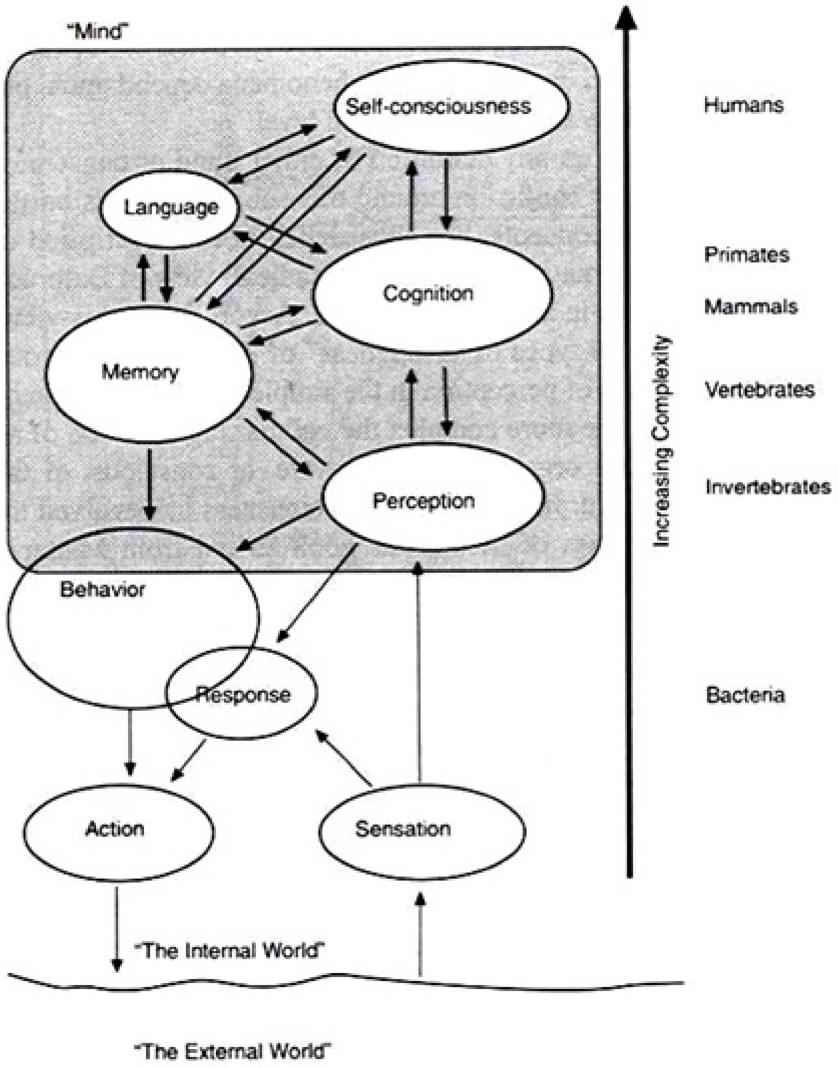


Fig. 3. A crude attempt to map various cognitive functions and relate them to each other on an "evolutionary scale" that is at the same time a measure of the degree of complexity. Intention would correspond to the

downward direction, and attention to the upward direction in this figure. (Adopted from Liljenström, 1997).

Consciousness and cognition apparently evolve through interaction with the environment, where the organism is embedded. Such exploration of the environment requires both attention and intention. The evolution of consciousness presumably occurs through larger leaps when new species appear, and through smaller steps within a species and even smaller steps within an organism. A great leap of consciousness must have happened when we became aware of ourselves and our own cognitive activity. That leap should also include an awareness of our intentions, a sense of a free will. This more advanced consciousness is presumably experienced, or at least reflected on, by humans alone.

## 5. Discussion

In previous sections, I have given an outline of a view on consciousness that is based on its complementary aspects of intention and attention, and more universal than commonly considered. It implies that both of these aspects of consciousness are essential for exploring our internal and external world. As suggested by William James (1890), consciousness could be viewed as a constantly changing *process*, interacting with a constantly changing environment. Another view is that consciousness can be seen as a "force field", similar to an electromagnetic field (Popper et al., 1993; Lindahl & Århem, 1994).

These views imply that we cannot reduce consciousness to neural or electrochemical processes. Indeed, that would have little meaning to us, even if we claimed we had succeeded. Concepts at one level are in many cases not transferable in a meaningful way to another level. New qualities and properties emerge at each new level in the hierarchical organization of matter, qualities which are irrelevant at lower levels. Such a "holistic" view was also given by Delbrück, who compared mind with quantum reality:

> "The mind is not a part of the man-machine but an aspect of its entirety extending through space and time, just as, from the point of view of quantum mechanics, the motion of the electron is an aspect of its entirety that cannot be unambiguously dissected into the complementary properties of position and momentum."

Penrose (1989, 1994) brings this analogy further, believing that mind indeed may need some quantum mechanical description. He argues that there are some aspects of mind, or mental phenomena, like e.g. understanding and insight, that are non-computable in nature, and thus, for example, can never be simulated on a computer. Such phenomena may even require a new physics, new laws and principles that are not mechanistically derivable from lower levels. With this perspective, consciousness seems to fundamentally transcend physics, chemistry and any mechanistic principle of biology.

If intentionality is a fundamental aspect of consciousness, and if an extended form of intentionality corresponds to our sense of free will, it is difficult to fit it within the framework of current science, which is based on deterministic laws and chance. In my view, consciousness provides a freedom beyond the indeterminism of quantum physics or the determinism of classical physics. Indeed, consciousness should perhaps not at all be viewed as a *phenomenon*, that is observable within the framework of current scientific approaches (even though science entails observation and experiment, as an advanced form of attention-perception and intention-action). Instead, consciousness could be considered a *meta-phenomenon* (or *noumenon*, in a Kantian sense), which can only be "observed" indirectly (by a conscious observer) through its effects on the material world.

The effects of consciousness is most clearly linked to intention, as its more active aspect, which has to be considered if we are to understand its role in evolution and in the universe. Exploration, through attention-perception and intention-action, is fundamental to all levels of existence. In this sense, consciousness is inseparable from life, expanding and evolving together. It is expressed and evolving through inter-relations (attention) and inter-actions (intention). Hence, consciousness can be regarded as a driving force in nature.

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