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Distributed Consciousness Theory (DCT)

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Abstract

Distributed Consciousness Theory (DCT) is a new theory of consciousness, which primarily addresses the substrate problem: what type of physical substrate best supports the phenomenology of consciousness? The theory describes mutual information non-locally 'distributed' in physical systems. This is formally described as closed systems having reduced degrees of freedom (entropy) due to mutual-information with the environment. This thermodynamic principle is generalised to a field with distance metric equivalent to the inverse of shared information. The theory describes how conscious objects may be represented in this distributed field and details information flows associated with conscious perception as well as processes in the brain which may interact with distributed information.

The theory is able to solve key problems in consciousness theory, including The Binding Problem (Bayne 2010) and a novel solution to The Hard Problem (Chalmers 1995). Consequences and remaining unsolved problems of the theory will be discussed including the problem of causal emergence.

0.1 Supplemental Material

A presentation from Models of Consciousness (Sapporo 2025) covering the key concepts of the theory is available online at https://r.greenant.net/published/DCT_presentation.

Figure 1. Ipomea

Introduction

This paper provides an outline of the key concepts of a new theory of consciousness, the Distributed Consciousness Theory. This theory has been developed on the basis of communications with a number of theorists, see Acknowledgements.

The Distributed Consciousness Theory is primarily motivated by the hypothesis that consciousness is a *distributed* phenomenon. We will formalise this hypothesis but for the moment it is enough to state that, for the purposes of the theory, 'distributed' means that the processes and contents of consciousness are reliant on non-local phenomena. The theory focuses largely on the question: "what physical processes can allow the types of conscious experience we experience to operate?". Therefore, DCT is largely a theory of the mechanism of consciousness, with the contents and states of consciousness being secondary considerations.

DCT attempts to address some of the key metaphysical problems inherent in other theories of consciousness. This paper will briefly contrast DCT's perspectives with alternative theories. DCT is grounded in modern physics, particularly information theory and quantum theory. However, it strenuously avoids *new physics*. While some physical interpretations may be novel, the theory does not rest on creating new forces or particles, and should be interpretable with well-established physical concepts and mathematics.

0.2 Background

Before getting into the specific elements and predictions of the theory, it is worthwhile identifying some of the key influential ideas which we will reference:

0.2.1 John Archibald Wheeler: "It from Bit"

In Wheeler's 1989 paper, "Information, Physics, Quantum: The Search for Links", he outlined a set of questions related primarily to the primacy of quantum information as a substrate for physics, aptly summarised in the term 'It from Bit' (Wheeler 1989). Wheeler's arguments included some cursory discussion of consciousness, particularly from the perspective of binary information – "yes-or-no indications" – and the role of "observer-participants". Importantly, he implored an understanding of "all of physics in the language of information", which he conceived as fundamentally based on binary conclusions about observables.

Many interpretations of this concept followed, including Anton Zeilinger's statement:

> "My interpretation [of "it from bit"] is that in order to define reality, one has to take into account the role of information: mainly the fact that whatever we do in science is based on information which we receive by whatever means."(*It from bit?* 2015)

Generally, the 'It from Bit' concept has been interpreted with reference to the dominant Copenhagen Interpretation of quantum physics, in which the probability of events evolve deterministically (under the Schrödinger equation (Equation 1), sometimes called Unitary Evolution) until the act of 'observation' collapses the wave-function indeterministically (the projection postulate)(Lombardi and Dieks 2014).

However, this interpretation raises a number of metaphysical challenges, not least of which is the Observer Problem; which types of observation lead to the collapse of unitary evolution, and what constitutes a measurement device.

$$i\hbar\frac{d}{dt}|\Psi(t)\rangle = \hat{H}|\Psi(t)\rangle$$

Equation 1. Time-dependent Schrödinger equation, $\hbar$=reduced Planck constant, t=time, $|\Psi(t)\rangle$=state vector, $\hat{H}$=Hamiltonian operator

It is important to be clear that the Distributed Consciousness Theory does not rely on this collapse mechanism. Instead, we ascribe to a 'no-collapse' interpretation, in which quantum information persists without being collapsed to classic observables (Passon 2018). These no-collapse interpretations share the common characteristic of formulating quantum theory without the projection postulate.

In Relational Quantum Mechanics, systems are described by the interaction between systems, rather than an absolute state of the system. This view does not establish primacy of a given, underlying state, rather a measurement is only relevant to the relationship between systems. This has been described as a "net of relationships" (Laudisa and Rovelli 2014). In Rovelli's formulation (Rovelli 1996, 1997), an event or state is only validly defined *with respect* to a system (for instance an observer system).

> (Rovelli 1996): "Quantum mechanics is a theory about the physical description of physical systems relative to other systems, and this is a complete description of the world".

Importantly, even though the events and state of an observer are relative to the system they observe; and different observers may have different observables, the rules of quantum mechanics ensure consistency when different accounts are reconciled by physical interaction.

The interpretation retains the mathematical frameworks of quantum mechanics, with the *dynamical state* of the system corresponding to the usual density matrix, evolving as defined by the Schrödinger equation. In contrast, the *value states* for a given system are constrained by the non-commutativity of observables, thus defining joint existence of properties, independent of knowledge of a system

An implication of this interpretation is that it is necessary to define a "privileged observable", and by extension the Hilbert space of the universe must have a preferred factorisation (as opposed to all factorisations being equally plausible).

$$H^{univ} = H^1 \otimes H^2 \otimes ... \otimes H^j \otimes ...$$

Equation 2. Decomposition of Hilbert Space

In the Atomic Modal Interpretation (AMI), this is usually interpreted as being synonymous with the standard model (the fundamental objects of the universe being elemental particles). However, for the purposes of DCT, we will take the fundamental objects to be composed of quantum informational objects, with particles 'dancing around' this information. In this way, we can extend the 'It from Bit' analogy into a formal description. In DCT, the properties of particles (position, momentum, etc.) are constrained by the more-fundamental quantum information of systems.

Importantly, this type of quantum information is not a *derived* quality of a system, it is fundamental to the dynamics of the universe's state space, H^{univ}.

Importantly, this interpretation allows to build a realist *substrate* for consciousness, expressed in the precise mathematics of quantum mechanics. Furthermore, it applies to all physical phenomena, no matter the measurement scale. Another interesting implication of the Atomic Modal Interpretation is that composite quantum systems can have collective properties that may not be explained by their atomic components (Dieks 1998). This will become important when we consider the causal efficacy components of the DCT.

Healey (1989) also considered how non-local quantum properties of entangled particles may possess a "holistic" property.

An extension of the modal interpretation is the *Perspectival Modal Interpretation* (PMI, Bene and Dieks 2002), in which the the quantum state of the whole universe with respect to itself is utilised as a "reference system". Observers in this formulation have different relational descriptions from their particular perspectives, but the position of macroscopic objects shows good agreement. These relational states are fundamental, not being derived from more fundamental non-relational states.

Modal interpretations define a space of possible events, from which only one of these becomes actual. Therefore, the interpretations are probabilistic (in contrast to many-worlds interpretations, for instance).

0.2.2 Out-of-equilibrium behaviour of quantum systems under drive

While the presence of quantum effects in biological systems is well established, there remains significant skepticism regarding whether quantum effects can be coherent and meaningful in large systems like the brain. This section will discuss some proposals for large-scale coherence in noisy environments.

Viewed from a traditional localist paradigm, the brain is a complex organ with emergent dynamics built on the activity of neurons, generating local field potentials and broader coherent activity which we observe behaviourally, and with the tools of electrical and magnetic neuro-imaging. The localist approach assumes that the *coding* of neural activity arises from the summed activity of neural firing, perhaps encoded in the firing patterns and/or the local fields generated in neural aggregates. However, consciousness theories usually require this local activity to be converted into global states, whether these be for perception, awareness or cognition.

This mapping from (micro) neural activity to (macro) states of consciousness has plagued all theories of consciousness. Various proposals attempt to explain emergent states, including minimisation of free energy, or causal integrations, functional workspaces, or higher-order monitoring processes. These theories often suffer from mathematical complexity (or intractability), making their mechanisms implausible or inefficient. It is the assertion of this paper that the core deficiency of these approaches is that they attempt to turn local activity into brain states while adhering to a localist view.

Instead, we can take a different approach, in which we consider these micro-states as contributing to a global, non-local field instantiated in the brain. Our best theory for describing non-local phenomena is quantum theory, in fact it could be argued that non-locality is the *key defining feature* of quantum theory. Non-locality in this context, does not mean just a distribution of information in a system, it implies that states themselves (and their accompanying informational states) are distributed and not describable simply by the sum of microstates.

There are many examples in physical experiments of these non-local states.

(Defenu, Lerose, and Pappalardi 2024)

1. Elements of the Theory

The following elements form the basis for DCT.

1.1 Mutual Information

1.2 The Protoconscious Field

1.3 The Human Perspective: conscious processes

2. Implications of Theory

2.1 For the Hard Problem

2.2 The Binding Problem

- non-locality helps

3. Discussion

3.1 Testing the Theory

3.2 Speculations

- holography

3.3 Next Steps

4. References

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