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Inverse Bayesian inference as a key of consciousness featuring a macroscopic quantum logical structure

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ABSTRACT

To overcome the dualism between mind and matter and to implement consciousness in science, a physical entity has to be embedded with a measurement process. Although quantum mechanics have been regarded as a candidate for implementing consciousness, nature at its macroscopic level is inconsistent with quantum mechanics. We propose a measurement-oriented inference system comprising Bayesian and inverse Bayesian inferences. While Bayesian inference contracts probability space, the newly defined inverse one relaxes the space. These two inferences allow an agent to make a decision corresponding to an immediate change in their environment. They generate a particular pattern of joint probability for data and hypotheses, comprising multiple diagonal and noisy matrices. This is expressed as a nondistributive orthomodular lattice equivalent to quantum logic. We also show that an orthomodular lattice can reveal information generated by inverse syllogism as well as the solutions to the frame and symbol-grounding problems. Our model is the first to connect macroscopic cognitive processes with the mathematical structure of quantum mechanics with no additional assumptions.

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1. Introduction

Since Chalmers established that the issue of understanding consciousness and qualia is an extraordinarily difficult problem (Chalmers, 1996), various researchers have approached it in different ways. Recent approaches based on phenomenal consciousness in neuroscience, robotics and philosophy have brought us closer to a possible solution, where the phenomenal consciousness could lack the nature of subjectivity relevant for measurement. While these approaches can be viewed as converging toward the dynamic nature of matter and quality, they need the measurement-oriented notion. This is consistent with endophysics (Rössler, 1996, 1998; Atmanspacher et al., 2002; Atmanspacher, 2003) or internal measurement in science (Matsuno, 1989; Gunji, 1994; Gunji and Kusunoki, 1997) (which we refer to collectively as endo perspective) as well as neutral monism in philosophy (Silberstein and Chemero, 2015; Strawson, 2006). We propose a model of the measurement process based on the contraction and relaxation of its probability space to implement such a dynamical nature. The connection between consciousness, phenomenal consciousness, neuroscience theories, neutral monism, and endo perspective is not clear. As a result, we first clarify and establish these relations.

When Chalmers conferred hard-problem status on consciousness and qualia, an essential difference between matter and mind in nature became accepted, at which point his idea was classified as naturalistic dualism (Chalmers, 2007). A subjective quality cannot be reduced to a physical property, and vice versa. Consequently, many scientists evaded this issue since it seemed incapable of being solved in principle. They simply accepted naturalistic dualism in the same way as they had done based on previous studies (Popper and Eccles, 1977).

The failure of classical artificial intelligence (AI) could lead to a sense of which fragments of proto-intelligence or knowledge are not in a center of consciousness (i.e., a particular local area) but instead are embedded in environments (Pfeifer and Scheier, 2001). This leads to the idea of subsumption architecture (Brooks, 1986, 1991) and/or morphological computing (Pfeifer et al., 2007). In trying to compute how to bend metallic robotic fingers to pick up a raw egg without breaking it, classical AI fails because of the amount of computation required. If the robotic fingers are covered with a

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rubber skin that can adequately absorb physical shocks, the task can be achieved without an excessive amount of computation. The rubber-skin interface allows negotiation of the physical world in which the egg exists and the virtual world in which symbolic manipulation can be programmed. In that sense, the interface is a type of body. Hence, constructing the interface as a physical body is referred to as an embodiment of intelligence (Varela et al., 1991). Although fragments of proto-intelligence are embedded in the body, the question arises as to whether intelligence exists in a programmable manipulation. If it does not, intelligence as a whole could be embedded not only in the body, but also in the environments surrounding it (Varela, 1997; Pfeifer and Gomez, 2009).

In subsumption architecture, a system of multi-agents plays a role in the interface. Each agent is merely a simple system following an equally simple rule, with no intrinsic intelligence. Contingent temporal configurations of agents are an embodiment of intelligence in a multi-agent system. Intelligence is not carried by a central system, but rather it arises collectively from the multi-agent system (Reynolds, 1987; Couzin et al., 2002; Olfati-Saber, 2006).

These ideas are consistent with the notion of phenomenal consciousness (Tye, 1997; Clark, 1998, 2003) developed in philosophy and cognitive science based on Husserl and Hedeggar's the phenomenology (Husserl, 1913=2001; Heidegger, 1927=1996). In phenomenology, anything is comprehensible by its surroundings. The relation between an object and its surroundings is embedded at each local site. When a particular function in the world appears as a concrete thing, such an object with a particular function is used as a particular tool ("presence-at-hand"); it is then bodily connected to the agent who uses it as a part of their body ("readiness-to-hand") (Heidegger, 1927=1996; Clark, 1998, 2003). A dynamic network of functional connections can give rise to a dynamic change of the owned body and/or consciousness as a whole; that is what is meant by phenomenal consciousness. The notion of a "thing" in the world can be extended to a human body, and the notion of usability can be extended to bodily sensations (Gallagher and Zahavi, 2008; De Jaegher et al., 2010). A sense of bodily agency and/or ownership (Tsakiris et al., 2006; Synofzik et al., 2008) can also be comprehended in the framework of phenomenal consciousness (Gallagher, 2000).

How are matters in neuroscience? Koch, who focused on neural correlates of consciousness (NCC) (Rees et al., 2002), also recently abandoned mind/matter dualism and confessed his sympathy for panpsychism in which mind can be contained in anything (Koch, 2012). Tononi, who proposed information integration theory (IIT) (Tononi, 2008; Oizumi et al., 2014), also proposed an idea based on panpsychism (Balduzzi and Tononi, 2009; Tononi and Koch, 2016). However, their ideas are consistent with phenomenal consciousness rather than panpsychism. After the finding of readiness potential (Libet et al., 1983; Haggard et al., 2002; Frith et al., 2000), intentional consciousness is regarded as an area employed in postdiction (Koch, 2012; Maeno, 2005). Neural networks used in the readiness potential are referred to as unconscious zombies. After the activities of these unconscious zombies, a neural area correlated with the intentional consciousness can interpret a voluntary action triggered not by the zombies but by the intentional consciousness itself (Koch, 2012; Maeno, 2005). Most neuroscientists, including Koch and Tononi, accept these views. A population of unconscious zombies can be compared to the system of multi-agents in subsumption architecture, to the layer of rubber skin in robotics, and to the dynamic network with respect to a functional connection. Although IIT is used to detect the intrinsic difference between an intent-wholeness (unity as a whole) and an extent-wholeness (sum of parts) (Tononi, 2008), it can also be considered as a way to estimate the relationship of intentional consciousness part and the population of zombies. Therefore, these theories are consistent with phenomenal consciousness.

Intentional consciousness covered by a population of zombies and body can sometimes include objects outside the body and exclude those inside it (Clark, 1998, 2003). That is an optimization process adapted to a given environment. Since both neuroscience and cognitive science focus on such an optimization, they tend to use only Bayesian inference in describing cognitive processes (Gigerenzer and Hoffrage, 1995; Knill and Pouget, 2004; Manktelow, 2012). Bayesian inference can reduce or contract the probability space dependent on empirical data, allowing the optimal solution to be found more readily. In contrast, the hypothesis of a global workspace (GWS) in neuroscience refers not only to a similar contraction of the probability space, but also to its expansion (Dehaene et al., 1998; Dehaene and Naccache, 2001; Dehaene and Changeux, 2011). A particular internally selected neural activity can be globally connected and propagated to various areas of the brain (Singer and Gray, 1995), which implies expansion of the space. The process of GWS might be directly related to generating a local singular structure, i.e., a "bundle" of qualities including qualia. We shall return to this issue later.

The question arises as to whether the singularity and/or locality carried in consciousness and qualia can be comprehended in phenomenal consciousness. In the case of rubber skin or the configuration of agents, many logical and programmable computational processes are not implemented directly in the system but could be indirectly embedded in non-logical material in a local area. In other words, the relation between logical states is embedded at a local site. If this embedding converges to a singular state under infinite recursive iteration, then this singular self-similar state (Scott, 1972; Gunji and Toyoda, 1997) is a candidate for local and singular states such as qualia and quality. However, the notion of phenomenal consciousness does not restrict the locality and singularity of consciousness and quality. A singular and local quality does not exist intrinsically, but appears instead as a phenomenon in the perspective of phenomenal consciousness. Although qualia and the subjective quality might be addressed by phenomenal consciousness, they could appear as illusions.

The proponents of singularity and locality of qualia and consciousness have moved to panqualityism or neutral monism (Strawson, 2006) because panpsychism has failed and suffers from a combinational problem (Chalmers, 2015). Panqualityism addresses the view that any physical thing can be endowed with quality, i.e., fragments of proto-qualia (Coleman, 2012). In mind/body dualism, there is the notion that if someone with a body temperature of 35 °C touches a physical object whose temperature is 50 °C, the sensation of hotness appears in the person's mind. In panqualityism, even this sensation is embedded in the physical object. While temperature is a quantity, hotness is a quality. Although there is an intrinsic difference between quantity and quality in nature, a 15 °C temperature difference can cause the sensation of hotness. If this differential structure is recursively embedded in a local site in a self-similar manner, a singular state could arise whose quality is so simple that it reveals not a dynamic nature but a static one (Scott, 1972). We have previously attempted a similar but dynamic self-similar construction for dynamics (Gunji, 1994; Gunji et al., 1997; Gunji and Toyoda, 1997).

However, one final question arises. How is it possible to have a physical object embedded with a subjective quality? Put differently, how is neutral monism implemented in science? This may seem to be more akin to spirituality. Although there have been some previous attempts—the quantum consciousness hypothesis, in which quantum coherence occurs in cytoskeletal structures (Hameroff and Penrose, 1996a,b), and the idea that the water mass in the brain could generate consciousness (Jibu et al., 1994) – the criticism has been made that quantum effects do not contribute to macroscopic phenomena at normal temperatures (Grush and Churchland, 1995). While the internal quantum state in a

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