Research Statement

Overview:

The goal of our research is to understand the physical substrate of consciousness. How is our conscious experience supported by our brain? To address this question, we need to make various breakthroughs. We strive to establish new paradigms and techniques based on our creative ideas. We will develop new and clever experimental or analytical developments. They will allow us to observe and manipulate consciousness for rigorous scientific investigation.

We have contributed to this in several domains (See Research focus so far). We are also building novel empirical methodologies (See Future and ongoing research).

Building on our basic research, we also work on research translation. In particular, into clinical and industry domains. These researches aim to improve the accuracy in measurement of consciousness. It also aims to improve conscious creativity while reducing mind wandering. It also aims to improve (collective) intelligence research informed by consciousness research.

Research focus so far

We have used various techniques. The range of techniques include but not limited to: psychophysics, neuroimaging, and modeling. We collaborate with researchers who work on the brains of humans and animals. Interdisciplinary collaboration has involved philosophers, clinicians, engineers, neurophysiologists, mathematicians and physicists.

1) Understanding the boundary between conscious and nonconscious processing.

One of the most effective ways to study consciousness is to contrast conscious and unconscious states of the brain. When conscious, people or animals are awake. Unconscious states can result from brain injury, general anesthesia, or deep sleep.

Another most effective method is to contrast conscious and nonconscious processing. When we are conscious, we perceive certain things but not others at a moment. That is the contrast in contents of consciousness, or qulia for short.

We invented a technique, known as Continuous Flash Suppression (CFS; Tsuchiya & Koch 2005).

CFS is a technique in visual psychophysics. With CFS, researchers can suppress a salient visual stimulus. CFS can suppress almost any image for a long duration in a controlled manner. CFS helps uncover the neural processing that does not give rise to consciousness. We used CFS to study nonconscious emotional processing in the lesion patients (Tsuchiya et al 2007). Cognitive neuroscientists worldwide use CFS in combination with neuroimaging. Our work continues to clarify the boundary between the conscious and the nonconscious.

2) Clarifying the relationships between consciousness and associated psychological processes

What is the relationship between consciousness and other psychological processes? Attention, memory, access and report are all important parts of our life. How are they related to consciousness?

Philosophers and psychologists have long discussed the relationship between attention and consciousness. And this discussion is now extending to AI and other fields.

Based on empirical evidence, we have been proposing to distinguish the two (Koch & Tsuchiya 2007). The two can work together but often dissociate. Sometimes working towards the opposite directions. We demonstrated it using psychophysics (van Boxtel, Tsuchiya, Koch 2010) and EEG (Davidson et al 2020). Key is to independently manipulate consciousness and attention. We have various paradigms at hands to do this (Matthews et al 2018).

No-report paradigms are also necessary to truly understand the neural basis of consciousness (Tsuchiya et al 2015). They allow us to distinguish the effects of the act or intention to report on the contents of consciousness.

3) Testing the quantitative theories of consciousness

We have been working on Integrated Information Theory (IIT) of consciousness. IIT is currently one of the most promising quantitative theories of consciousness. Its

explanatory and predictive power on consciousness is quite attractive. Yet, IIT has been criticized as being impossible to be tested.

Our aim is to test IIT in its prediction. Towards this aim, we developed accurate proxies of integrated information (Oizumi et al 2016 x2, Cohen et al 2019). Our tools are available on the web. We have characterized integrated information in relation to other known measures. Based on these developments, we have started testing IIT's claims with real neural recordings (Haun et al 2017, Leung et al 2021). Our measures of integrated information can be applied to other fields of network science. Physicists, social neuroscientists and others have started using them for their research objectives.

Future and ongoing research

4) Big data analysis on loss of consciousness

We have been trying to distinguish states of wakefulness from loss of consciousness. We try to develop better classification between wake and anesthesia-induced loss of consciousness (Cohen et al 2017, 2018, Leung et al 2021). We are also interested in distinguishing dreamful vs. dreamless NREM sleep (Wong et al 2020). We are extending this direction into conscious vs. unconscious brain injured patients.

Our focus so far has been on electroencephalography (EEG) data. EEG has high temporal resolution. making it easy to test some theoretical measures of consciousness. EEG is available in many hospitals and much cheaper than other devices. Thus any methods to detect consciousness based on EEG is easier to translate to clinics.

To develop novel methods, we have collaborated with physicists to apply complexity measures (Munos et al 2020). We are also applying >7700 analysis methods at the same time on the same data to search for the best . This method is called highly comparative time series analysis (Fulcher 2017). For this end, we are quite keen to collaborate with many scientists to construct a large EEG dataset.

5) Massive report paradigms to characterise the structure of conscious experience.

Traditional psychophysics on consciousness has focused on binary categorical responses. For example, seen vs. unseen responses through button presses. While easy to analyze,

they are poor in capturing richness of consciousness. We need a better way to characterize the structure of human conscious experience.

We have been developing various ways to extend reporting methods. We call these as "massive report paradigms" to distinguish it from simpler alternatives. To collect a big enough dataset, we develop various web-based psychophysics experiments.

The challenge of these new experiments is the complexity of the analysis. We have been exploring automatizing the scoring procedure. Here, we see a huge opportunity for collaborating with researchers in other fields. AI, math, linguistic and topological data analysis.

6) Discovering a structural mapping between consciousness and information

What do we need to understand the relationship between the brain and consciousness? We have proposed a three-step approach (Tsuchiya et al 2016). It starts with revealing the structures of consciousness. In parallel, it tries to reveal the structures of information. This information structure has to be relevant to consciousness. Then, it eventually reveals the structural mapping between consciousness and information.

The last step of the project requires collaboration with theoreticians. We are using various concepts from category theory and tools from applied mathematics. It benefits from interdisciplinary collaboration with mathematicians, physicists and artificial intelligence.