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A neural coarse graining theory of consciousness

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ABSTRACT

Neural systems process information through different levels of organisation in a hierarchical manner. Information at lower levels is finer-grained and can be coarse-grained for higher level computation. However, one is aware of information processed only at specific levels. Theorists have addressed this issue. For example, the intermediate level theory of consciousness suggests that the intermediate level seems to be privileged with respect to consciousness. It is true that we do not experience information processed by individual neurons which is always highly noisy. Besides, we have no conscious experience from interpersonal activities albeit massive interactions among individuals. Instead, neurophysiological evidence has been showing that conscious experience tends to covary with information encoded in coarse-grained neural states such as neural population codes. We argue that the neural states within the scope of the information closure determine the contents of consciousness and brain processes outside apart from the representations of that level remain unconscious. This argument suggests a distinction between conscious and unconscious processing and provides a generic computational framework. Finally,

using the deep learning network, we can measure information closure in deep hidden layers. Our preliminary results show that information closure representation emerged after learning. We further decoded the information from the representation and compared it with human conscious perception.

Keywords: theory of Consciousness, information closure, neural coarse-graining, level of analysis, keyword, keyword, keyword, keyword

1 INTRODUCTION

2 NEURAL COARSE-GRAINING

* *"Neural population code: the set of response features of a population of neurons that carry all information about the considered stimuli. These features consist of spatio-temporal sequences of action potentials distributed across neurons and/or time."*

¿ The diverse response selectivity of sensory neurons ¿ *"How a neural population represents information is partly determined by the diverse selectivity of individual neurons Shamir (2014)"*

Stanley (2013) Quian Quiroga and Panzeri (2009)

* Sensors can only receive partial information * Through coarse-graining, higher level cortical areas can integrate those partial information to infer hidden causes.

2.1 The advantage of NCG

2.1.1 Resist to noise

2.1.2 Operate on deterministic and abstract level

2.1.3 Predictive power

2.1.4 Reduce energy cost

3 NON-TRIVIAL INFORMATION CLOSURE

"Our theoretical interest concerns the type of system that is a unity for and by itself and not only for an external observer distinguishing some entity from the rest of the world. This requires a system that can be described as a whole without reference to its environment. In systems theory, this property is usually referred to as closure."(BERTSCHINGER et al., 2006)

"These concepts of closure play an important role in the architecture of systems theory, because they are used to 1. define the system (in distinction to its environment) and to 2. explain the autonomy of the system. "

> Informational closure: The higher process is informationally closed, i.e., there is no information flow from the lower to the higher level. Knowledge of the microstate will not improve predictions of the macrostate (PFANTE et al., 2014, p. 4).

"A system that is independent from its environment trivially achieves informational closure." (BERTSCHINGER et al., 2006)

3.1 Mathematical definition of information closure

"The notion of informational closure refers to a situation where the information flow between the environment and the system tends to zero. "

BERTSCHINGER et al. (2006) suggests that information closure can be defined as the degree of information flow between environment and the system.

$$\begin{aligned} J_n(E \to S) &= MI(S_{n+1}; E_n|S_n) \\ &= H(S_{n+1}|S_n) - H(S_{n+1}|S_n, E_n) \\ &= H(E_n|S_n) - H(E_n|S_n, S_{n+1}) \\ &= H(E_n|S_n) - H(E_n|S_n, S_{n+1}) \end{aligned} \tag{1}$$

3.2 Non-trivial information closure

Information closure could be trivial. That is, when a system is fully independent from the environment, no information can flow into the system from the environment and also leak to the environment from the system.

Equa. xxxx shows the mathematical description of trivial information closure. When mutual information between the environment and system future state close to 0, and the system transition is independent from the environment, the system can reach informational closure. However, such systems do not have any functional meaning and evolutional advantages.
Therefore, it's important to ensure the informational closure that the system reach is non-trivial.

[[cite 2006 and nic's paper]]
To achieve non-trivial information closure,
(BERTSCHINGER et al., 2006)
(Guttenberg et al., 2016)

3.3 how to achieve information closure

"This demonstrates that a system exhibiting certain internal regularities as measured by $A^* = MI(Sn + 1; Sn)$ *can achieve informational closure either by gaining information about the environment or by increased autonomy, i.e. by becoming unpredictable or uncontrollable from the (13) environment. Therefore, information about the environment, i.e. modeling, and autonomy can be considered as complementary strategies for achieving informational closure."*

3.4 information closure and Level Identification

4 MY CLAIM OF CONSCIOUSNESS

* We claim that the coarse-grained state in the information closure determines contents of consciousness. * It's important that not the neural states but the coarse-grained state determine contents of consciousness.

4.1 Information and system theory

[[Closure can define a system, consciousness is information]]
[[Could be linked to system theory, but may need help]]

"This self-referential distinction from its environment therefore gives rise to the specific autonomy of such a system. Consequently, in systems theory, closure properties and autonomy are considered to be closely related concepts which are both at the heart of defining the system itself. "

5 BIOLOGICAL EVIDENCE OF INFORMATION CLOSURE IN NEURAL SYSTEM

Sederberg et al. (2018)

6 RELATION TO EMPIRICAL FINDINGS

6.1 Explain normal and abnormal conscious/non-conscious experience

6.2 Deterministic vs probabilistic

Dehaene et al. (2017) Vul et al. (2008); Moreno-Bote et al. (2011); Asplund et al. (2014); Vul et al. (2009)

7 COMPARISON WITH OTHER THEORIES

7.1 Intermediate Level Theory

7.2 Global Workspace

7.2.1 Ignition in GWT

[[Explain ignite]]

7.3 Sensorimotor contingency

7.4 IIT

7.5 Internal simulation and self-modeling

8 COUNTERINTUITIVE PREDICTION

9 EVOLUTION OF CONSCIOUS MIND

Dennett (2008)

10 CONCLUSION

NCC: To find NCC, it's not about where and when, it's about scale and level of discription

FUNDING

Details of all funding sources should be provided, including grant numbers if applicable. Please ensure to add all necessary funding information, as after publication this is no longer possible.

ACKNOWLEDGEMENTS

This is a short text to acknowledge the contributions of specific colleagues, institutions, or agencies that aided the efforts of the authors.

SUPPLEMENTAL DATA

Supplementary Material should be uploaded separately on submission, if there are Supplementary Figures, please include the caption in the same file as the figure. LaTeX Supplementary Material templates can be found in the Frontiers LaTeX folder.

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FIGURE CAPTIONS

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