IoB Middleware

Moonshot Research and Development Program Goal 1 Kanai Project

Is the Quality of Subjectivity the Same or Different Between Individuals?

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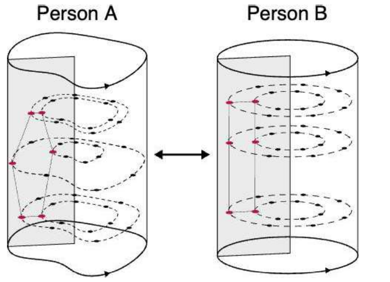
Overview

When two people look at the same thing, are the qualities of their subjective experience the same? Or are they different? If they are different, how do they differ? By focusing on equivariance in information processing systems, we have developed a theory that predicts which aspects of subjective quality (qualia) are common across individuals and which may differ from person to person. Based on this theory, we predict that the aspects of qualia common across individuals correspond to how the system behaves equivariant. Outside this equivariance, qualia can differ from person to person. Alongside proposing this theory, we also introduce a new research paradigm for studying human subjective qualities under this framework.



Decomposition of Qualia: Rigid Qualia × Plastic Qualia

1. Consistency between the structure of qualia and the structure of neural activity

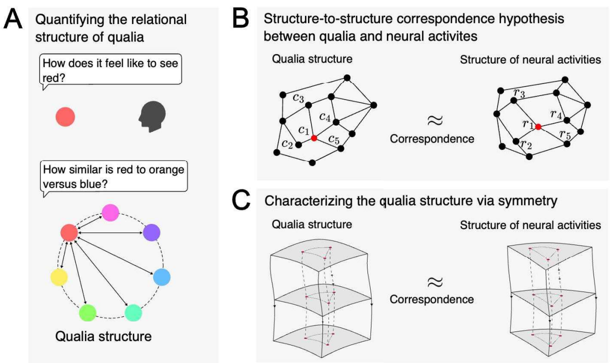


Figure 1. An approach to qualia focusing on structure

2. Decomposition of Qualia via Equivariance: Rigid Orbit × Plastic Quotient Space

Equivariance is defined with respect to transformations applied to a system's input. A system is said to be equivariant to a given input transformation when its processing commutes with that transformation (Figure 2). Focusing on equivariance enables us to treat different systems within a unified framework. In understanding systems through the lens of equivariance, we examine their behavior from two aspects.

One concerns transformations the systems are equivariant to (the orbit: geometry of qualia attributes). The other concerns things they are not (the quotient space: geometry of qualia signatures) (Figure 3). When two systems share equivariance to the same transformation, they exhibit the same topology in the output trajectories generated by applying that transformation to a seed input (the main result of this research). In other words, equivariance ensures behavioral alignment between systems in that equivariance.

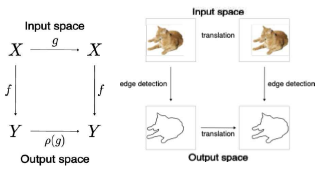


Figure 2. Definition of equivariance

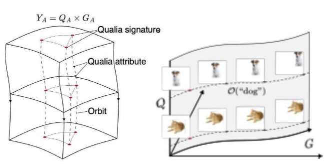


Figure 3. Decomposition by orbit and quotient space

Proposed Research Paradigm

3. Comparison Across the Entire Structure of Qualia

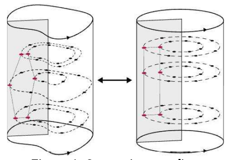


Figure 4. Comparison qualia structure on entire space

Based on our decomposition of qualia, we propose a new research paradigm for understanding how the qualia structures of two individuals are similar and how they differ. In this paradigm, we analyze similarity both at the level of the entire structure (Figure 4) and at the level of its decomposed components (Figure 5). This approach allows us to systematically examine not only the extent to which the two individuals' qualia structures resemble each other, but also how they are similar.

4. Comparing by breaking down the structure

First, we compare rigid qualia (the orbit). It may reflect natural transformations that occur in the external world, such as translation or rotation. Next, we compare plastic side (the quotient space). It may reflect an individual's innate characteristics and past experiences, giving rise to differences between individuals.

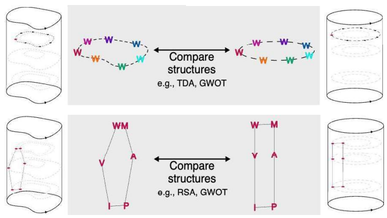


Figure 5. Comparison by breaking down the structure

Validation with Color equivariant Neural Networks (Color-equiv. NN)

Our theoretical results predict that two systems sharing the same equivariance will exhibit greater behavioral alignment in comparisons on the orbit than systems that do not share it. Additionally, our results predict that two equivariant systems will exhibit differences in comparisons on the quotient space to a similar extent as two non-equivariant systems do.

To validate these theoretical predictions, we examined the behavioral alignment of two pairs of neural networks: a color-equiv. pair and a non-color-equiv. pair. In comparisons over the entire color space, the color-equiv. networks exhibited more similar outputs than the non-equiv. ones to color stimuli. We then analyzed their behavior on the orbit (changes in hue) and on the quotient space (changes in saturation and lightness). In the orbit comparisons, the color-equiv. networks showed higher behavioral similarity than the non-equiv. ones. Conversely, in the quotient space comparisons, both pairs showed similar levels of behavioral similarity (Figure 6).

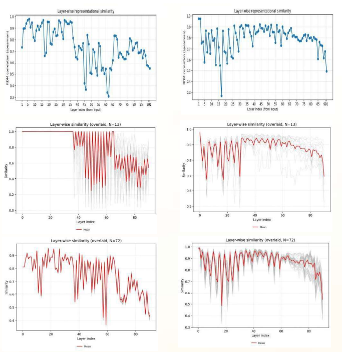


Figure 6. Effect of equivariance on orbit and quotient space

Summary of Results

In this study, we developed a theory predicting where subjective qualities share commonalities and differences between individuals, while simultaneously proposing a new experimental paradigm based on that theory. （Oizumi, Lim, and Kanai. Principal Bundle Geometry of Qualia: Understanding the Quality of Consciousness from Symmetry. PsyArXiv, 2025）

Future Prospects

The results presented here are still theoretical predictions about qualia, supported only by preliminary *in-silico* experiments. As a next step, we aim to validate these predictions using real-world data. We believe this research will contribute to technologies that can more clearly convey what "I" feel. At the same time, we expect it to provide a foundation for understanding how we communicate—specifically, what aspects of our subjective experience are shared and what aspects can differ—from the perspective of the brain's information-processing mechanisms. We hope this work will contribute to deeper mutual understanding of the subjective experiences held by different individuals, and we intend to advance our research with this goal in mind.

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Graduated from the Department of Physics, Faculty of Science, The University of Tokyo. Earned a Ph.D. from the Laboratory of Masato Okada, Graduate School of Frontier Sciences, The University of Tokyo. Assumed current position in April 2019. After obtaining his Ph.D., he was a member of the Shunichi Amari Team at the RIKEN Brain Science Institute until March 2017. From October 2011 to October 2013, he was a member of Giulio Tononi's laboratory at the University of Wisconsin-Madison. From April 2015 to October 2016, he was a member of Naotsugu Tsuchiya's laboratory at Monash University, Australia.From March 2017 to March 2019, he was a member of the Basic Research Group, Technology Department, at Araya Corporation.

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