Are Information or Data Patterns Correlated with Consciousness?

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**Talk Overview**
- Scientific work on the correlates of consciousness.
- What is information?
- Problems with an information/data approach to the correlates of consciousness.
- Conclusions.

**Scientific Study of the Correlates of Consciousness**
- Makes as few metaphysical commitments as possible.
- Gathers data about the relationship between consciousness and the physical world.
- Basic procedure:
  - Measure consciousness
  - Measure the physical world
  - Look for spatiotemporal structures in the physical world that covary with conscious states.
- Contrastive analysis that compares the conscious and unconscious brain.

**Correlates of Consciousness**
- Substantial amount of experimental work has been carried out over the last 20-30 years.
- We may eventually be able to develop theories that can make accurate predictions about consciousness based on measurements of the physical world (and vice versa).
Physical Correlates of Consciousness
- Patterns in specific physical structures that are correlated with consciousness.
- For example:
  - Neural synchronization
  - Connection patterns
  - Activation in particular brain areas
- Results are not generalisable: consciousness is only correlated with a specific pattern in a particular physical structure.

Information/Data Correlates of Consciousness
- Information/data patterns that are correlated with consciousness independently of the physical structures that happen to instantiate them at a particular point in time (neurons, electromagnetic waves, etc.).
- Information integration theory of consciousness is the most well developed of these theories.

Information Integration Theory of Consciousness
- Information integration is a combination of integration and differentiation in the information states of a system.
- Algorithm are used to analyse system for information integration.
- Identify:
  - The area of the system potentially linked to consciousness.
  - The predicted amount of consciousness, measured using the number $\Phi$.
  - A structure corresponding to the contents of consciousness.

State of the System

Apply Algorithm to Identify Conscious Part of the System

Contents of Consciousness

$\Phi = 45$

$\phi = 2$ bits
Information Integration Theory of Consciousness
- Tononi claims that information integration *is* consciousness.
- Here I am interested in the claim that information integration is *correlated* with consciousness.

Information Integration Algorithms
- A number of algorithms related to information integration have been put forward:
  - Neural complexity (Tononi, Sporns and Edelman, 1994)
  - Stateless Φ (Tononi and Sporns, 2003)
  - State-based Φ (Balduzzi and Tononi, 2008)
  - Causal density (Seth et al., 2006)
  - Liveliness (Gamez and Aleksander, 2011)

Experimental Evidence for Information Integration Approach
- Some experimental evidence for a link between measures of information integration and consciousness:
  - Lee et al. (2009)
  - Massimini et al. (2009)
  - Ferrarelli et al. (2010)
  - Fujii et al. (under review)
- This has not demonstrated a link between information integration and consciousness.
- At most a link between certain neural patterns and consciousness has been shown.

What is Information?
- A correlation between information patterns and consciousness can only be experimentally demonstrated when we have a clear definition of information.
- Floridi (2009) makes a set of distinctions that are useful for addressing this problem:
  - Dedomena
  - Data
  - Information

Dedomena
- The world as it is in itself.
- Structure of the world that exists prior to human measurements.
- Condition of possibility for experienced data.
- Similar to Kant's noumena.
Data

- A lack of uniformity in the world.
- Measured by defining a level of abstraction.
- For example, neuron firing events are data at one level of abstraction in the brain.

Information

- Well-formed meaningful data.
- Difficult to define what meaningful data is.
- Floridi (2009) suggests that meaningful data could be a combination of data and queries.
- Representational states in the brain could be interpreted as information.

Dedomena Correlates of Consciousness?

- Dedomena are the most objective aspect of a physical system and the most plausible candidate for a correlates-based approach to consciousness.
- But dedomena cannot be directly measured.

Information Correlates of Consciousness?

- Information is too poorly defined to be a plausible candidate for the correlates of consciousness.
- Information depends on data, which has problems of its own.
- Representational states could be a good place to look for information in the brain.

Data Correlates of Consciousness

- We can look for data patterns in the brain that might be correlated with consciousness.
- These include the patterns identified by Tononi’s information integration approach, which is more accurately described as a theory of data integration (Gamez 2011).

Experimental Procedure for Identifying Data Correlates of Consciousness

- Measure consciousness.
- Define a level of abstraction (electromagnetic waves, neurons, ion channels, etc.)
- Define a procedure for converting measurements of the physical system to numbers (spatial and temporal resolution, units of measurement, etc.)
- Measure system over a period of time to obtain numbers.
- Put numbers into data algorithm – for example, Balduzzi and Tononi (2008).
- Look for correlations between output of data algorithm and consciousness.
Key Claim to Test about Data Correlates of Consciousness

- Data patterns in the brain are correlated with consciousness independently of the physical structure in which the data pattern is found.
- Difficult to prove this experimentally.
Levels of Abstraction

- Consciousness must be correlated with an objective property of the system.
- But the data that is measured in a system results from the experimenter’s choice of a level of abstraction.
- In the brain we can measure:
  - Electromagnetic waves
  - Neuron activity
  - Ion channels
  - ...
- Different levels of abstraction are likely to lead to different data measurements.
**Single Level Analysis**
- It might be thought that we could analyze data at a single level, such as the neural level.
- Identify correlations between spatiotemporal patterns at this level and consciousness.
- Claim that we have identified correlations between data patterns and consciousness.
- But this is wrong!
- It would only show that a particular *neuron pattern* was correlated with consciousness, not that a data pattern was correlated.

**Cross-level Analysis**
- Avoid subjectivity in the choice of levels by developing an algorithm that works across all possible levels.
- For example, the level at which data integration is maximized could be correlated with consciousness.
- Tononi suggests this approach.

**Illustration of Cross-level Maximization**
- Output of the algorithm at different levels of the unconscious brain.

**Output of Data Algorithm**
- Ion channels are the level at which the data algorithm produces a maximum value of 5.
Cross-level Maximization

- Output of the algorithm at different levels of the conscious brain.

Illustration of Cross-level Maximization

- Conclusion: data pattern is correlated with consciousness when it passes a threshold of 5.

Potential Issues

- A complete cross-level analysis cannot be done:
  - The number of levels of abstraction of a real world system is probably infinite.
  - The lower levels of the system (molecules, atoms, quarks) will be inaccessible for the foreseeable future.
  - The results at each level might contradict each other.

Cross-level Analysis

- It is possible that the data patterns at different levels will coincide.
- The analysis at each level would be identifying the same data at different scales.
- However, it is highly unlikely that the data patterns at different levels of abstraction will coincide.
Coincidence (or not) Between Different Levels

Data Pattern or Physical Correlate?
- We need to experimentally distinguish between two claims:
  - A pattern of data is correlated with consciousness
  - A pattern of an aspect of the physical world is correlated with consciousness.
- Remember key claim: Data patterns in the brain are correlated with consciousness independently of the physical structure in which the data pattern is found.

Data Pattern or Physical Correlate?
- One way of demonstrating that data patterns are the actual correlates is to use an algorithm that finds a maximum across multiple levels of abstraction.
- If one level correlated with consciousness at one time and another level correlated with consciousness at another time, then it could be claimed that the data patterns are correlates of consciousness, and not the physical patterns at one particular level.
- This would only work if the levels did not coincide.

Data Pattern or Physical Correlate?
- Experiment 1: Neuron level provides perfect predictions about consciousness.
- Experiment 2: Electromagnetic wave level provides perfect predictions about consciousness.
- Conclusion: consciousness is correlated with a data pattern, not with a pattern in a particular physical substrate.

Data Values
- Measurements extract numbers from the physical world, but the values of these numbers are highly arbitrary.
- For example, distance can be measured in feet, cubits, metres, etc.
- In science different measurement systems are coordinated with each other.
- Algorithms for measuring data patterns need to take this into account.

Causal Powers of Data Patterns
- When we describe our consciousness it seems reasonable to claim that consciousness or the correlates of consciousness caused the report.
- If consciousness is a particular pattern of data, then this data pattern must be capable of causing reports about consciousness.
- This constrains the data patterns that could be correlated with consciousness.
Causal Powers of Data Patterns

Unconscious Data Patterns
- The current information/data algorithms are likely to return a positive result for the unconscious brain.
- This would contradict the observation that we have no consciousness when we are unconscious.
- Data algorithms for the correlates of consciousness should return zero when they are applied to the unconscious brain.

Experimental Issues
- We have very limited access to the brain’s 80 billion neurons.
  - fMRI: Each voxel corresponds to average activity of ~50,000 neurons over a few seconds.
  - EEG: Large scale brain measurements typically through scalp. Good temporal resolution.
  - Optogenetics: Currently ~100,000 neurons in close to real time, but only possible in animals.
- If we could measure the brain’s 80 billion neurons with high spatial and temporal resolution, it would be impossible to analyze this data with our current computer power.

Conclusions
- Information/data correlates of consciousness is an interesting idea with supporters among the scientific community.
- The key claim is that information/data patterns are correlated with consciousness independently of the material base.
- If this could be proved, then it would provide a good starting point for looking for consciousness in artificial systems.
- Has implications for computational accounts of cognition.

Conclusions
- This approach has a number of problems:
  - Subjectivity in the choice of level of analysis.
  - Difficulties with cross-level analysis
  - Difficulty proving that consciousness is correlated with information/data patterns and not patterns at a particular physical level.
  - Very limited access to conscious brain.
- Some of these issues can be explored by simulating the brain at multiple levels (molecules, ion channels, electromagnetic waves, etc.) and exploring how data algorithms could operate across these levels.
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References


More Information

- Slides: www.davidgamez.eu/talks/
- Papers related to this material: www.davidgamez.eu/publications/
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