Integrated Information as a Metric for Group Interaction: Analyzing Human and Computer Groups Using a Technique Developed to Measure Consciousness

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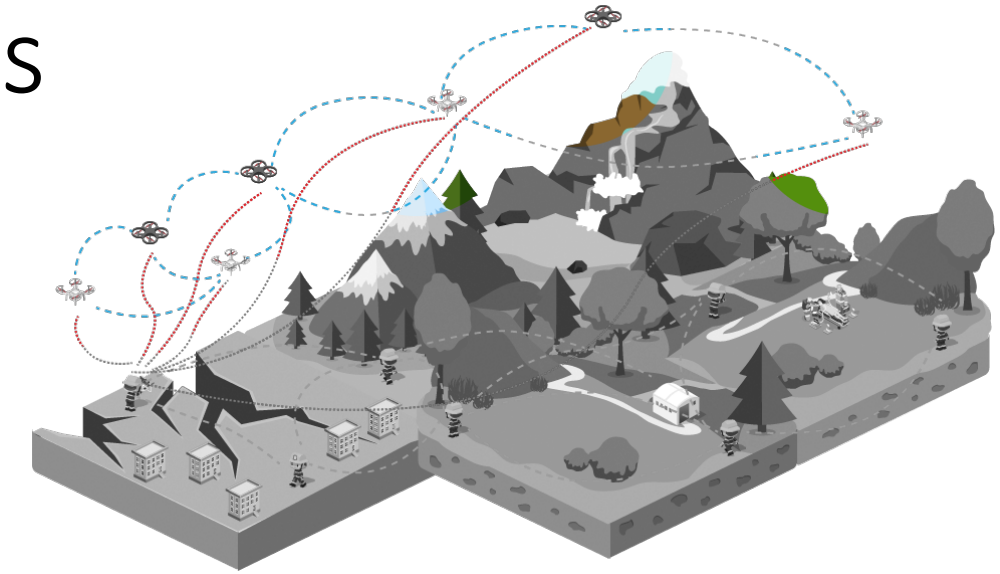
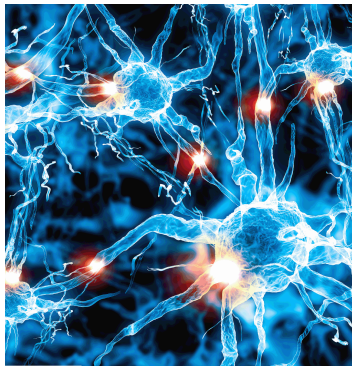
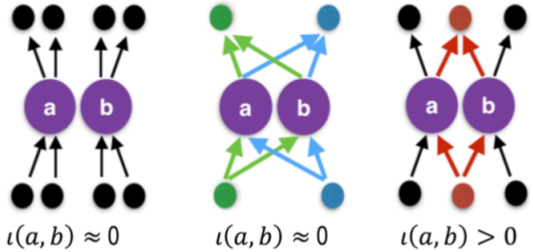
Analyzing group interactions





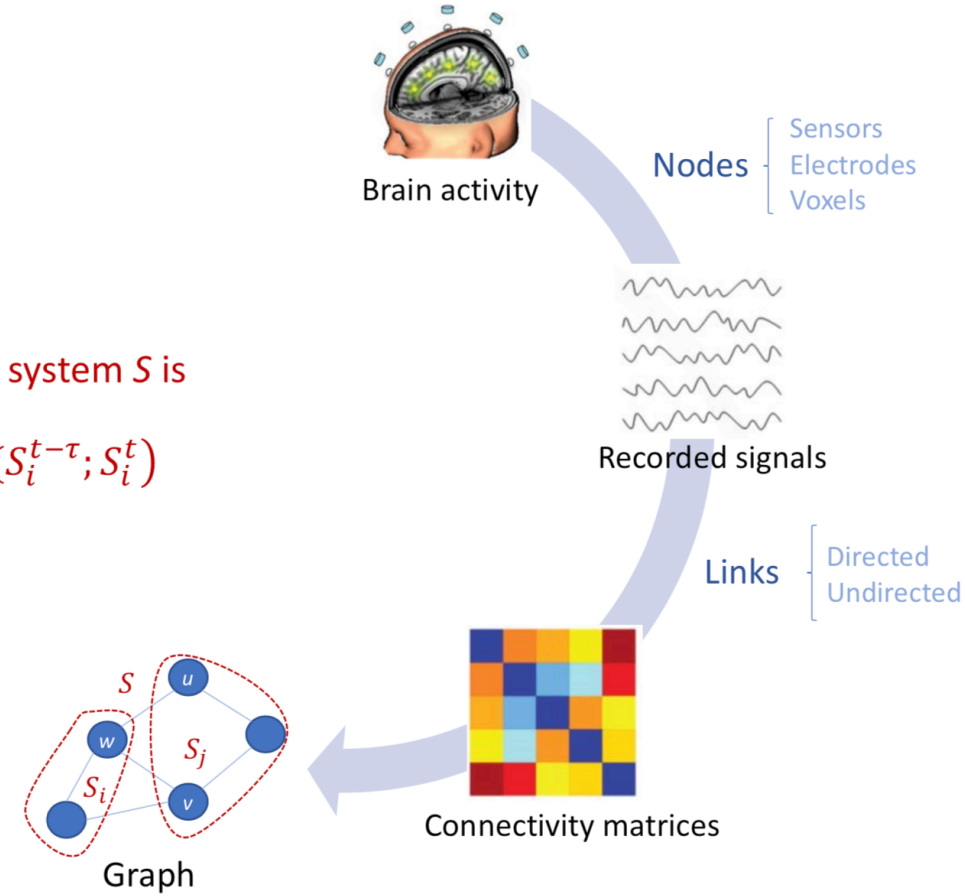
Integrated Information (Φ)

- Amount of information generated by the system as a whole that is more than just the sum of its parts
- Differentiation and Integration



The integrated information in system S is

$$\Phi(S) = I(X^{t-\tau}; X^{t}) - \sum_{i=1}^{n} I(S_i^{t-\tau}; S_i^{t})$$



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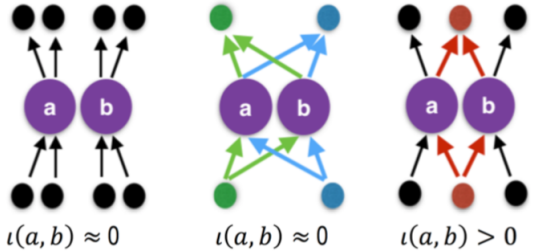

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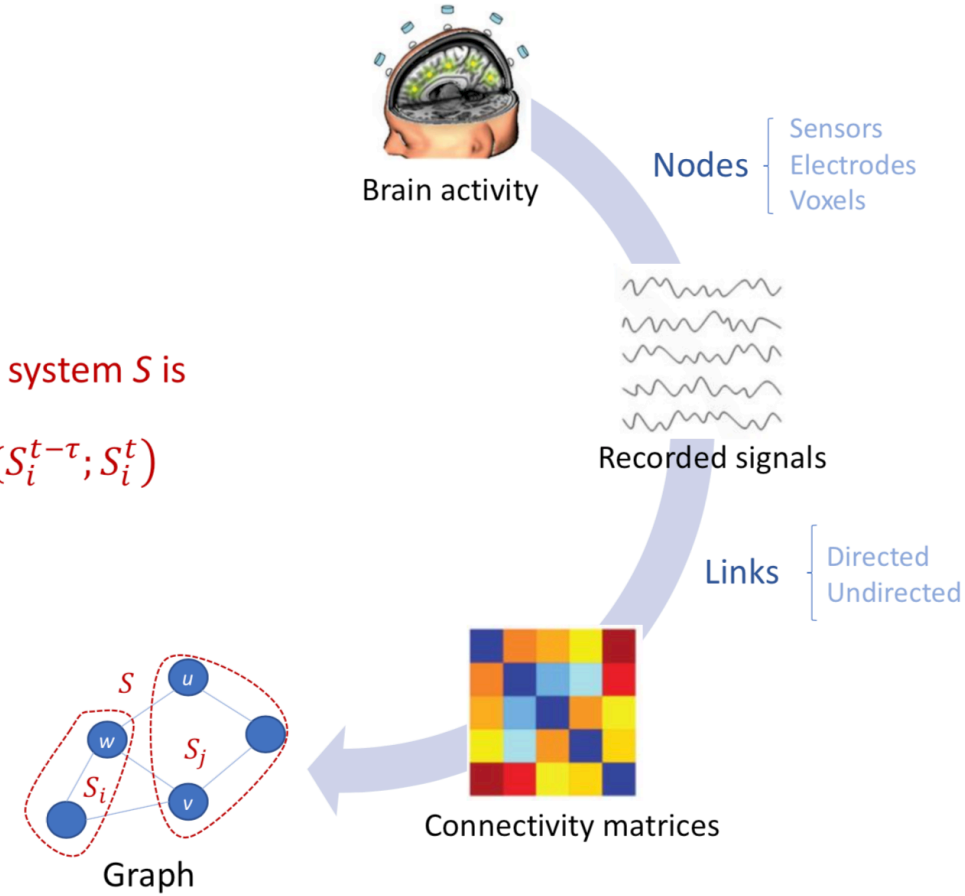

Can we use Φ to analyze group interaction ?

Φ as a measure of group interaction

- Applying Φ to the activity of 3 types of groups that involve people and computers

Results (study 1)

- **4-person work groups** with higher measured Φ perform a wide range of tasks more effectively, as measured by their Collective Intelligence (CI)

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- **4-person work groups** with higher measured Φ perform a wide range of tasks more effectively, as measured by their Collective Intelligence (CI)
- How? Measuring CI by asking 68 groups of 4 people each to perform a range of tasks, from brainstorming and memory tasks to solving visual and word puzzles
  - **States of the groups**: which group member was communicating at which point in time. This yielded a binary state vector for each person (talking or not talking) in each time step
    - F2F: record separate audio files for each person and encode which individuals were talking at each time
    - Online: analyze chat logs to determine which group members sent messages at each time
  - **Time delay**
    - F2F: on the order of a few seconds, the approximate time it takes for a person to hear and respond to what someone else says
    - Online: influence of what is said in one comment on the next comment. The time delay is set to 1 time step, the time from one textual comment to the next one

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- **4-person work groups** with higher measured Φ perform a wide range of tasks more effectively, as measured by their Collective Intelligence (CI)
  - Φ was significantly correlated with the measured CI of the groups in both the F2F condition (*r=0.401*, *p=0.047*) and the online condition (*r=0.352*, *p=0.035*)
  - The correlation was also very significant when Φ and CI scores are normalized and combined both conditions (*r=0.372*, *p=0.003*)

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- How?
  - Analyzing the edit history of the articles from the “vital articles” list in Wikipedia which at the time of retrieval contained 1000 articles
  - The quality of articles is classified by the community into the FA classes (Featured Article), which is the highest class, followed, in order of decreasing quality, by the categories A, GA (Good Article), B and C
  - Examine all edits made in the 30-, 60-, and 90-day periods before an article was promoted to its current quality level, discarding the periods in which only one or two editors were active

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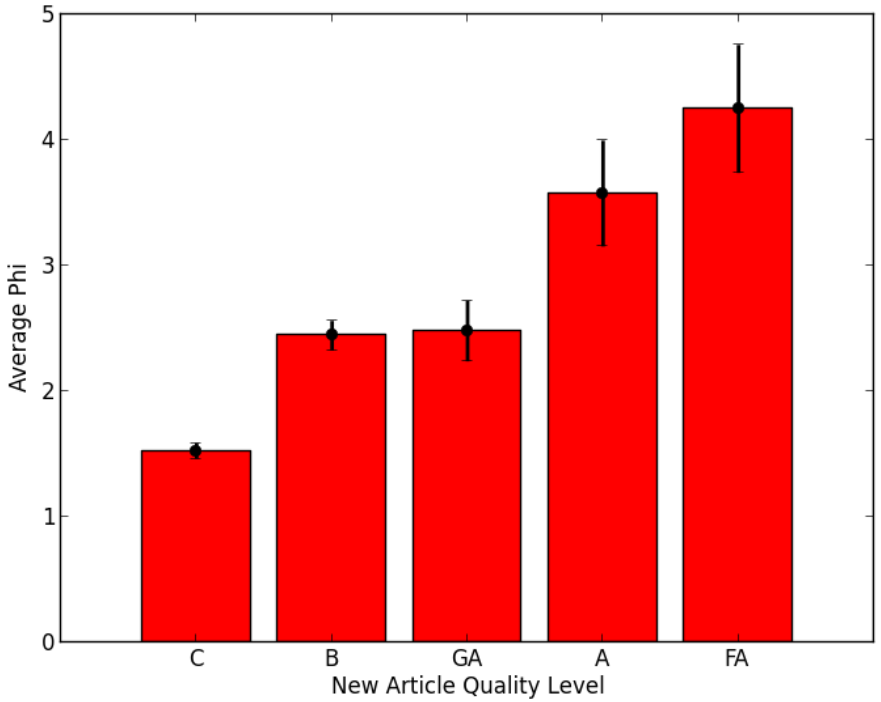

Fig. 2: Average phi for groups editing Wikipedia articles of different quality levels in the 60-day period before the articles were promoted to their current quality level. Quality levels are arranged in order of increasing quality. Error bars show standard error.

Groups of editors who produce higher quality articles have significantly higher Φ

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- How?
  - Applying Φ to a sample of the Internet traffic that passed through one Internet backbone over a 6-year period
  - Sampling 1-minute segments of traffic separated by approximately 6-month intervals over this period
  - Encoding the state of the system in terms of whether a given machine was active (i.e., sent a data packet) at a given time
  - Picked a time delay of 1 time step and chose the time step size that maximized Φ averaged over all years in the dataset (Fig 3)

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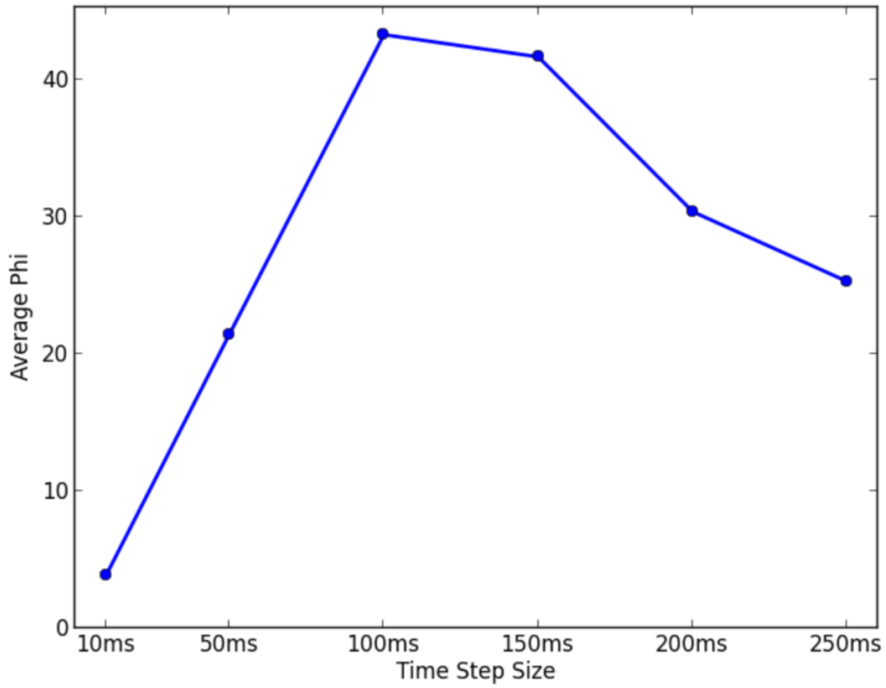

Fig. 3. Average phi for Internet traffic computed with different time step sizes.

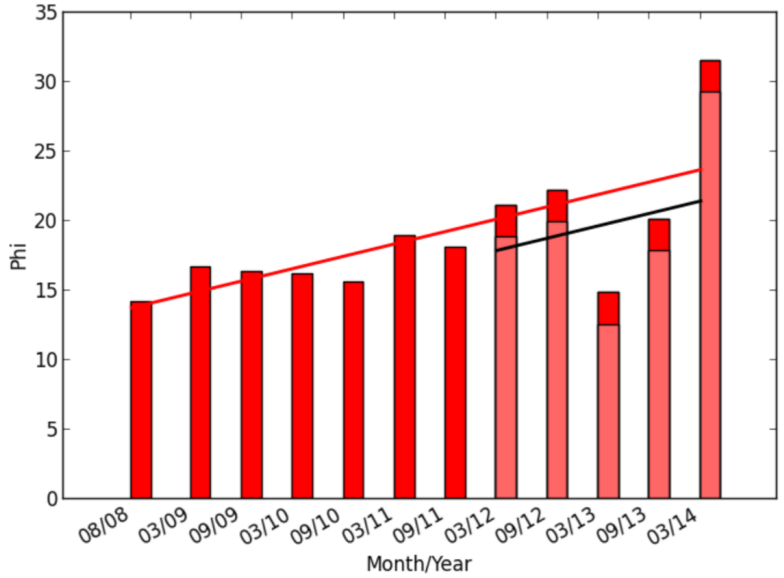

Fig. 4: Average phi computed on Internet traffic data over a span of 6 years (node sampling = random walk, node sample size = 100, time step size = 100 ms. See details in Methods). A change in hardware at the recording site between 2011 and 2012 caused a drop in subsequent recorded traffic **[35]**. The actual traffic in subsequent years is indicated by a horizontal black line and light red bars. The red bars and the red line show values adjusted to compensate for this change (see Methods).

Summary

- Integrated Information (Φ)
  - Can be a useful way of characterizing a certain kind of **interactional complexity** that, at least sometimes, predicts group performance
  - Can be viewed as a potential metric of effective **group collaboration**
  - Since the metric was originally developed as a measure of consciousness, the results also raise intriguing questions about the conditions under which it might be useful to regard groups as having a kind of **consciousness**

Deco, Gustavo, et al. "Rethinking segregation and integration: contributions of whole-brain modelling." Nature Reviews Neuroscience 16.7 (2015): 430.