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# Intracranial Recordings Applied Towards a Better Predictor of Unconscious States

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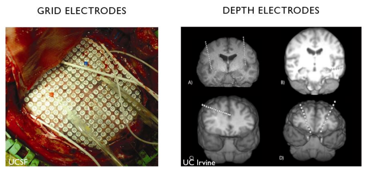
## Introduction

Anesthetics have been used to aid medical procedures for decades; however, despite careful monitoring, many people still experience explicit and sometimes traumatic conscious awareness under anesthesia (Orser, 2008). Current methods of monitoring rely on imperfect correlates of unconsciousness, making it impossible to distinguish between states with perfect accuracy. Newer methods that detect stability of models of cortical signals have recently been used to discriminate between awake and anesthetized states in non-human primates where other methods could not (Solovey, 2015). Open questions remain regarding whether stability analyses will be able to generalize to more anesthetics and oscillations across subcortical structures.

## Methods

While patients were being administered anesthetics, they were asked to respond to simple motor commands, to give a behavioral estimate of conscious awareness. Eight subjects completed this task, four were administered intravenous propofol anesthesia, and two were administered inhaled sevoflurane anesthesia. We examined ECoG data (from both grid and depth electrodes: Fig 1) recorded during this task for stability. Stability is defined as the magnitude of the eigenvalues extracted from the time evolution matrix of first order autoregressive models fit to short, non-overlapping time windows of data, with smaller eigen values corresponding to more stable oscillations.

## Figure 1: Electrode Types

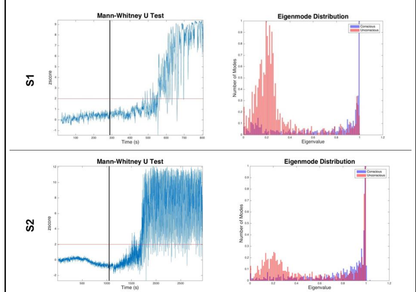



(Left) Grid electrodes, placed on the cortical surface. (Right) Depth electrodes, accessing subcortical structures.

## Preliminary Results

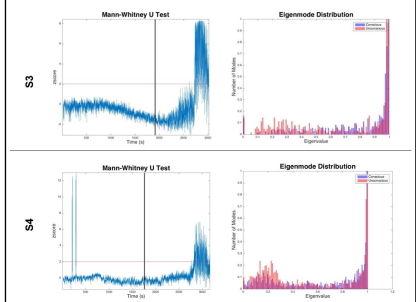
Stability appears to be a successful indicator of consciousness in humans in most cases, despite lower doses and reduced cortical coverage compared to previous work. It is worth noting that more rigorous statistical tests comparing actual distributions to distributions from time-shifted surrogate datasets are needed for a more accurate characterization of significance. Subjects with cortical coverage (S1, S2), and propofol anesthesia showed an apparent increase in the average stability of oscillations after a behavioral loss of consciousness was observed (Fig 2). In addition to the increase in stability, and increase in the variance of the eigenvalue median is also seen. A similar change was observed in subjects S3 and S4 with depth electrodes, although the changes are not as robust (Fig 3). Lastly, subjects S5 and S6 with sevoflurane anesthesia showed a substantial, but transient increase in stability, in contrast to the sustained difference seen under propofol (Fig 4). Analysis of the concentration of sevoflurane in the system would be a helpful complementary analysis.

## Figure 2: Propofol Anesthesia with Grid Electrodes




(Left) Time course of changes in stability. The distribution of eigenvalues at every timepoint compared to a distribution of 20s of consciousness via Mann-Whitney U Test. Black line indicates behavioral loss of consiousness. (Right) Eigenvalue distribution from 20s of conscious data (blue) vs 20s of unconscious data (red). Smaller eigenvalues and larger z-scores are associated with stability

## Figure 3: Propofol Anesthesia with Depth Electrodes




Same as above. Note that a change in stability is still apparent, but is less pronounced.

## References

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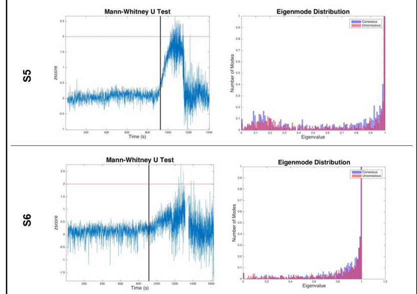
Orser, BA, Mazer, CD, & Baker, AJ (2008). Awareness during anesthesia. CMAJ?: Canadian Medical Association Journal = Journal de l'Association Medicale Canadienne, 178(2), 185–8.

Solovey, G, Alonso, LM, Yanagawa, T, Fujii, N, Magnasco, MO, Cecchi, GA, & Proekt, A. (2015). Loss of Consciousness Is Associated with Stabilization of Cortical Activity. Journal of Neuroscience, 35(30), 10866–10877.

## Figure 4: Sevoflurane




Same as above. Note the transient change in stability.

## Conclusions and Future Directions

Stability analyses show potential to serve as a more accurate, if not universal indicator of consciousness. Changes in stability are present across subjects with different types of coverage. However, the dynamics of these changes vary. More work could be done exploring stability associated with other anesthetics, as well as other states of unconsciousness, such as sleep. Additionally, analysis of spatial trajectory could give insights into which brain regions drive this phenomenon.