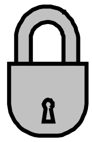
Decisions Have Consequences



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Precis of talk given at the recent Banbury Center workshop on decision making in the brain.

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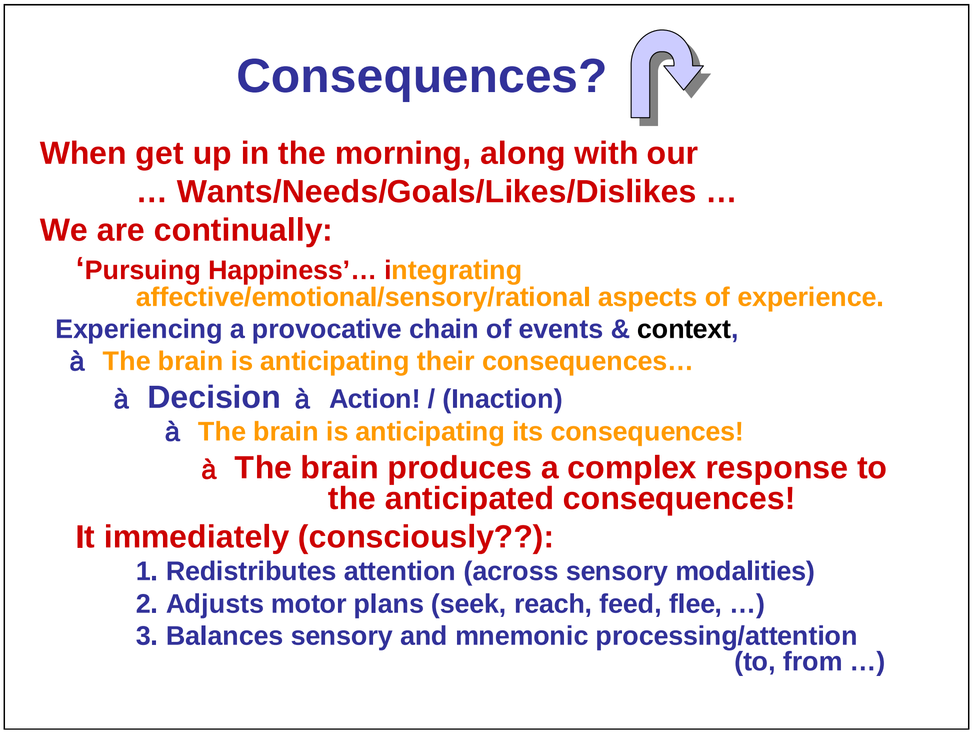
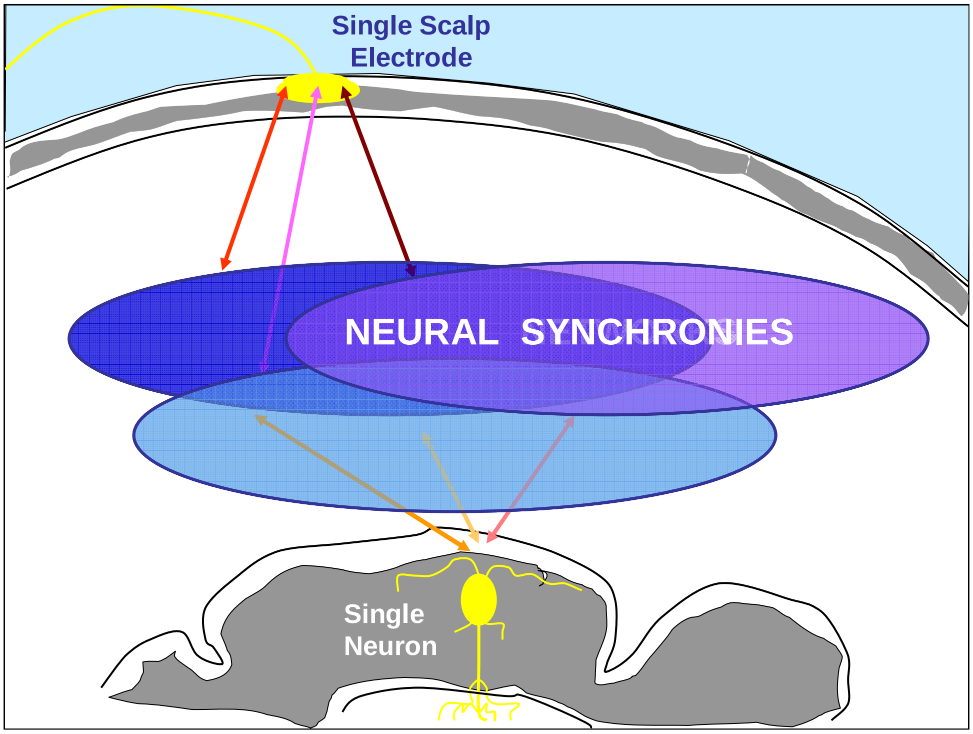


This slide gives an overview of the concepts. Points 1-3 require coordinated processing in several/many parts of the brain and cortex. The end result must be coherent behavior, optimized through evolution & learning…

It is here that coordinated cortical field dynamics, recordable on the scalp as EEG dynamics, appear to play an active role (or roles)…



‘The single scalp electrode (pair) is as far away from ‘the brain’ as the single neuron!’

How/Why?

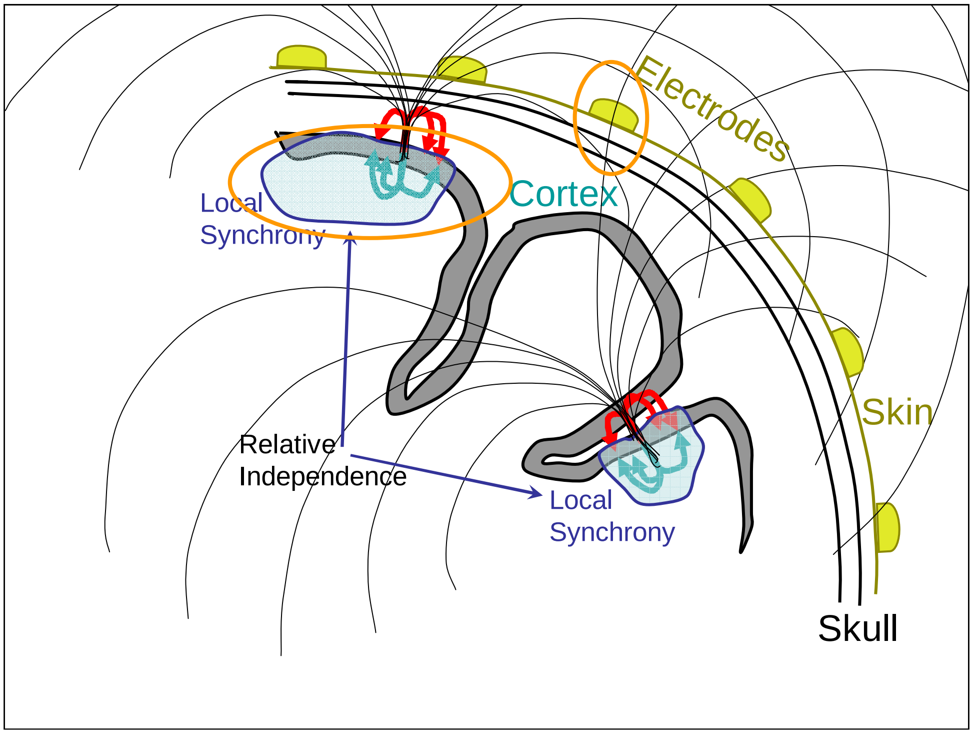
1. Neurons react (and, in particular, spiking neurons spike) to synchronous inputs to their dendritic arbors…

2. Scalp electrodes pick up synchronous activity across discrete areas of cortex…

Brain network dynamics (not actually in CSF as above!) produce both phenomena!

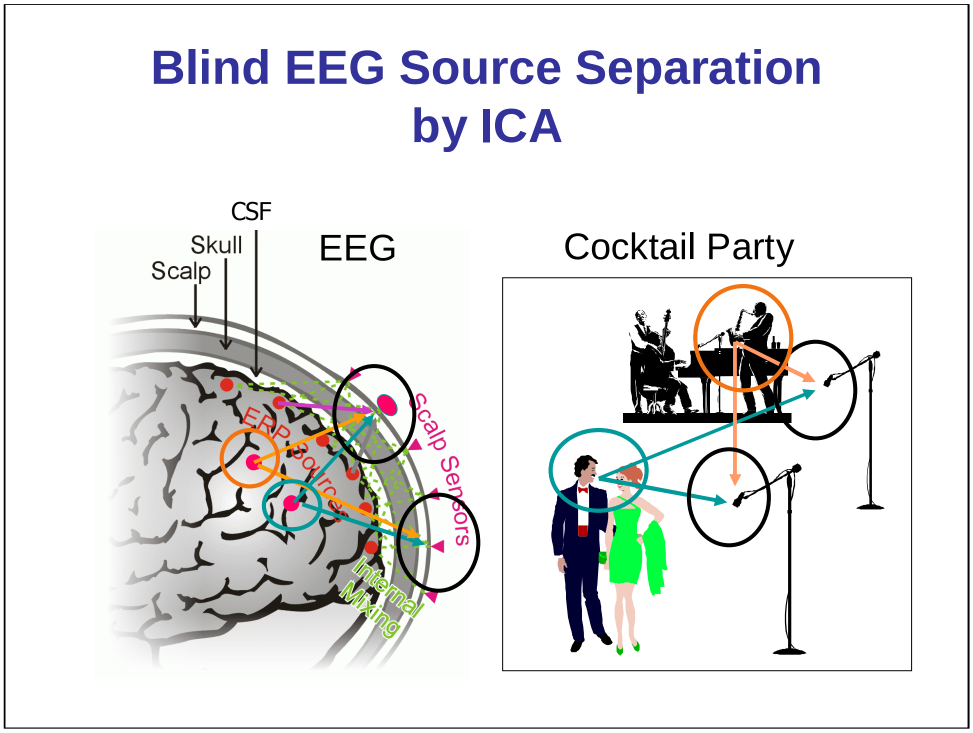
EEG signals are produced by emergent macrodynamics in cortex – conceptually akin to this hurricane ‘emerging’ on Florida!

Walter Freeman, who for decades studied cortical macrodynamics using a 3-mm grid placed on the cortex of animals, likens EEG patterns to spreading patterns on a pond as here during a light rain… (Note: the propagation of the field potential waves in cortex is much faster, relative to the extent of the synchronized area, than in water! At frequencies below 40 Hz, small (few-cm) ‘phase cones’ would have almost equal phase across them – i.e. would act almost as patched of synchronous activity, concordent with our observations of EEG using (spatially static) ICA filtering.



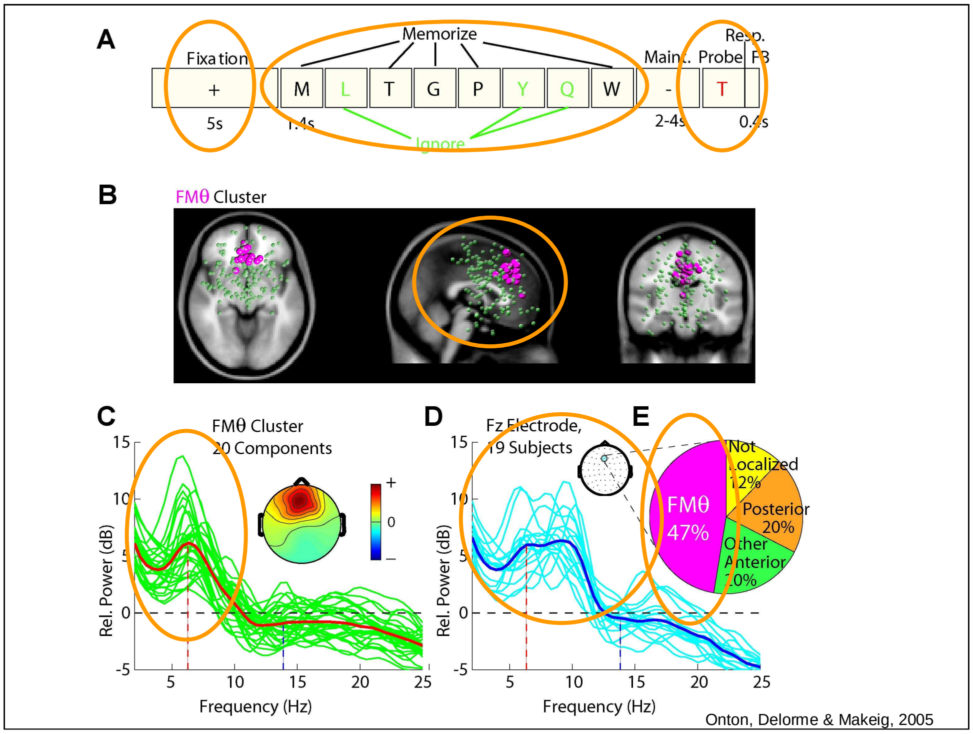
Scalp electrodes record weighted sums (i.e., linear mixtures) of far-field potentials arising in multiple synchronized cortical domains. The dipolar field patterns from such areas are also distorted when they pass through tissue-type boundaries, particularly CSF/skull!

(This is not shown in the cartoon above – Also, this person must be swimming in salt water for the field patterns to extend outside the head as above!)

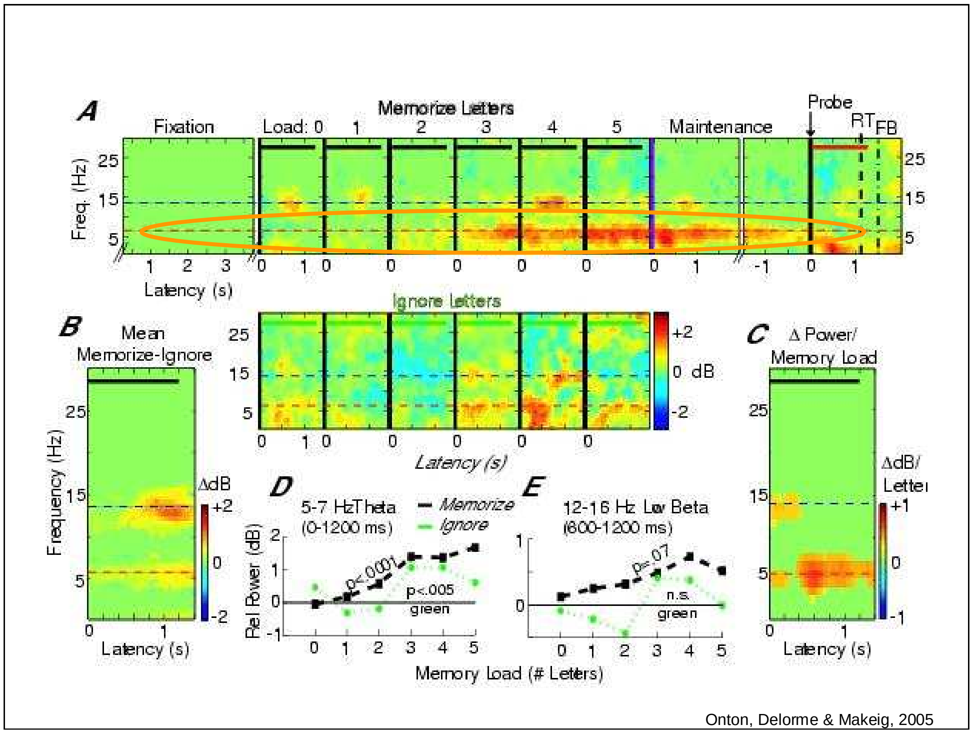


Independent Component Analysis (ICA) (right) can be used to separate N sound sources summed in recordings at N microphones, without relying on a detailed phonological model of the sounds characteristics of each source – this is so-called “blind separation.” ICA uses the presumption that the waveforms of the individual sound sources are independent over time.

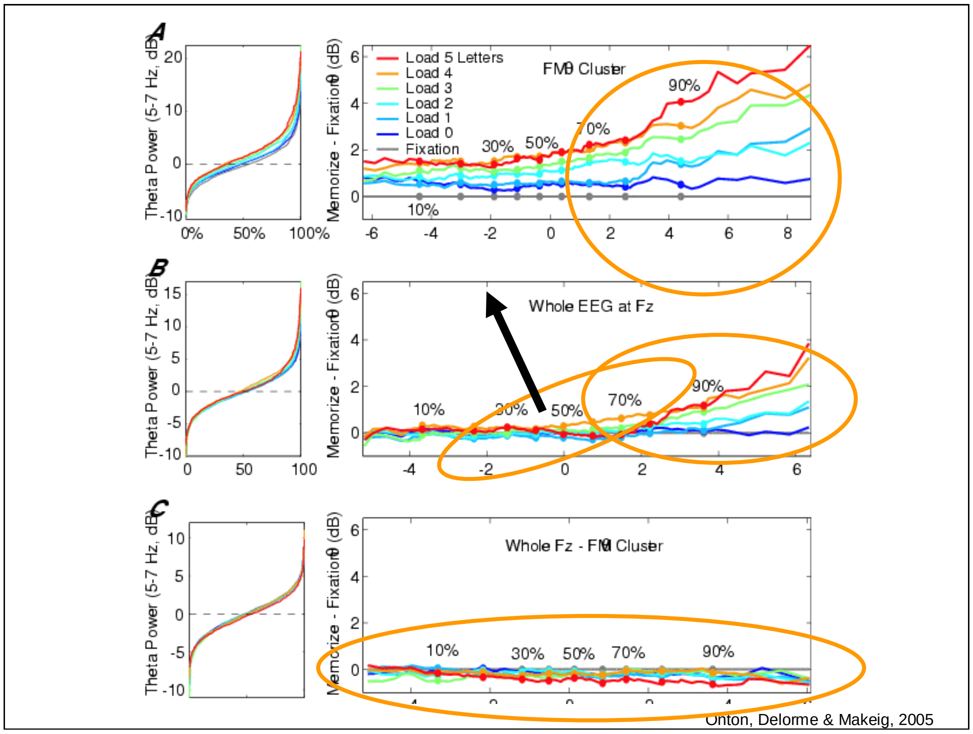
Applied to EEG data (left), ICA assumes that the EEG is predominantly composed of a number of domains of synchronous neural (or neuroglial) activity, each of which must, by simple biophysics, project to most of the recording scalp electrodes. If synchronous activity within these domains are predominantly independent of each other, ICA can separate the summed signals from these domains into records of their separation activities, given that the number of such domains making large contributions to the recorded signals are smaller than the number of recording sites.



In this article, in press in NeuroImage, Julie Onton and Scott Makeig study the dynamics of a cluster of source (pink above) located in/near dorsal anterior cingulate cort4x (ACC) that produced the strongest theta-band (here 5-6 Hz) EEG during a working letter memory task. C shows the component spectra and mean scalp projection. D. Shows the spectrum of the raw EEG signal recorded from the overlaying electrode (here referred to right mastoid) – This is much less specifid since it mixes activity from other cortical areas. E. The ACC components contribute (only) half the theta power to this scalp electrode.



A. As subjects added letters to their memory/rehearsal string, mean theta band EEG power from the ACC component processes.grew (slightly)… replicating a well-known result.



But considering trial-to-trial variability in theta power (<= 30 dB!, left) – the rise in the mean (~2 dB) is tiny and near inconsequential…

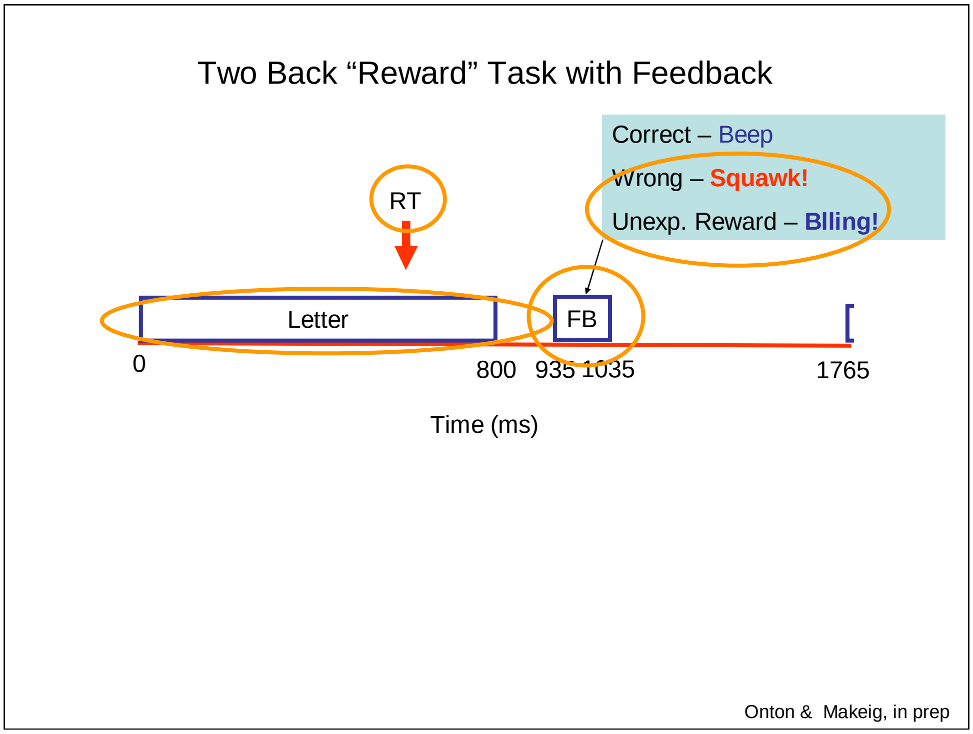
This figure shows that the distirbution of theta power across trials becomes skewed during higher memory loads (A, right) towards 10-15% of epoch with quite high theta power.

B shows that the same effect is observable (weakly) at the overlaying Fz electrode. C shows that removing the ACC component cluster from the activity recorded at Fz also removes the entire memory-load related effect!

What is the meaning of the 30-dB trial-to-trial variability, and the increased intermittency during memory load in the ACC cluster?

Is this variability just “noise” added to the small mean-increase “signal” – clearly not, since the brain has no time to average over many trials to make use of its short-term memory capabilities.

We hypothesize that the variability is optimized to deal with **differing cognitive demands** of each trial!



We are now studying data from a 'letter twoback task with feedback'" to test this hypothesis…

Decisions have consequences

à Top-down control of cortical dynamics

à Changes in local field spectra

à Changes in scalp EEG dynamics

For further information and papers

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For more information, please see the extensive web pages of the Swartz Center and under my personal home page, http://sccn.ucsd.edu/~scott

Scott Makeig

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