

# **The Conscious-‘pop’: A Nonconscious Processing Framework for Problem Solving**

Cold Spring Harbor Laboratory

*New Frontiers in Studies of the Unconscious*

4/09/07

Jerry Swartz

The Swartz Foundation



The mission of the Swartz Foundation is to explore the application of physics, mathematics and computer engineering principles to neuroscience, as a path to better understanding the brain/mind relationship.



“Consciousness may get all the focus, but consciousness is a small part of what the brain does, and it’s a slave to everything that works beneath it.”

*--Mastery of Emotions*

**Joseph E. LeDoux**

Scientific American Mind, 02/06

# Adaptive Unconscious Processing

“This sophisticated [mental] system operates under the radar of consciousness ... We need to *process so much information* to survive that some of it has to occur unconsciously...”

“A [good] working definition [of the unconscious] is *mental processes that are inaccessible to consciousness but that influence judgments, feelings, or behavior.*”

--*Strangers to Ourselves*

**Timothy D. Wilson**

University of Virginia

# Nonconscious Processing (NCP)

“...conscious thought refers to ...  
deliberation while attention is directed at  
the problem at hand, unconscious thought  
can be defined as...deliberation in the  
absence of attention directed at the  
problem...”

-- *On Making the Right Choice: The Deliberation-Without-Attention Effect*  
**Ap Dijksterhuis, Maarten W. Bos, Loran F. Nordgren, Rick B. van Baaren**  
Science Magazine, 2/06

# Overview

- We focus on problem solving & 'Aha!' reaction
- Conscious-pop ('C-pop') viewed as a selectively triggered spontaneous event
- Mathematical Modeling
- Mix of conscious & nonconscious processing ( $d_c$ )
- EEG/ICA Phrase Completion Experiment

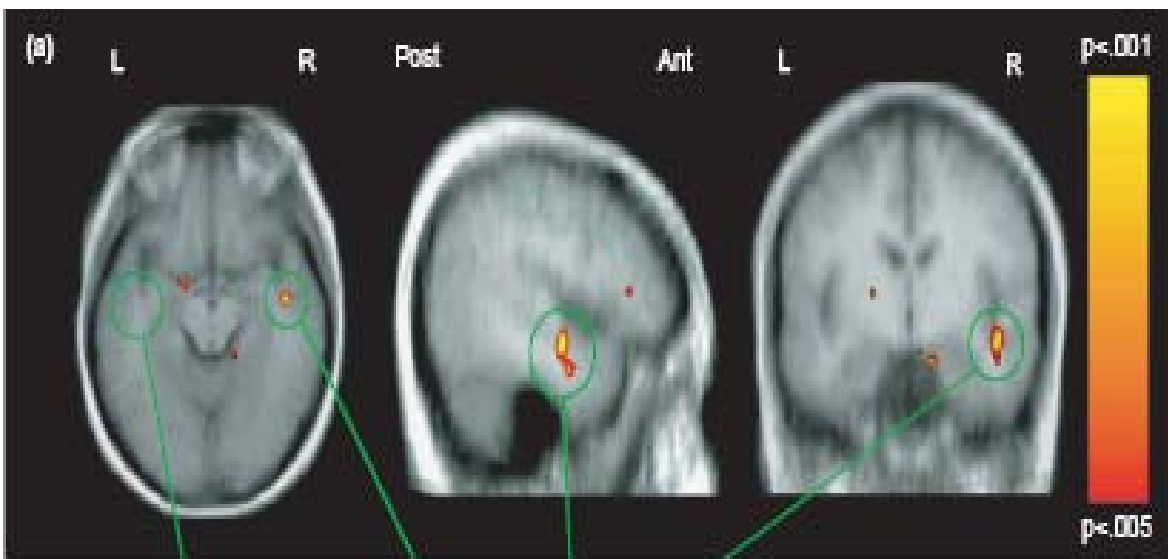
# ‘Aha!’

“...the clearest defining characteristic of insight problem solving is the subjective “Aha!” or “Eureka!” experience that follows insight solutions...”

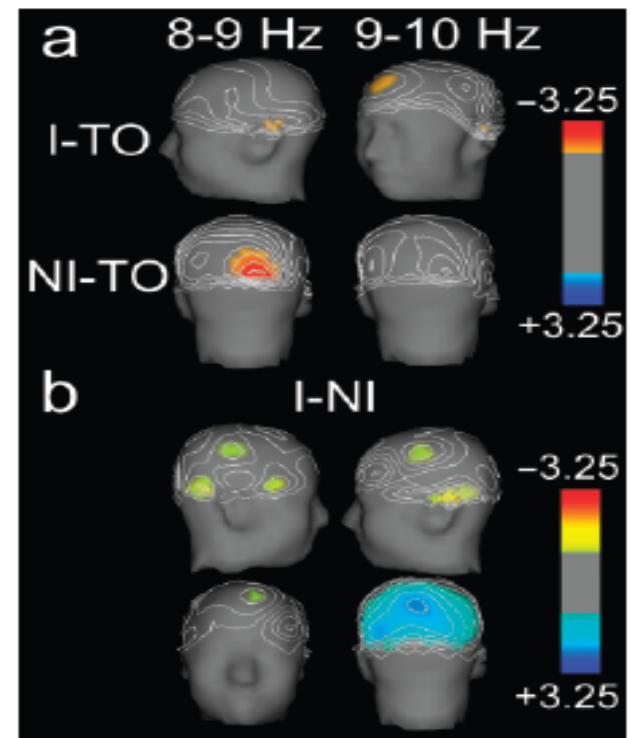
*-- Neural Activity When People Solve Verbal Problems with Insight*

**Mark Jung-Beeman, Edward M. Bowden, Jason Haberman, Jennifer L. Frymiare,  
Stella Arambel-Liu, Richard Greenblatt, Paul J. Reber, John Kounios**

PLoS Biology, 4/04



--*New Approaches to Demystifying Insight*  
**Edward M. Bowden, Mark Jung-Beeman,**  
**Jessica Fleck and John Kounios**  
 Trends in Cognitive Sciences, 7/05



--*The Prepared Mind*  
**John Kounios, Jennifer L. Frymiare, Edward M. Bowden, Jessica I. Fleck,**  
**Karuna Subramaniam, Todd B. Parrish, and Mark Jung-Beeman**  
 Psychological Science, 2006



# Random **E**pisodic **S**ilent **T**hought

“...it may allow us to better understand a variety of spontaneous thought phenomena, such as the rare but characteristic “leaps of thought”, leading to an insight into the solution of a problem...”

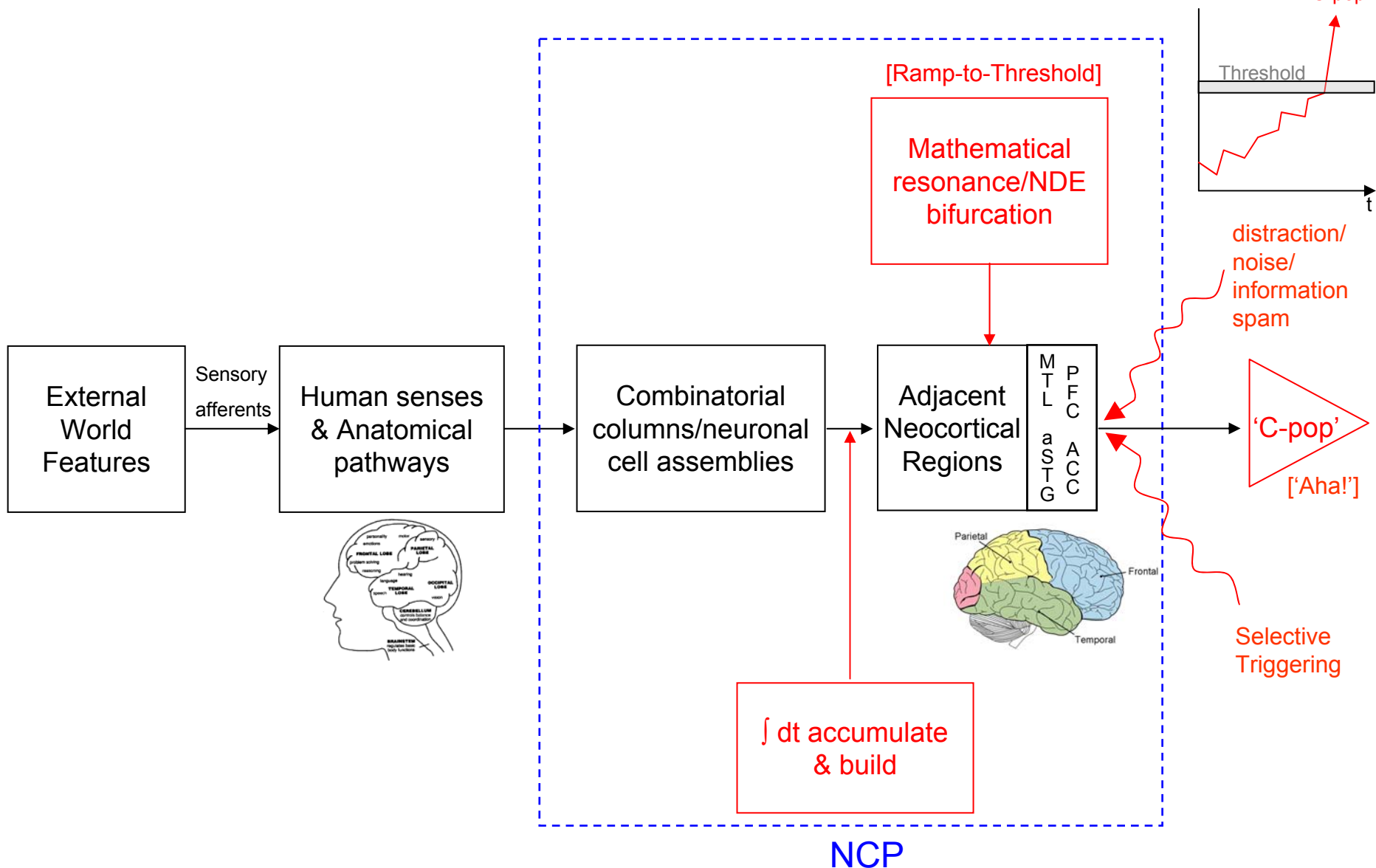
“...behavioural and neuroimaging evidence indicate that spontaneous, task-unrelated cognitive processes share common cognitive and neural mechanisms with purposeful, task-related thought processes.”

*-- Neural Basis of Spontaneous Thought Processes*

**Kalina Christoff, Justin M. Ream, and John D. E. Gabrieli**

Cortex, 04

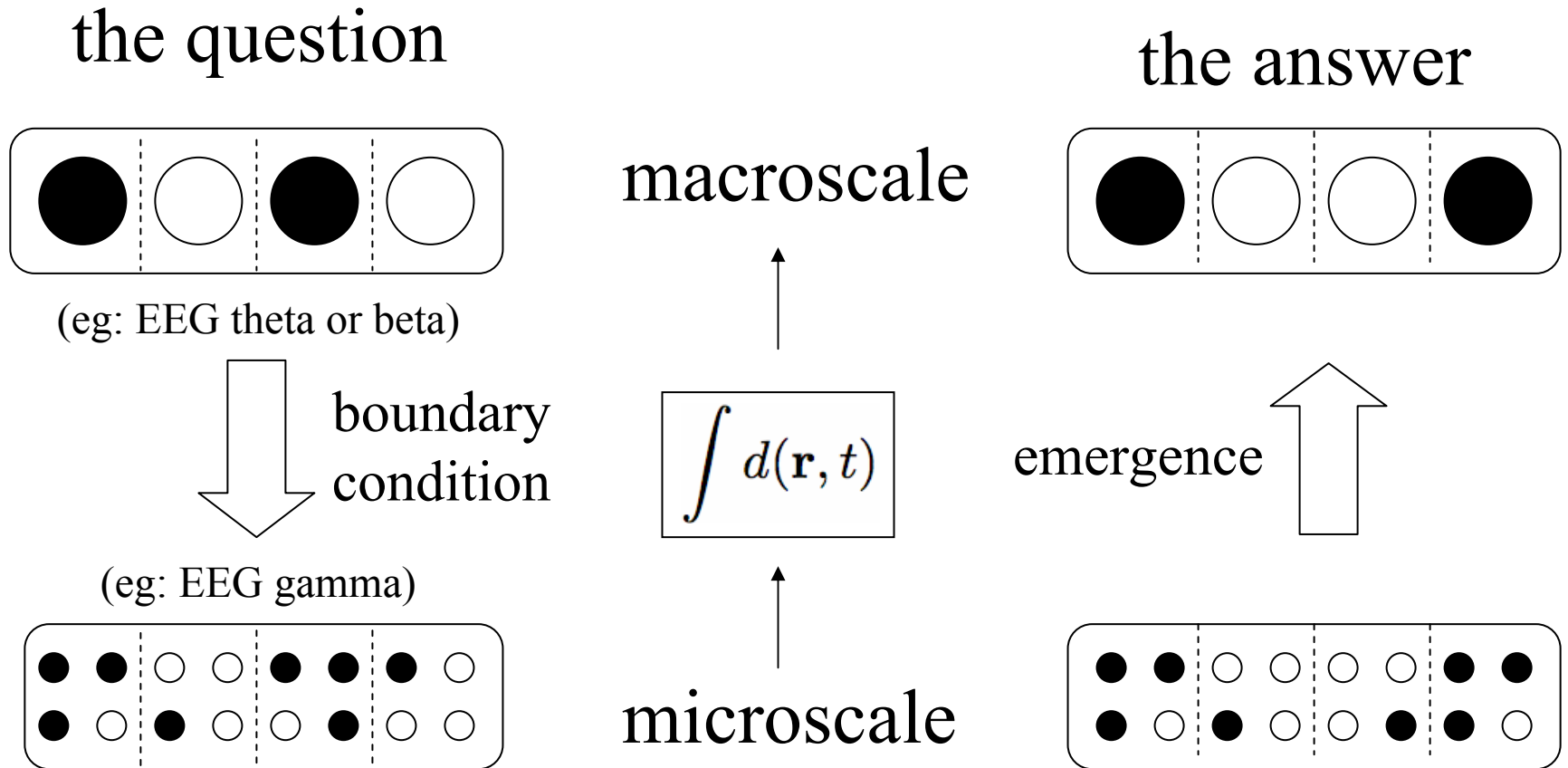
# Generalized NCP/ 'C-pop' Framework



*'Pathways & Math(ways)' Block Diagram*

# Cross-level Conscious Emergence

## *Problem Solving Q&A*



*Temporal Dynamics*

# Consciousness – “An All or None Bifurcation” (?)

“...consciousness is associated with the interconnection of multiple areas processing a stimulus ... If the primary activation evoked by a stimulus exceeds this threshold, reverberation takes place and stimulus information gains access...”

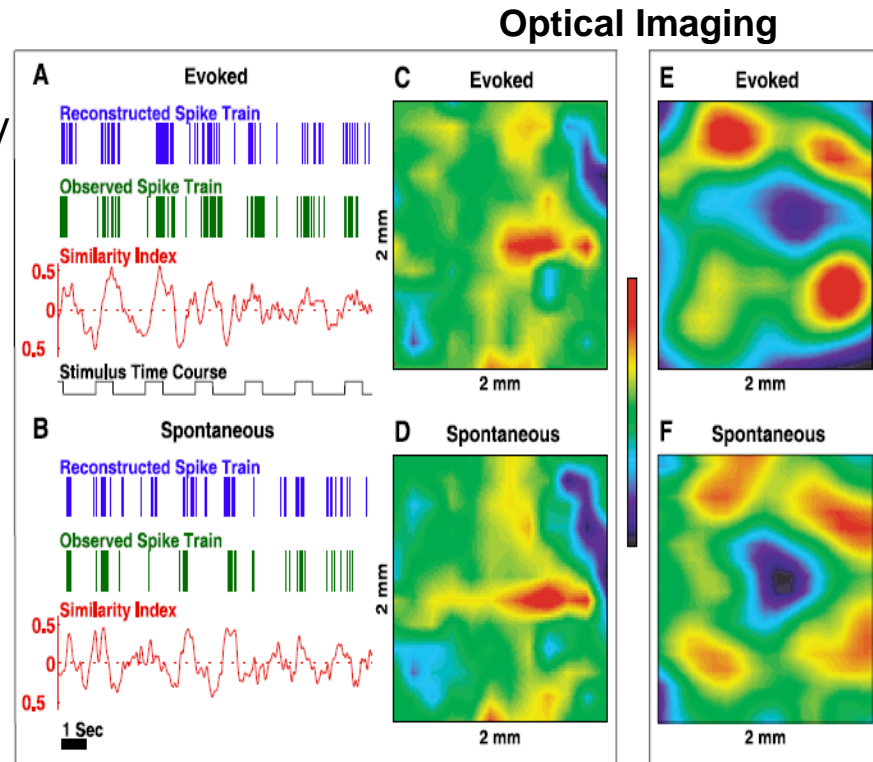
“...Below this threshold, stimulus information remains unavailable to these processes... predict[ing] an all-or-nothing transition between conscious and unconscious perception...”

“... many non-linear dynamical systems with self-amplification are characterized by the presence of discontinuous transitions in internal state...”

*--Is Consciousness a Gradual Phenomenon?  
Evidence for an All-or-None Bifurcation During the Attentional Blink*  
**Claire Sergent and Stanislas Dehaene**  
American Psychological Society, 2004

# Spikes and Population Go Together

•A plausible conclusion is that organized activity can occur w/o attention or awareness, and may be a generator of task-specific or problem-solving circuit activity. The implication is that the brain can self-stimulate to accomplish goals independent of awareness.



•The same (micro) spike-to-(macro) LFP relation occurs in evoked and spontaneous activity.

•There are patterns of spontaneous brain activity, relevant to sensory stimuli that occur even in the absence of the stimulus. Such patterns can occur over spatial scales, larger than a hypercolumn.

*--Linking Spontaneous Activity of Single Cortical Neurons  
and the Underlying Functional Architecture*

**Misha Tsodyks, T. Kenet, A. Grinvald, and A. Arieli**

Science, 1999

# Mathematical Modeling

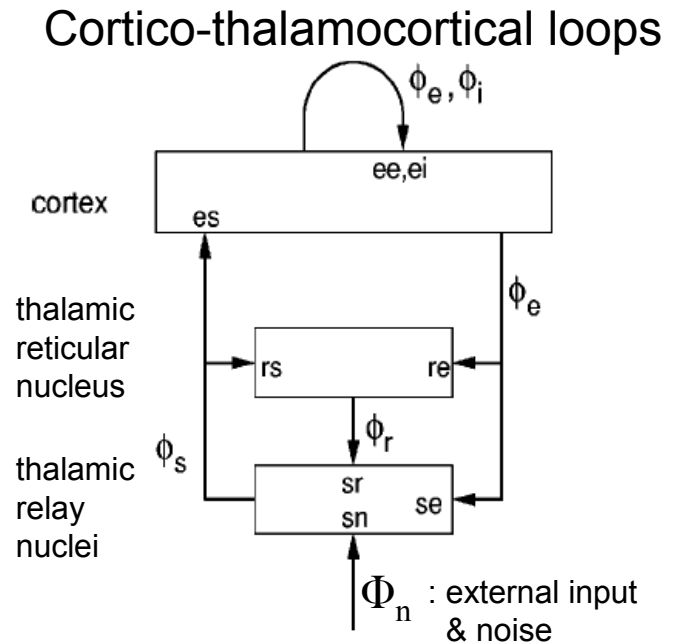
P.A. Robinson et al.'s  
"Multiscale Brain Modeling"  
(Royal B, 2005)

- ODE Linear Approximation

$$\frac{d^2 \mathbf{V}_a}{dt^2} + (\alpha + \beta) \frac{d\mathbf{V}_a}{dt} + \alpha\beta \mathbf{V}_a = \alpha\beta \sum_a N_{ab} s_{ab} \phi_a(\mathbf{r}, t - \tau_{ab})$$

- Nonlinear Differential Equation (DDE) Generalization – State Vector Formulation

$$\mathbf{Y}'(\mathbf{r}, t) - \mathbf{f}(\mathbf{r}, t, \mathbf{Y}(\mathbf{r}, t), \mathbf{Y}(\mathbf{r}, t - \tau)) = \mathbf{X}(\mathbf{r}, t, \Phi_n, \phi)$$



# Unconscious Thought Theory (UTT)

“UTT, can be said to contain three routes: an effortless route that involves no thought at all, an unconscious route that takes time but is relatively effortless, and a conscious route that is effortful.”

“UTT deviates from the general “effort is good” idea in that it does not predict conscious efforts will generally lead to better outcomes than unconscious efforts...”

--*A Theory of Unconscious Thought*  
**Ap Dijksterhuis and Loran F. Nordgren**  
University of Amsterdam, '06

“...most of these [Aha!] insights are rather minor events... However, there are many anecdotes...about insights involved in the solution of far more complex and important problems.”

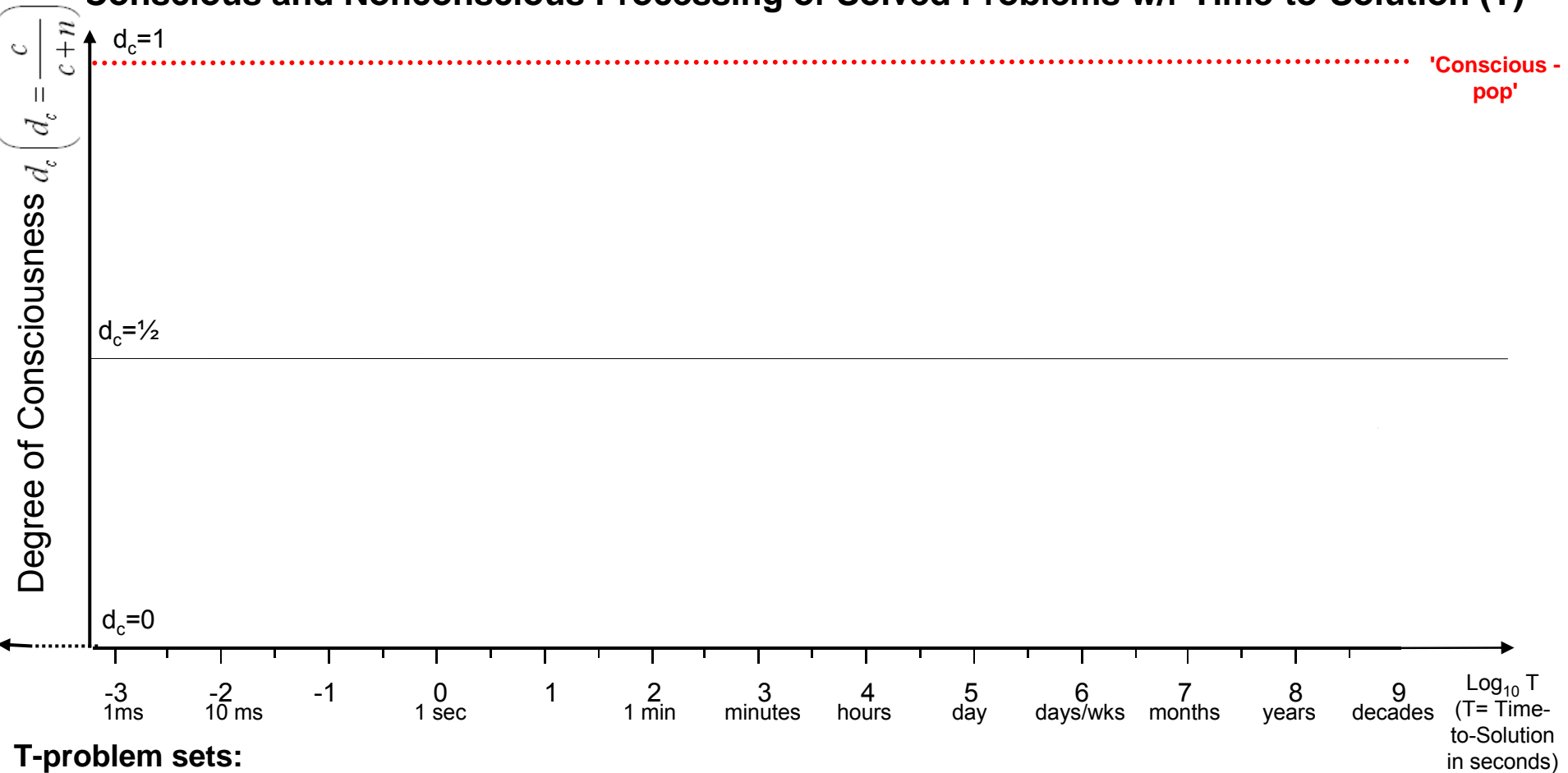
-- *New Approaches to Demystifying Insight*

**Edward M. Bowden, Mark Jung-Beeman, Jessica Fleck and John Kounios**

Trends in Cognitive Sciences, 7/05

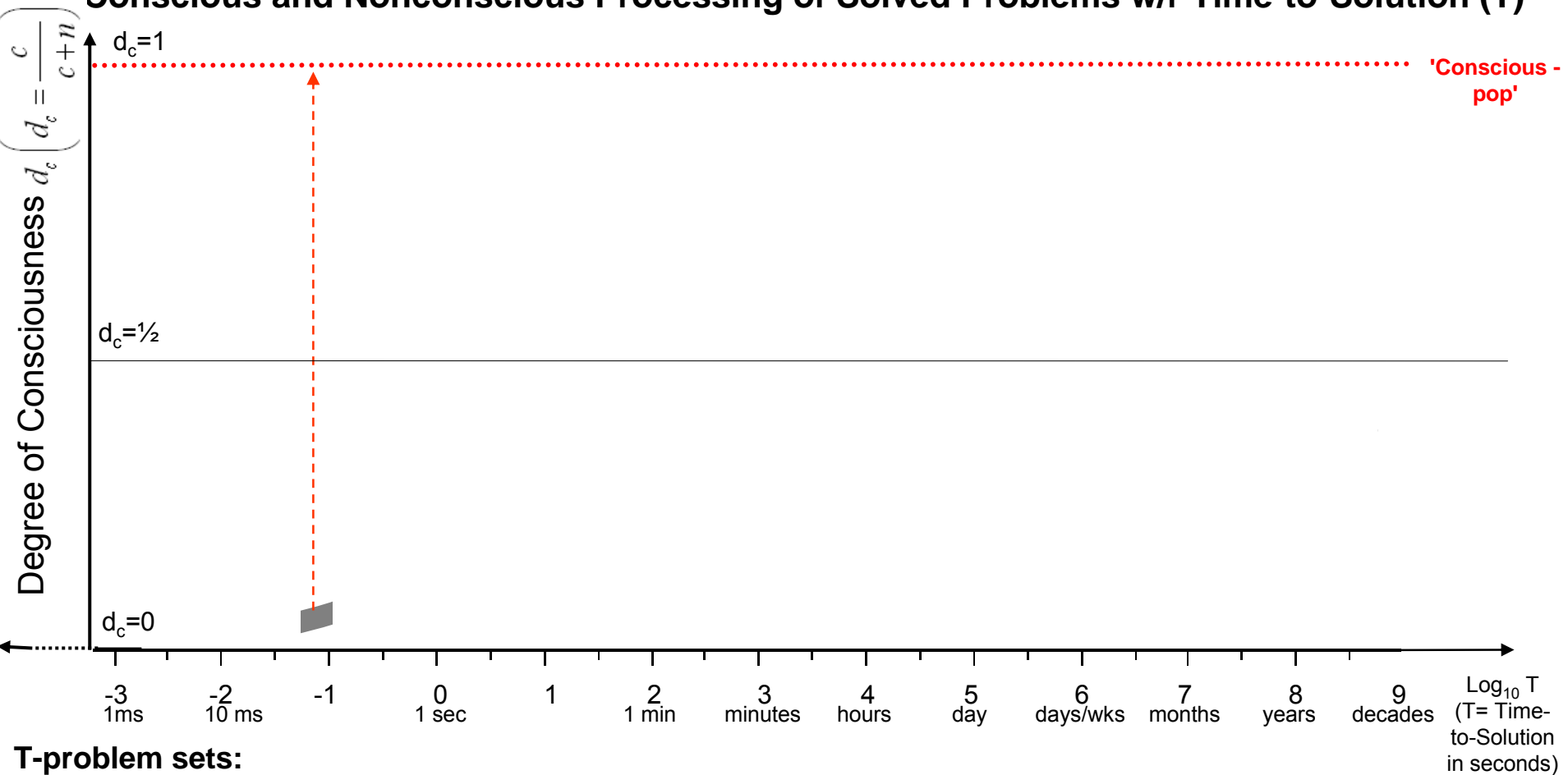


# Conscious and Nonconscious Processing of Solved Problems w/r Time-to-Solution (T)

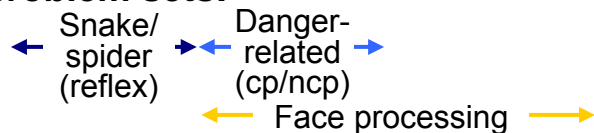


Note:  $(1 - d_c)$  = the 'strength' of a problem solving 'C-pop'/'Aha!'

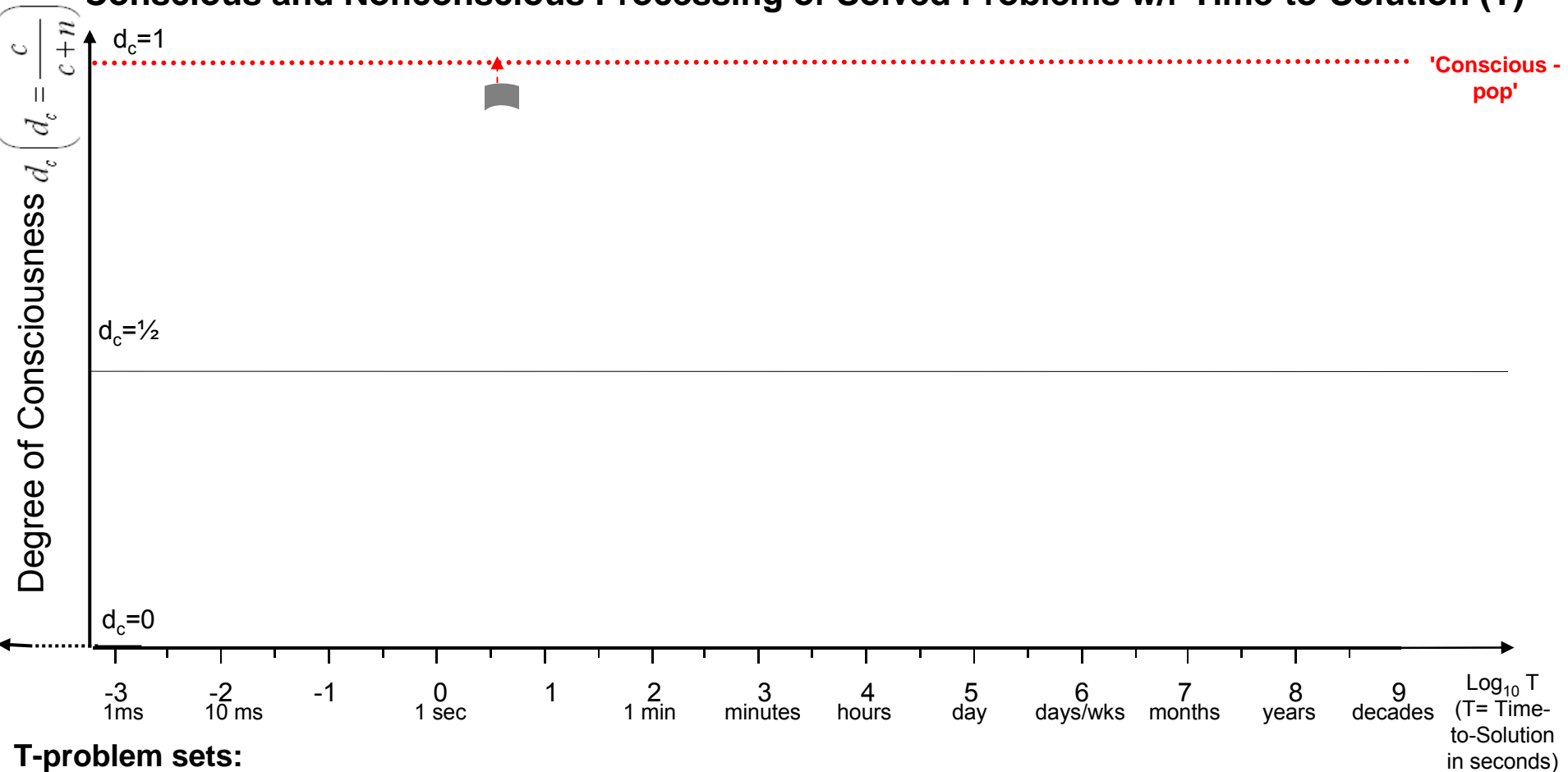
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## T-problem sets:



# Conscious and Nonconscious Processing of Solved Problems w/r Time-to-Solution (T)



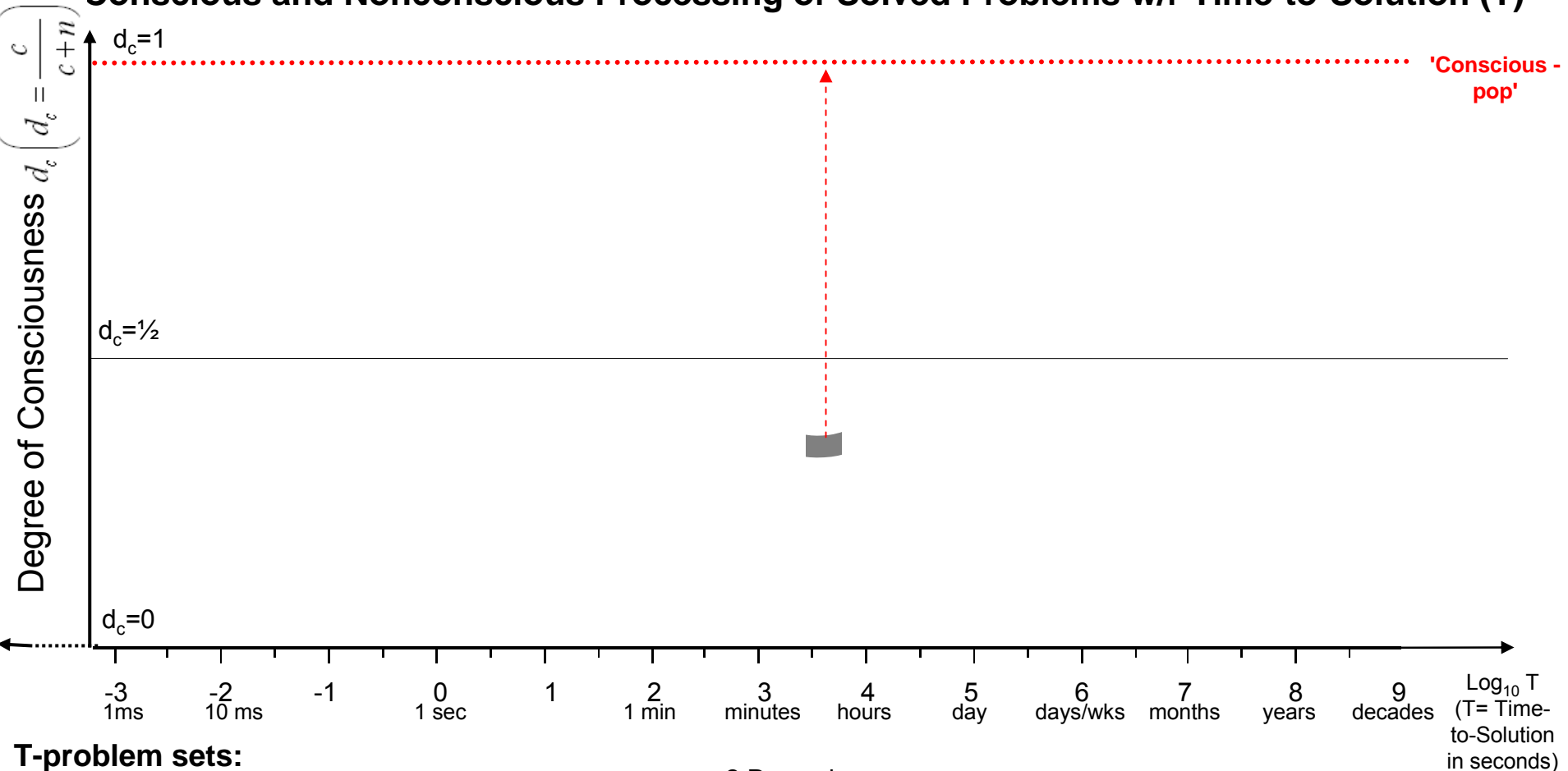
T-problem sets:

"1+1=2"  
(simple arithmetic)

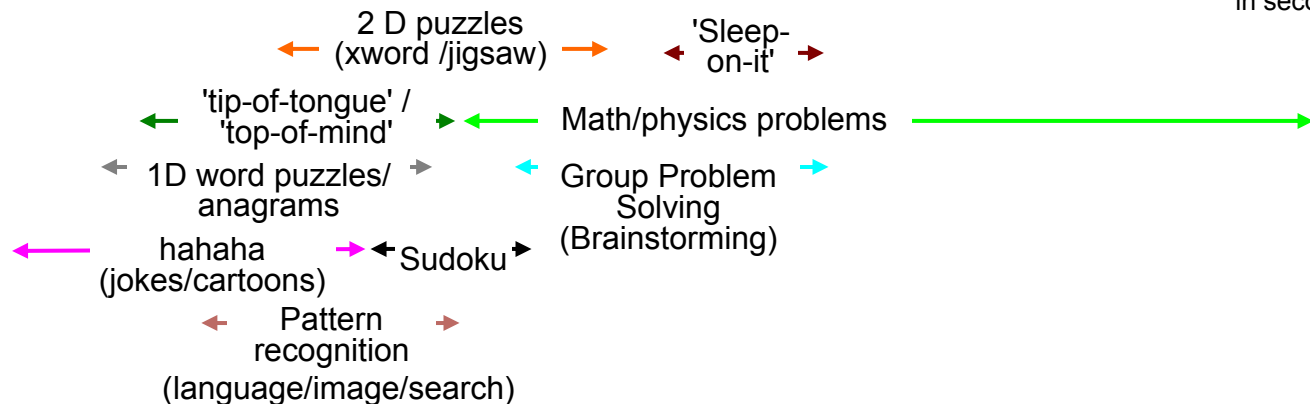
Face processing

hahaha  
(jokes/cartoons)

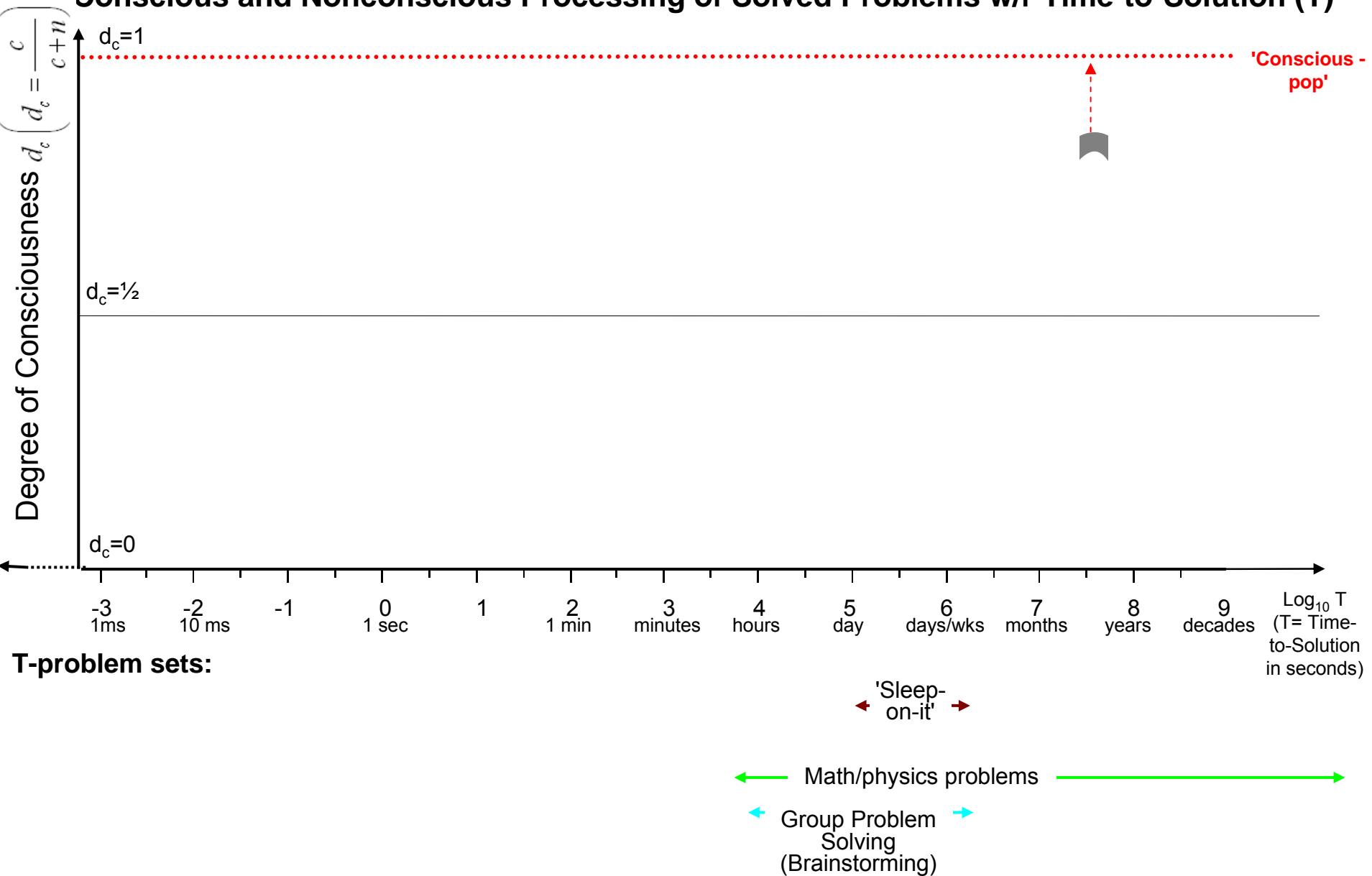
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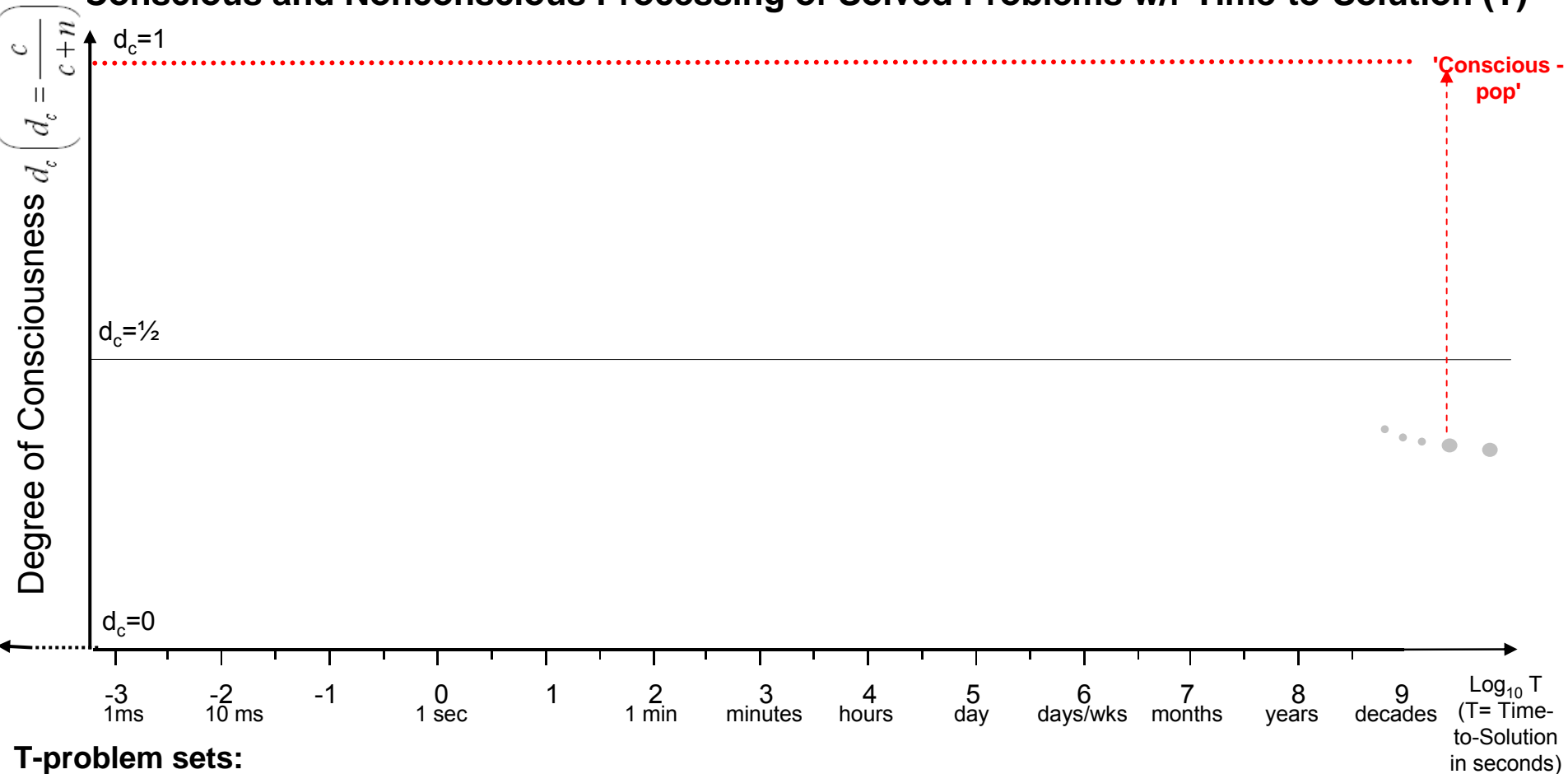
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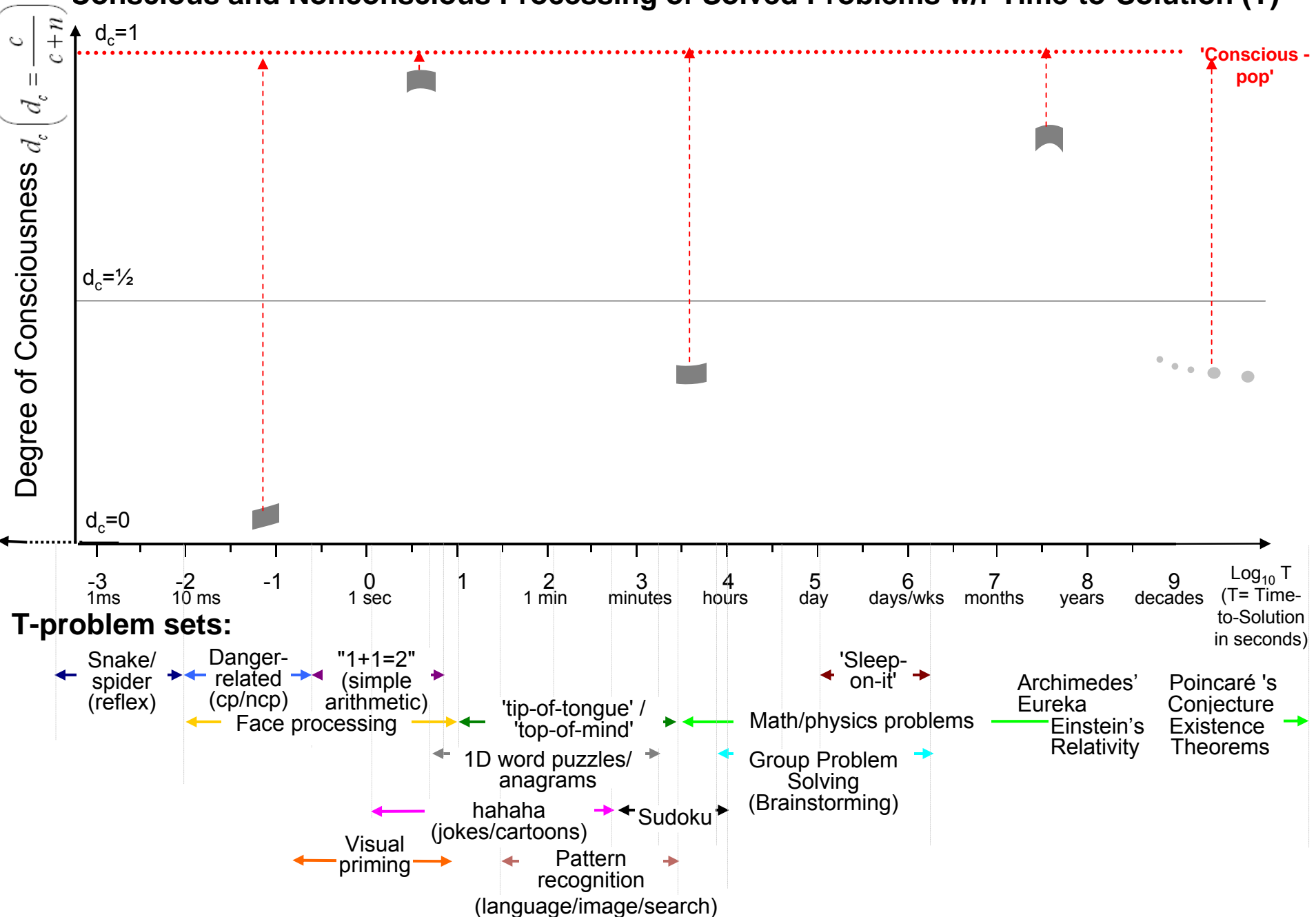


T-problem sets:

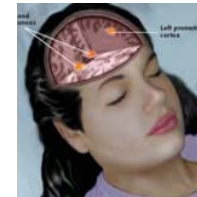
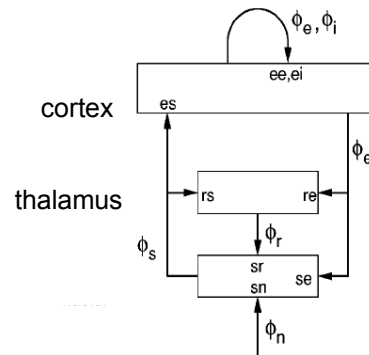
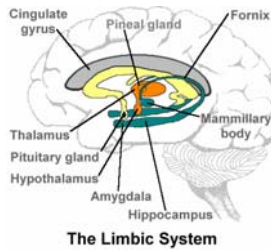
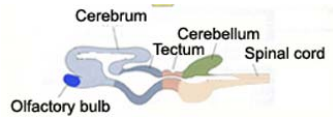
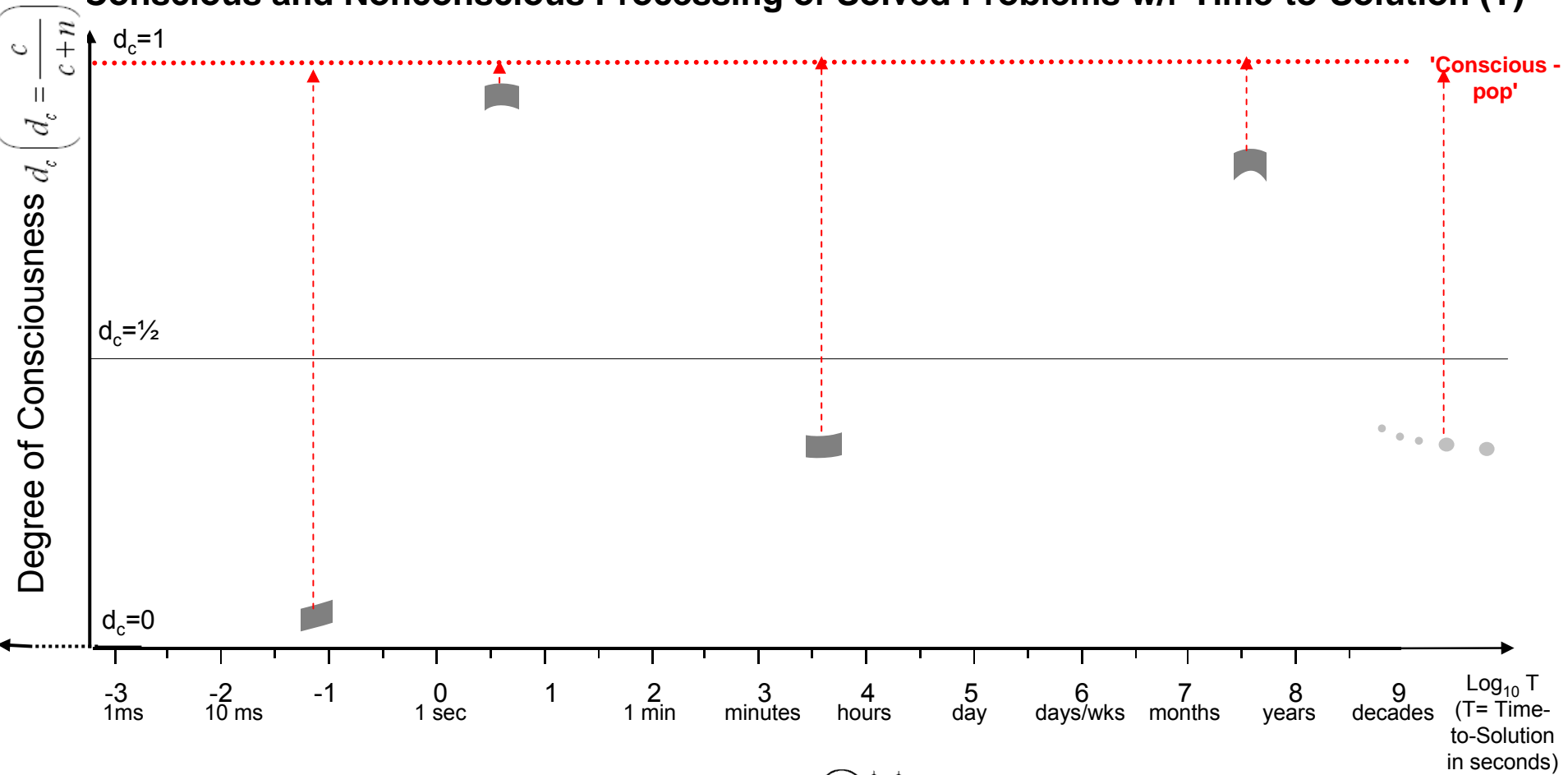
Archimedes' Eureka      Poincaré's Conjecture  
 Einstein's Relativity      Existence Theorems

←      →

# Conscious and Nonconscious Processing of Solved Problems w/r Time-to-Solution (T)

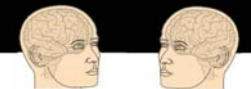


# Conscious and Nonconscious Processing of Solved Problems w/r Time-to-Solution (T)



$$Y'(t) - f(t, Y(t), Y(t - \tau)) = X(t, \Phi_n, \phi_a)$$

$$\frac{d^2 V_s(r, t)}{dt^2} + (\alpha + \beta) \frac{dV_s}{dt^2} + \alpha \beta V_s = \alpha \beta \sum_s N_{ss} \epsilon_{ss} \hat{\phi}_s(r, t - \tau_{ss})$$

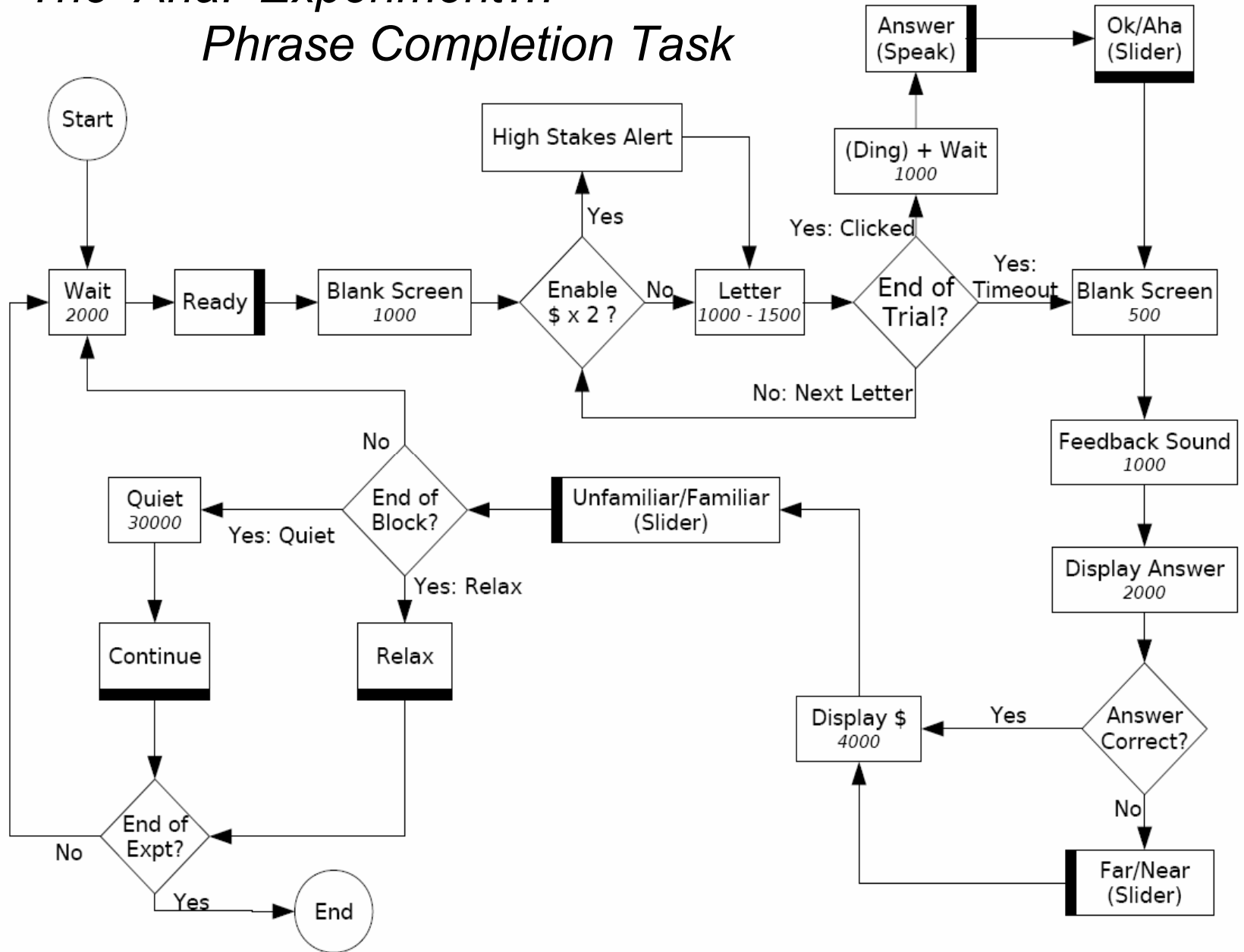


Anatomical Pathways  
(evolutionary time scale (t))



# The 'Aha!' Experiment...

## Phrase Completion Task



— —      T H —      T — P      — F      M —      T O — G — —

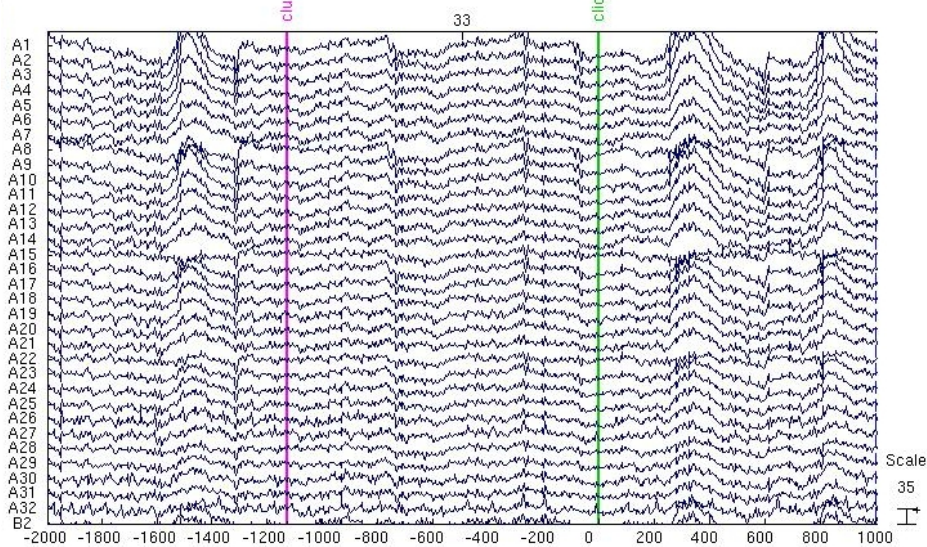
\_ \_    T H \_    T \_ P    O F    M Y    T O \_ G \_ \_

\_ N      T H \_      T \_ P      O F      M Y      T O N G \_ \_

O N      T H \_      T \_ P      O F      M Y      T O N G \_ E

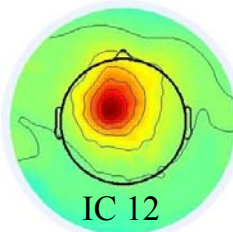
O N      T H E      T I P      O F      M Y      T O N G U E

## Scalp Channel Activations



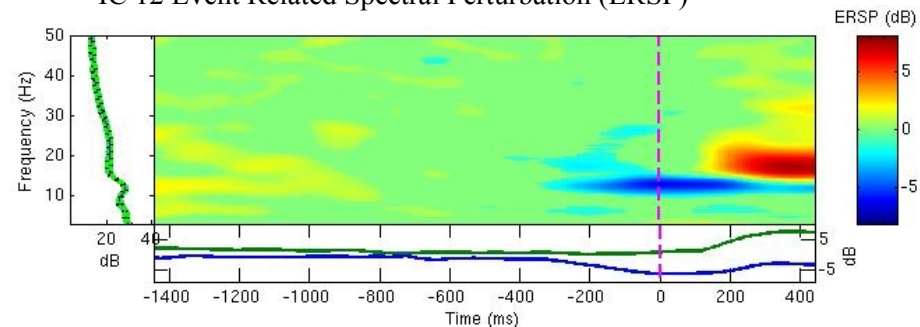
→ Button press

→ Preceding letter

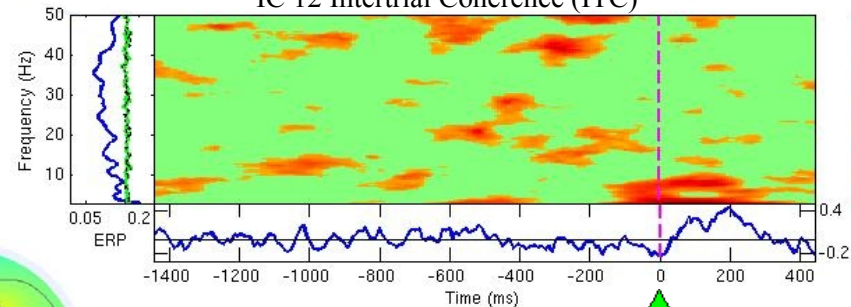


IC 12

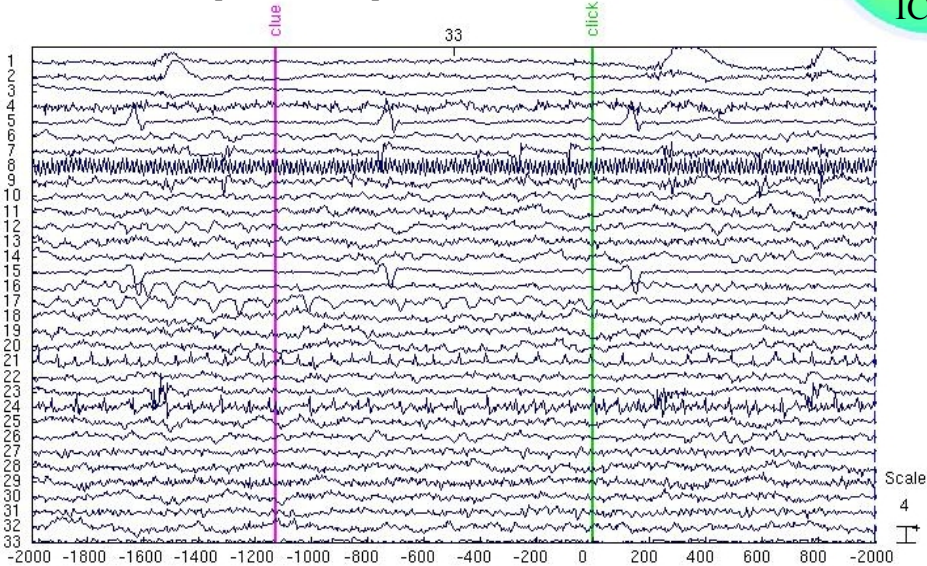
## IC 12 Event Related Spectral Perturbation (ERSP)



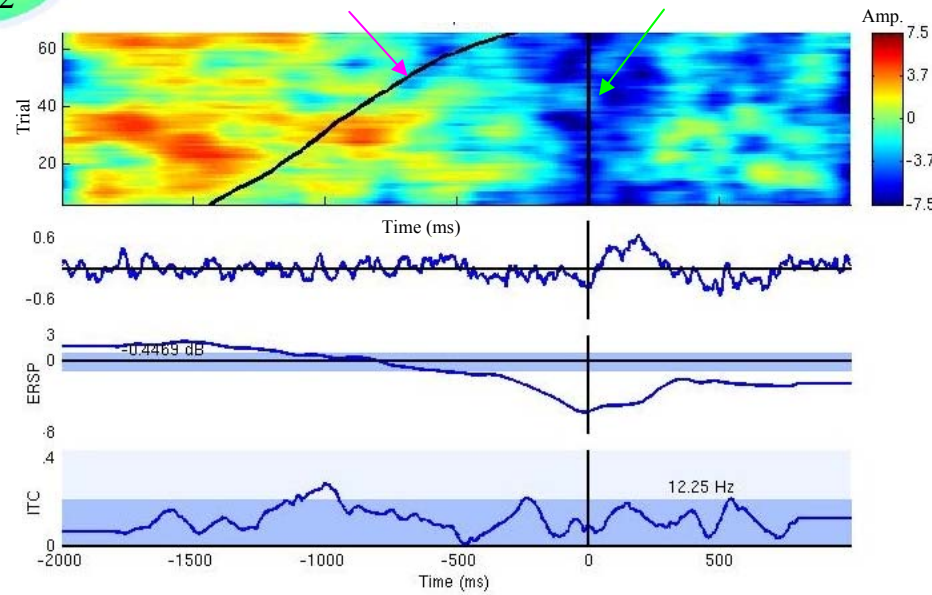
## IC 12 Intertrial Coherence (ITC)



## Independent Component Activations



## IC 12 Spectral Amplitude (10-23 Hz) Vs. Time Vs. Trial



# NCP

“...it is necessary to shed more light on how unconscious thought works and when and how the unconscious transfers its information to consciousness...[Our] knowledge represents no more than the tip of the iceberg, and there is much more about the processes involved that remains to be discovered.”

*--A Theory of Unconscious Thought*

**Ap Dijksterhuis and Loran F. Nordgren**

University of Amsterdam, '06

Thanks to...

T. Bell, A. Chou, H. Cohen, R. DeBellis, R. Low, S. Makeig, J. Victor