Attention, Binding, and Consciousness

1. Perceptual binding, dynamic binding
2. Neural Correlates of Consciousness: Binocular rivalry
3. Attention vs. consciousness
4. Binding revisited: Split-brain, split-consciousness

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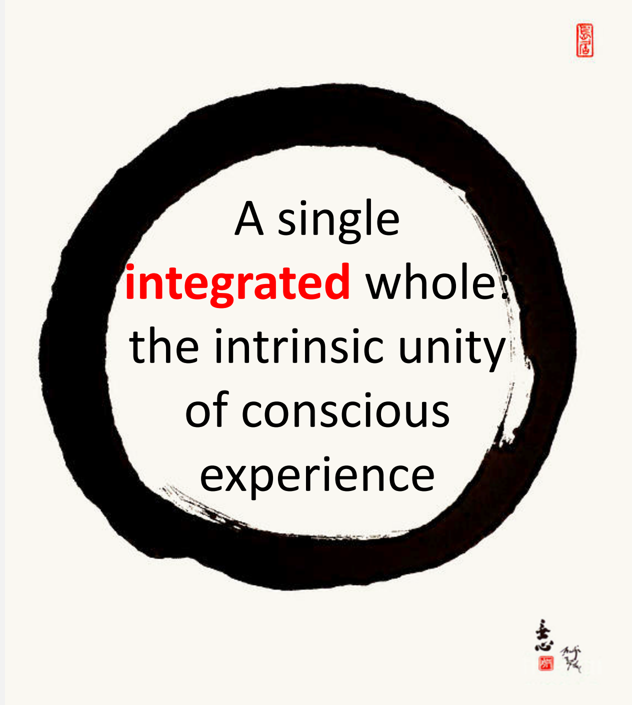
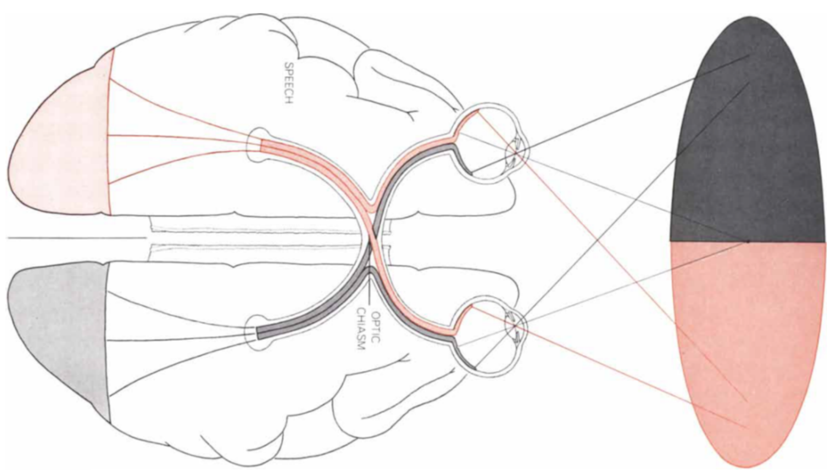
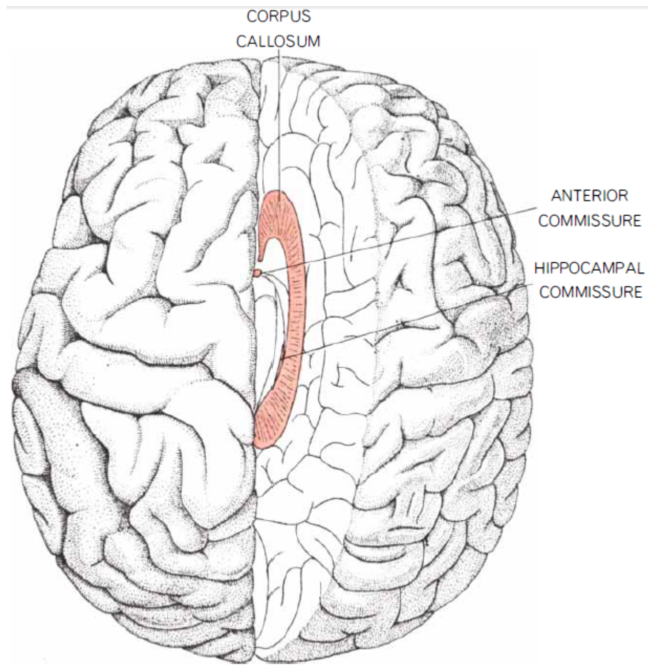


WHAT UNITY OF CONSCIOUSNESS?

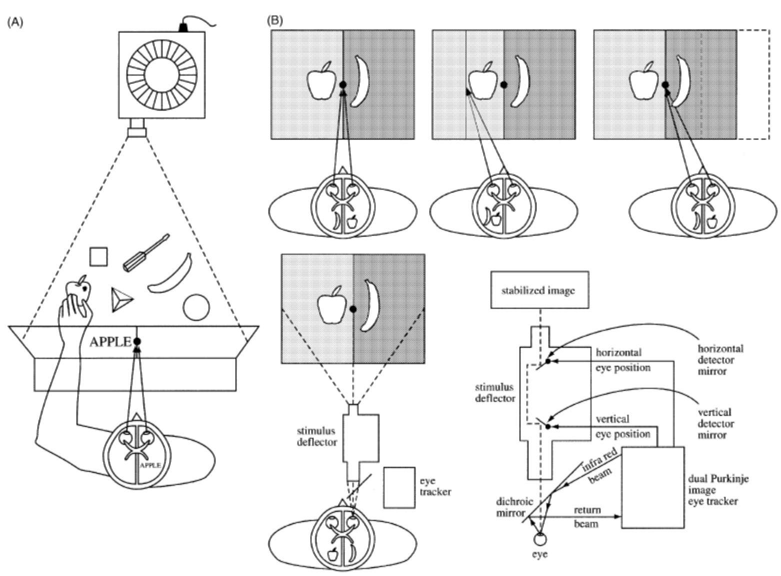


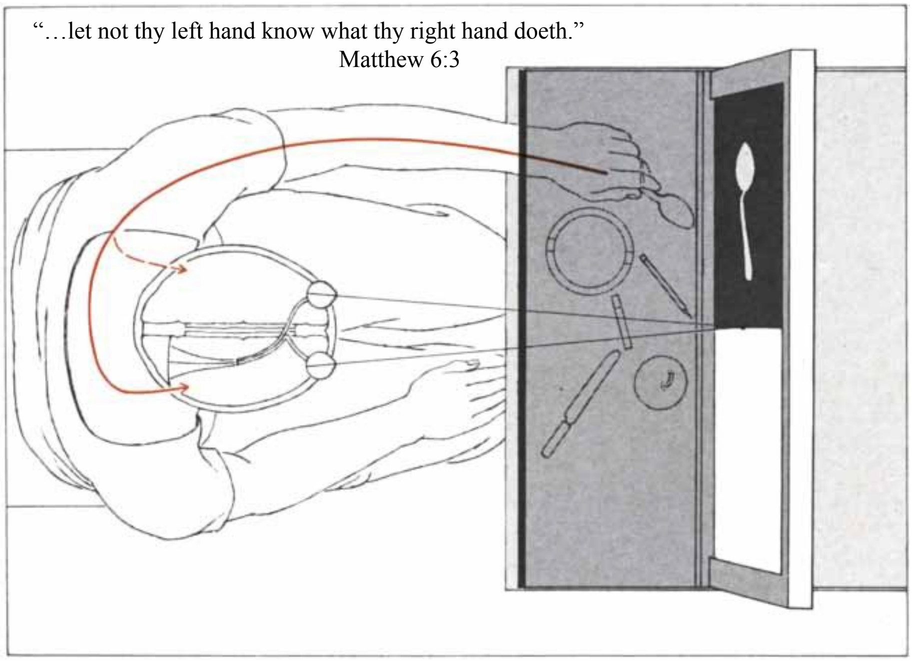
The Split Brain

Mike Gazzaniga 1967

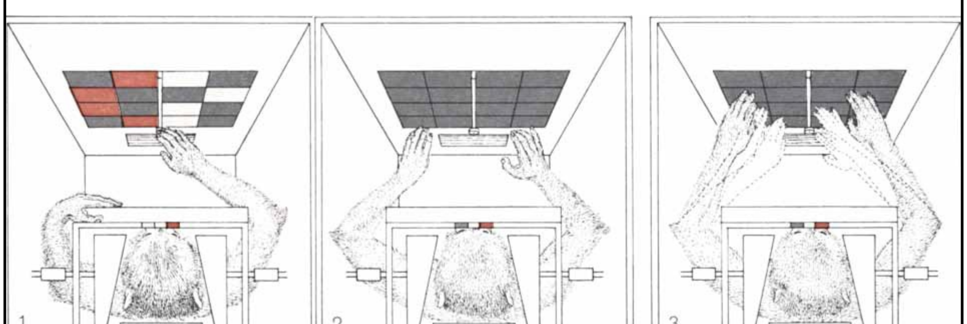


Communicating with a single hemisphere



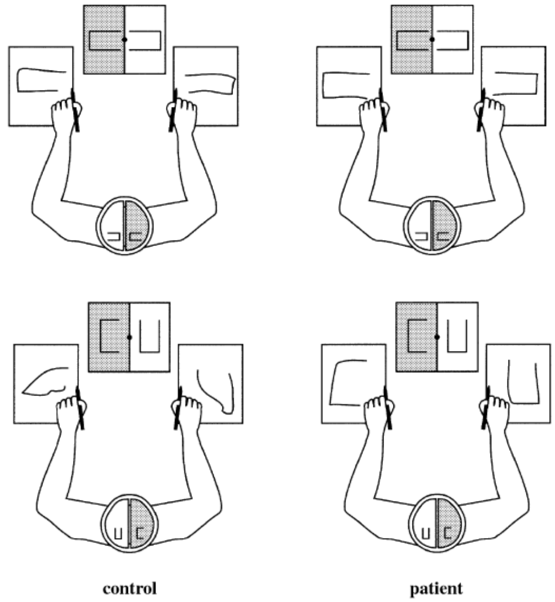


Multitasking: splitting the attentional bottleneck

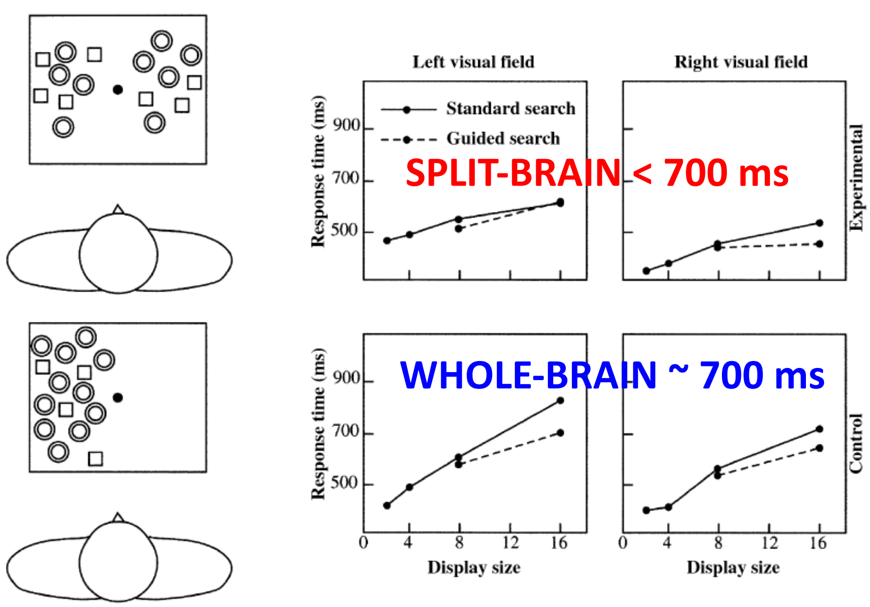


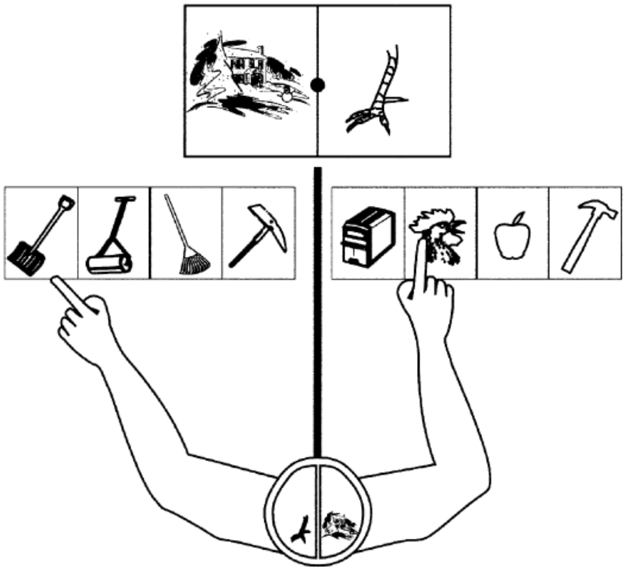
SPLIT-BRAIN MONKEYS can handle more visual information than normal animals. When the monkey pulls a knob (*1*), eight of the 16 panels light momentarily. The monkey must then start at the bottom and punch the lights that were lit and no others (*2*). With the panels lit for 600 milliseconds normal monkeys get up to the third row from the bottom before forgetting which panels were lit (*3*). Split-brain monkeys complete the entire task with the panels lit only 200 milliseconds. The monkeys look at the panels through filters; since the optic chiasm is cut in these animals, the filters allow each hemisphere to see the colored panels on one side only.

Inter-hemispheric interference



Serial search — in parallel!





The left-hemisphere **interpreter** establishes a *running narrative* and **self**-concept

Why did you pick those pictures? "Oh that's simple. The chicken claw goes with the chicken, And you need a shovel to clean out the chicken shed.

Hemispheric specialization

Left is better at

- Speaking, language
- Problem solving, planning, intelligence
- Interpretation, hypothesizing, story-making, confabulation
- Voluntary smiling, top-down attention

Right is better at

- Pattern matching
- Face recognition
- Perceptual grouping/illusory contours
- 3D drawing
- Being veridical
- Global attention

Conclusions from split-brain studies

- Although the right hemisphere has very limited verbal abilities, surgically separating the hemispheres appear to result in **two independent consciousnesses**, one in each hemisphere: split-brain, split consciousness.
- This result does not conflict with the observation or claim that **consciousness is an intrinsically unified state.**

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Consciousness Conclusions

- We seek the NCC—the minimal brain events sufficient for a conscious percept.
- Conscious awareness may be associated with neural synchrony and/or the firing of small groups of neurons in higher-order sensory areas like IT and STS.
- Ultimately our theory of consciousness should relate it consistently to other phenomena described by science.

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Perceptual decisions and the Diffusion model

1. Area MT and motion perception
2. Area LIP and evidence accumulation

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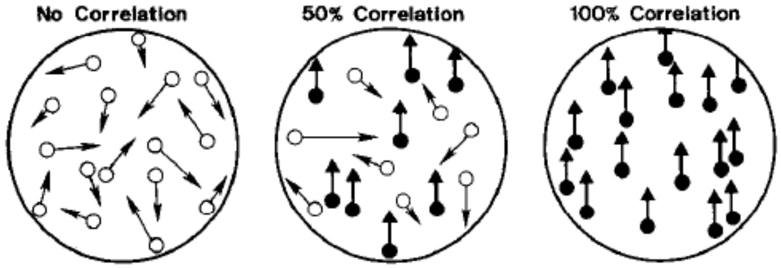
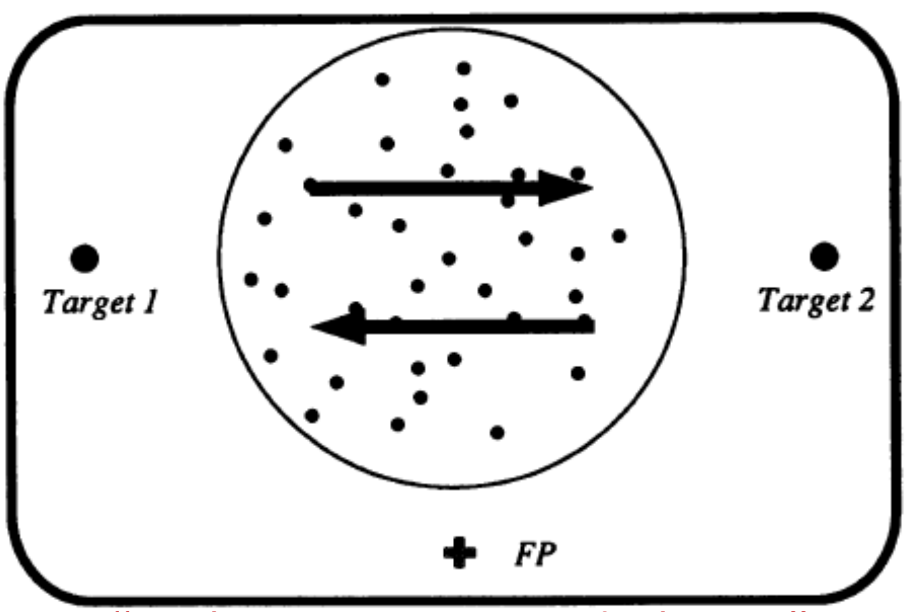
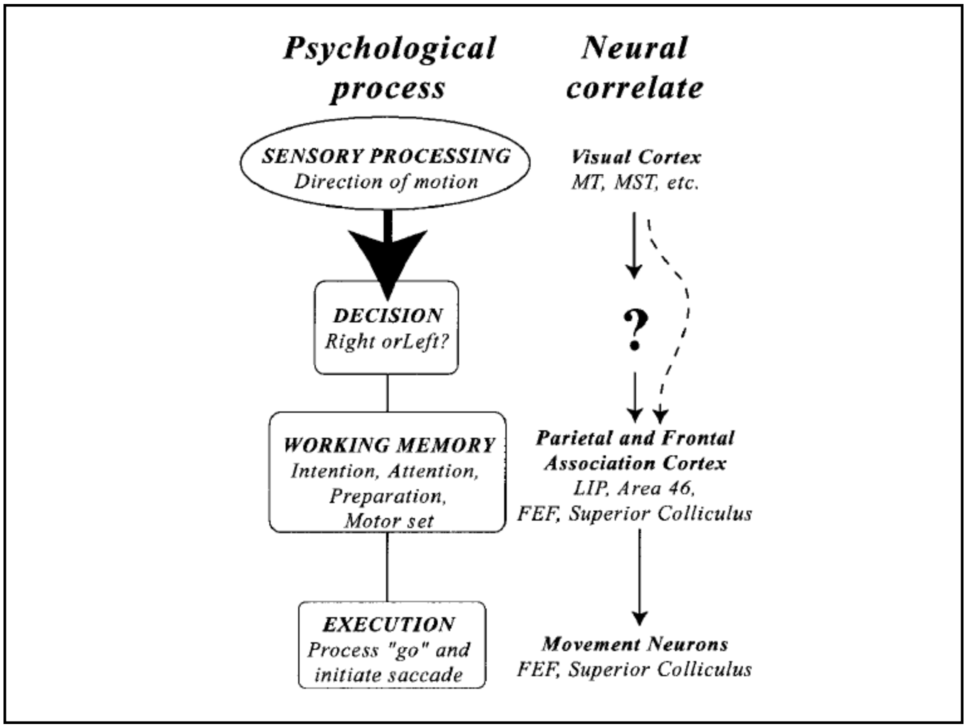


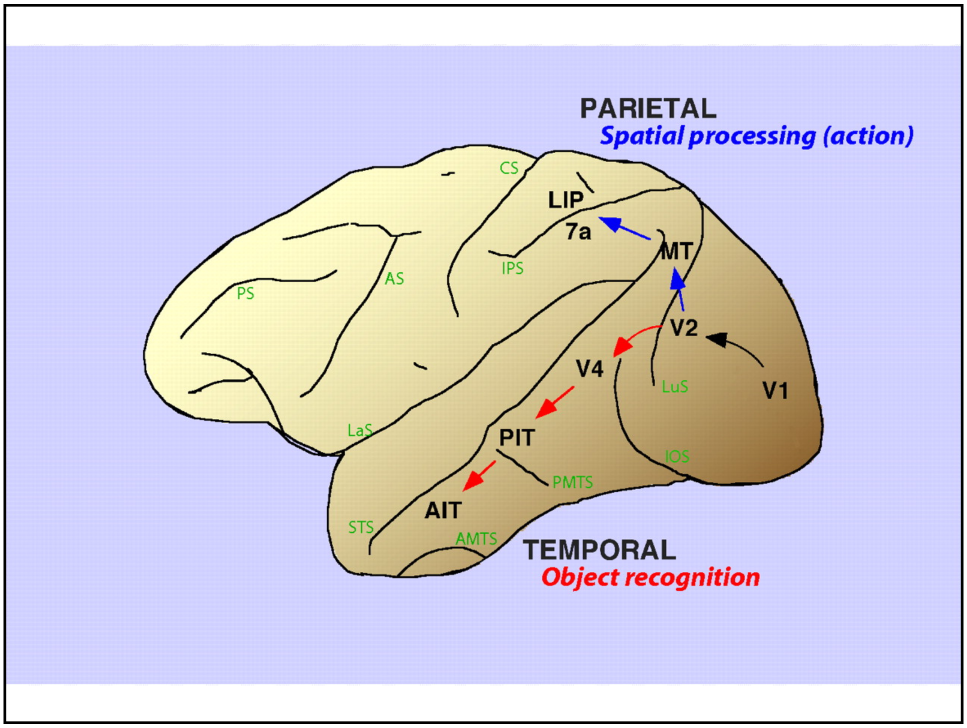
Figure 1. A schematic diagram of the stochastic motion stimulus employed in this study. Each stimulus was composed of a stream of randomly positioned dots plotted on a CRT monitor. The strength of the motion signal in the display was determined by the amount of "correlation" introduced as the dots were plotted. The *left panel*, for example, illustrates the 0% correlation state in which each dot position was chosen completely at random. This stimulus comprised "white noise" in the motion domain since all directions and speeds were equally present in the display. The *center panel* depicts the 50% correlation state in which half of the dots were positioned randomly ("noise" dots) while the remaining half were plotted with a fixed spatial and temporal offset with respect to previously plotted dots ("signal" dots). In this version of the display, a unidirectional motion signal coexisted with a masking motion

Motion discrimination task



"2 Alternative Forced Choice"


Psychological process
Neural correlate
SENSORY PROCESSING
Direction of motion
Visual Cortex
MT, MST, etc.
DECISION
Right orLeft?
?
WORKING MEMORY
Intention, Attention, Preparation, Motor set
Parietal and Frontal Association Cortex
LIP, Area 46,
FEF, Superior Colliculus
EXECUTION
Process "go" and initiate saccade
Movement Neurons
FEF, Superior Colliculus


PARIETAL
Spatial processing (action)
CS
LIP
7a
MT
IPS
AS
PS
V2
V4
LuS
V1
LaS
PIT
IOS
PMTS
STS
AIT
AMTS
TEMPORAL
Object recognition

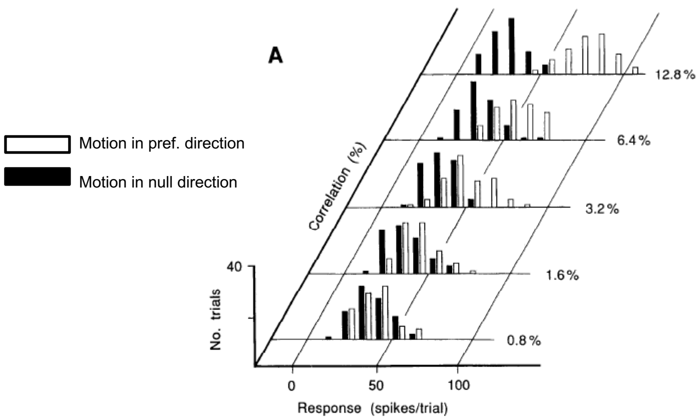
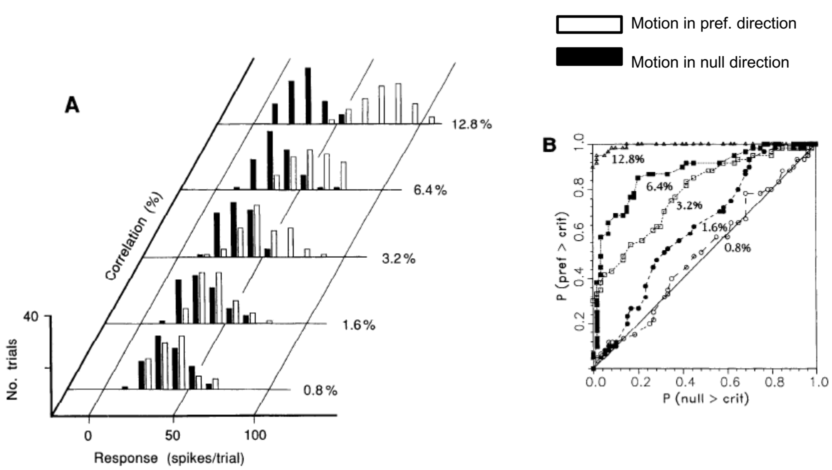
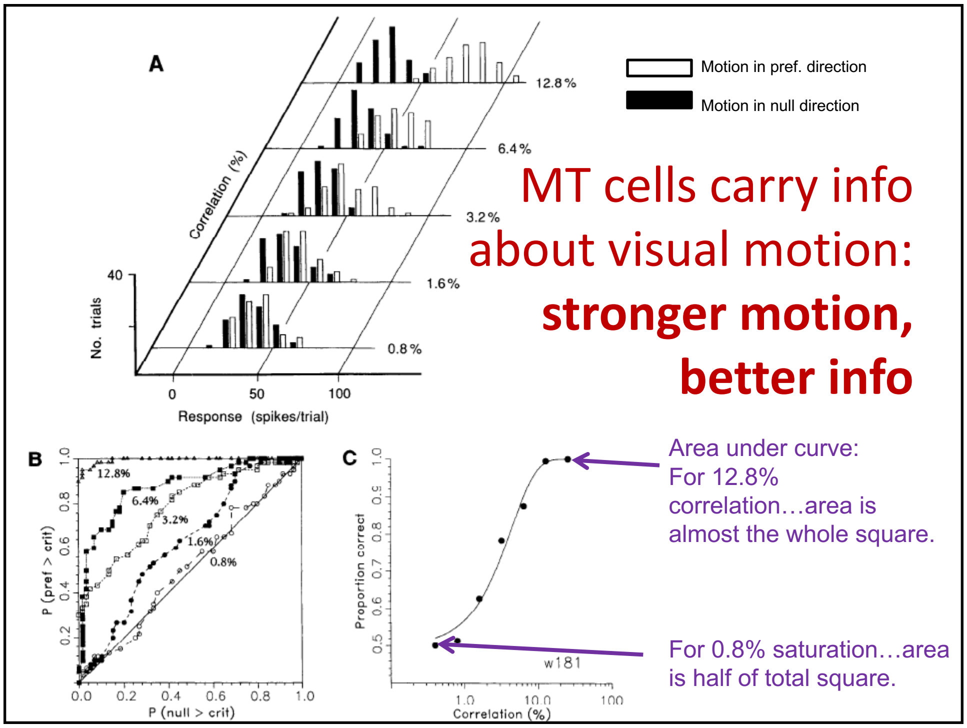


Figure 5. Analysis of physiological data. *A*, This three-dimensional plot illustrates frequency histograms of responses obtained from a single MT neuron at five different correlation levels. The *horizontal axis* shows the amplitude of the neuronal response, and the *vertical axis* indicates the number of trials on which a particular response was obtained. The *depth axis* shows the correlation of motion signal used to elicit the response distributions. *Open bars* depict responses obtained for motion in the neuron's preferred direction, while *solid bars* illustrate responses for null direction motion. For this neuron, each distribution is based on 60 trials.



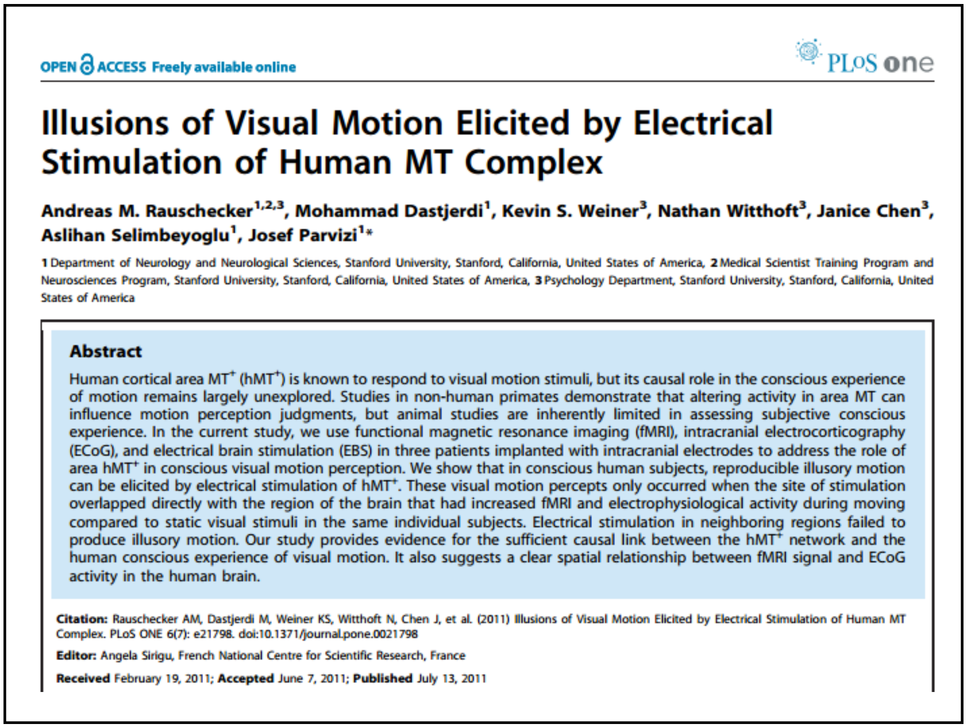


Cortical microstimulation influences perceptual judgements of motion direction

C. Daniel Salzman, Kenneth H. Britten & William T. Newsome*

Department of Neurobiology, Stanford University School of Medicine, Stanford, California 94305, USA

NEURONS in the visual cortex respond selectively to perceptually salient features of the visual scene, such as the direction and speed of moving objects, the orientation of local contours, or the colour or relative depth of a visual pattern. It is commonly assumed that the brain constructs its percept of the visual scene from information encoded in the selective responses of such neurons. We have now tested this hypothesis directly by measuring the effect on psychophysical performance of modifying the firing rates of physiologically characterized neurons. We required rhesus monkeys to report the direction of motion in a visual display while we electrically stimulated clusters of directionally selective neurons in the middle temporal visual area (MT, or V5), an extrastriate area that plays a prominent role in the analysis of visual motion information[1–8]. Microstimulation biased the animals' judgements towards the direction of motion encoded by the stimulated neurons. This result indicates that physiological properties measured at the neuronal level can be causally related to a specific aspect of perceptual performance.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PLoS one

Illusions of Visual Motion Elicited by Electrical Stimulation of Human MT Complex

Andreas M. Rauschecker[1,2,3], Mohammad Dastjerdi[1], Kevin S. Weiner[3], Nathan Witthoft[3], Janice Chen[3], Aslihan Selimbeyoglu[1], Josef Parvizi[1]*

1 Department of Neurology and Neurological Sciences, Stanford University, Stanford, California, United States of America, 2 Medical Scientist Training Program and Neurosciences Program, Stanford University, Stanford, California, United States of America, 3 Psychology Department, Stanford University, Stanford, California, United States of America

Abstract

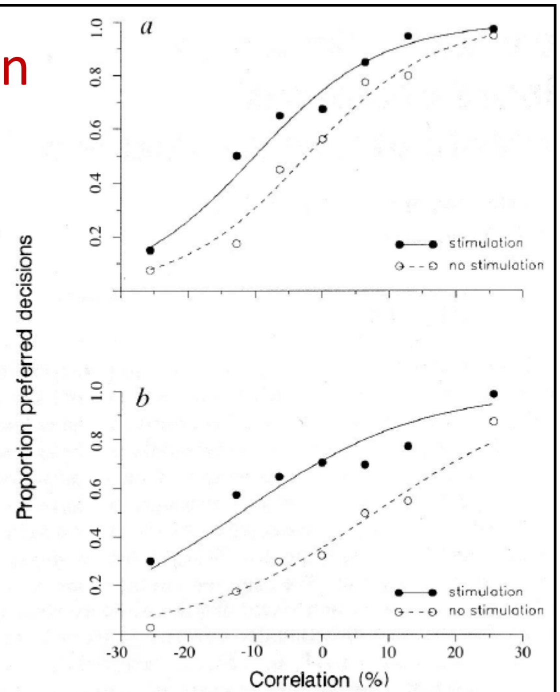
Human cortical area MT^+ (hMT^+) is known to respond to visual motion stimuli, but its causal role in the conscious experience of motion remains largely unexplored. Studies in non-human primates demonstrate that altering activity in area MT can influence motion perception judgments, but animal studies are inherently limited in assessing subjective conscious experience. In the current study, we use functional magnetic resonance imaging (fMRI), intracranial electrocorticography (ECoG), and electrical brain stimulation (EBS) in three patients implanted with intracranial electrodes to address the role of area hMT^+ in conscious visual motion perception. We show that in conscious human subjects, reproducible illusory motion can be elicited by electrical stimulation of hMT^+. These visual motion percepts only occurred when the site of stimulation overlapped directly with the region of the brain that had increased fMRI and electrophysiological activity during moving compared to static visual stimuli in the same individual subjects. Electrical stimulation in neighboring regions failed to produce illusory motion. Our study provides evidence for the sufficient causal link between the hMT^+ network and the human conscious experience of visual motion. It also suggests a clear spatial relationship between fMRI signal and ECoG activity in the human brain.

Citation: Rauschecker AM, Dastjerdi M, Weiner KS, Witthoft N, Chen J, et al. (2011) Illusions of Visual Motion Elicited by Electrical Stimulation of Human MT Complex. PLoS ONE 6(7): e21798. doi:10.1371/journal.pone.0021798

Editor: Angela Sirigu, French National Centre for Scientific Research, France

Received February 19, 2011; **Accepted** June 7, 2011; **Published** July 13, 2011

Microstimulation in area MT shifts the psychometric curve



Perceptual decisions and the Diffusion model

1. Area MT and motion perception
2. Area LIP and evidence accumulation

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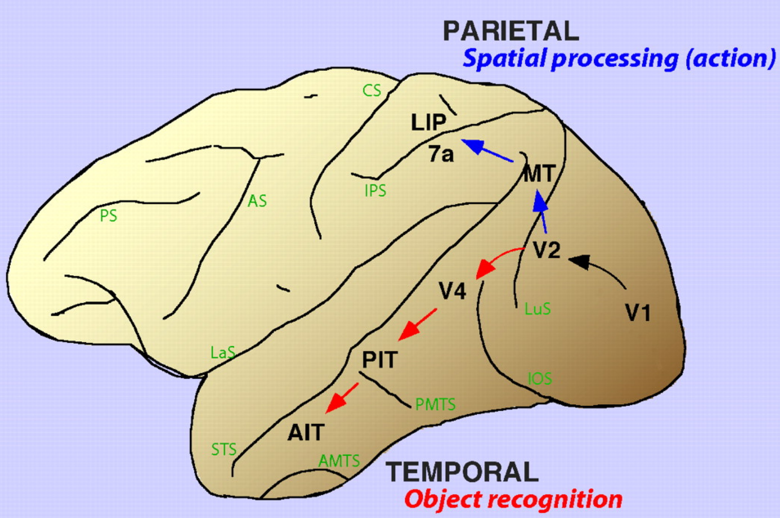
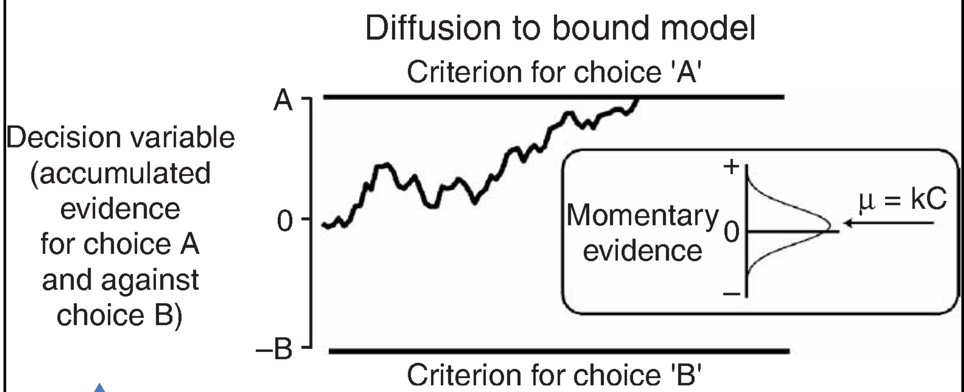
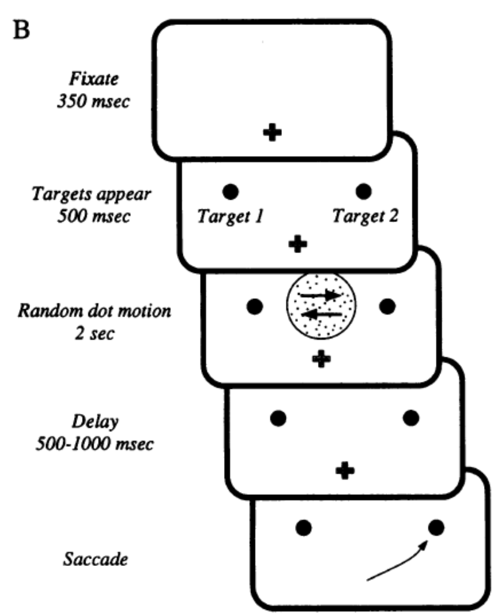


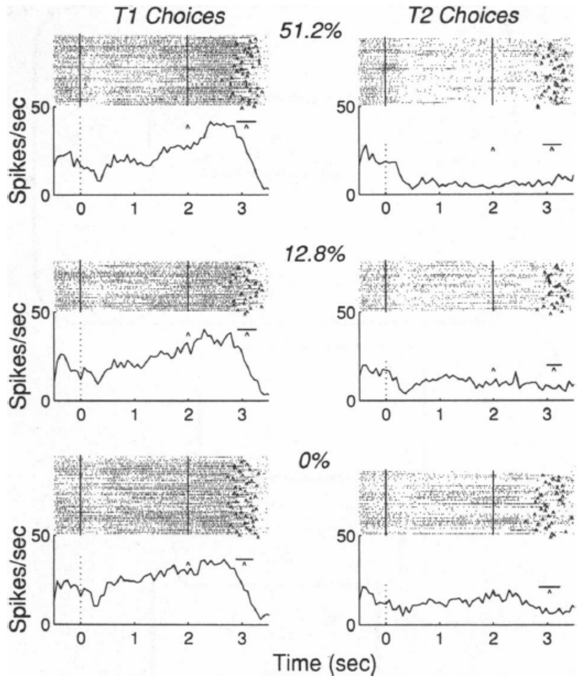
Diffusion model of a perceptual decision

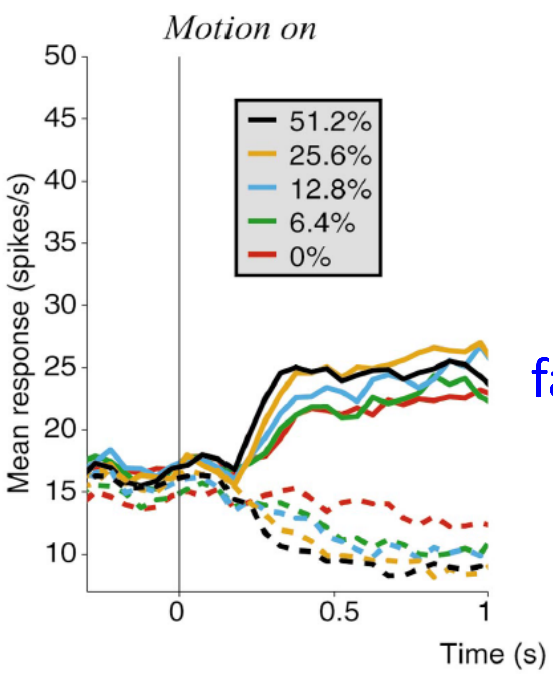


I.e. integrates the <u>difference</u> between evidence for and against choice A



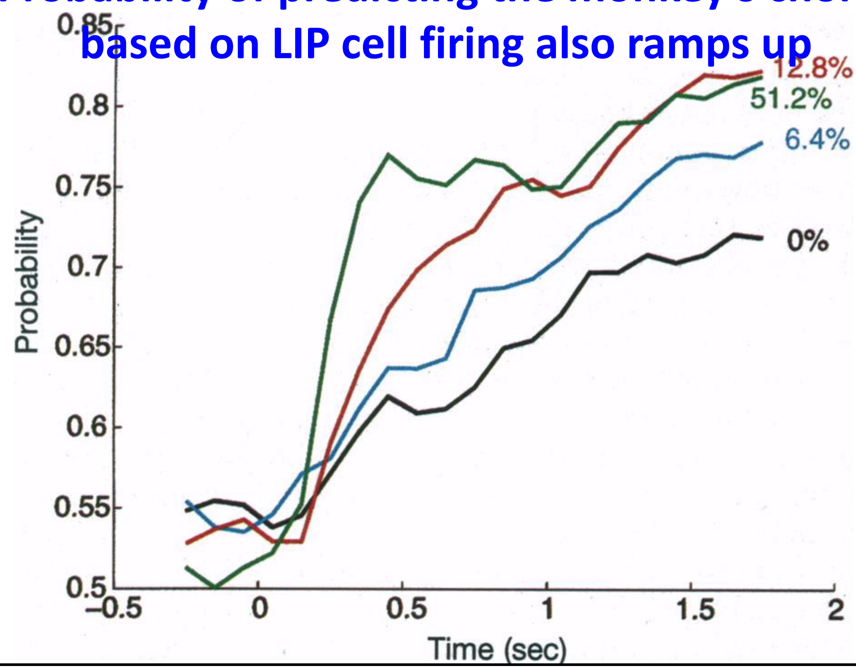
LIP activity ramps up during the motion stimulus



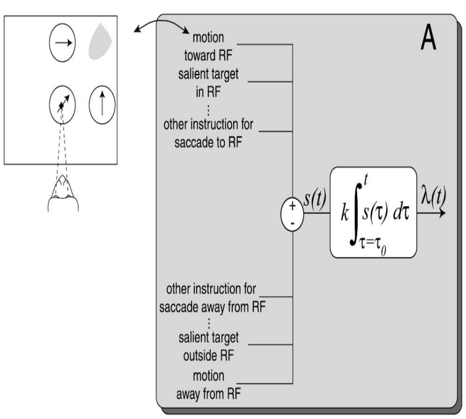


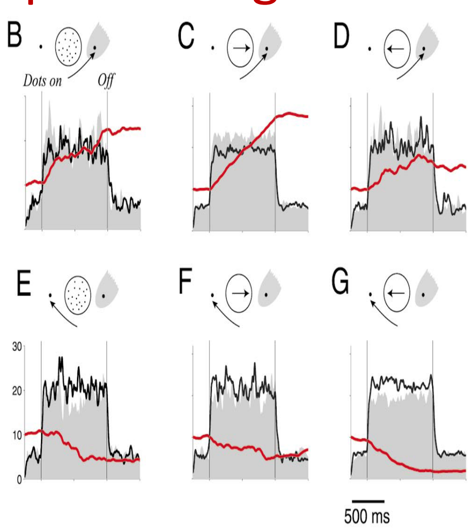
Stronger motion, faster ramp up

Probability of predicting the monkey's choice based on LIP cell firing also ramps up



LIP neuron as temporal integrator





MT left = solid black

MT right = gray filled

LIP = red line = time integral of MT difference

Microstimulation of macaque area LIP affects decision-making in a motion discrimination task

Timothy D Hanks[1], Jochen Ditterich[1,2] & Michael N Shadlen[1]

A central goal of cognitive neuroscience is to elucidate the neural mechanisms underlying decision-making. Recent physiological studies suggest that neurons in association areas may be involved in this process. To test this, we measured the effects of electrical microstimulation in the lateral intraparietal area (LIP) while monkeys performed a reaction-time motion discrimination task with a saccadic response. In each experiment, we identified a cluster of LIP cells with overlapping response fields (RFs) and sustained activity during memory-guided saccades. Microstimulation of this cluster caused an increase in the proportion of choices toward the RF of the stimulated neurons. Choices toward the stimulated RF were faster with microstimulation, while choices in the opposite direction were slower. Microstimulation never directly evoked saccades, nor did it change reaction times in a simple saccade task. These results demonstrate that the discharge of LIP neurons is causally related to decision formation in the discrimination task.

2006

Aims of the paper

General Goal

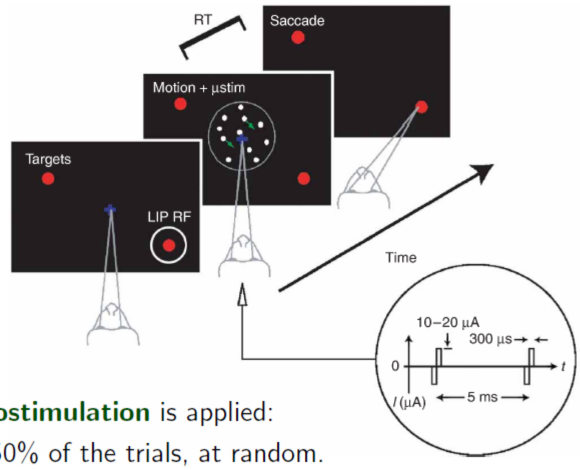
Understand the neural basis of Decision Making.

Specific Goal

- **Context:** Random-dot **motion discrimination** with **saccadic** response.
- Check the **causal role** of LIP neurons in Decision Making using microstimulation.
- Find and understand the differences between MT and LIP stimulation.

Journal club slides from Dani Marti

Task

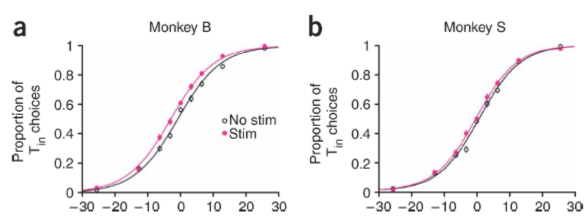


Now monkey can respond any time after the motion stimulus appears

Microstimulation is applied:

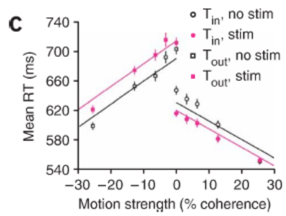
- 50% of the trials, at random.
- from the onset of the stimulus until the initiation of the saccade.

Microstimulation affects choice



μstimulation biases monkeys to choose the direction of motion associated to the **RF** of the stimulated area (T_{in} **choice target**).

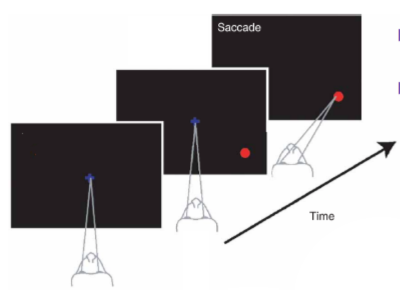
Microstimulation affects reaction time



- As usual, **stronger** motion leads to **faster** reaction times.
- μstimulation **reduces** the reaction time for T_{in} choices.
- μstimulation **increases** the reaction time for T_{out} choices.

Discarding effects on motor response

Are these effects attributable to changes in motor stages?



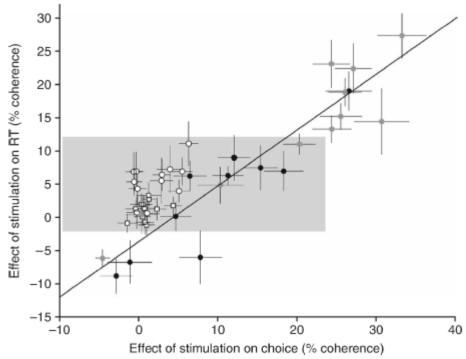
Cued saccade

- No perceptual decision.
- From an **eye movement control** point of view, identical to the original task.

Latencies in motor responses not affected by μstimulation.

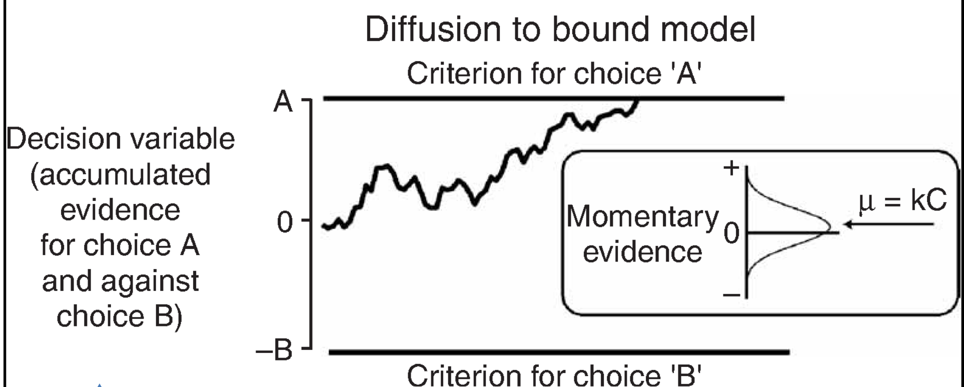
Comparison of MT and LIP stimulation

Using data from Ditterich et al. *Nat Neurosci* **6** 2003



LIP stimulation has a greater average effect on RT than on choice.

Diffusion model of a perceptual decision



I.e. integrates the <u>difference</u> between evidence for and against