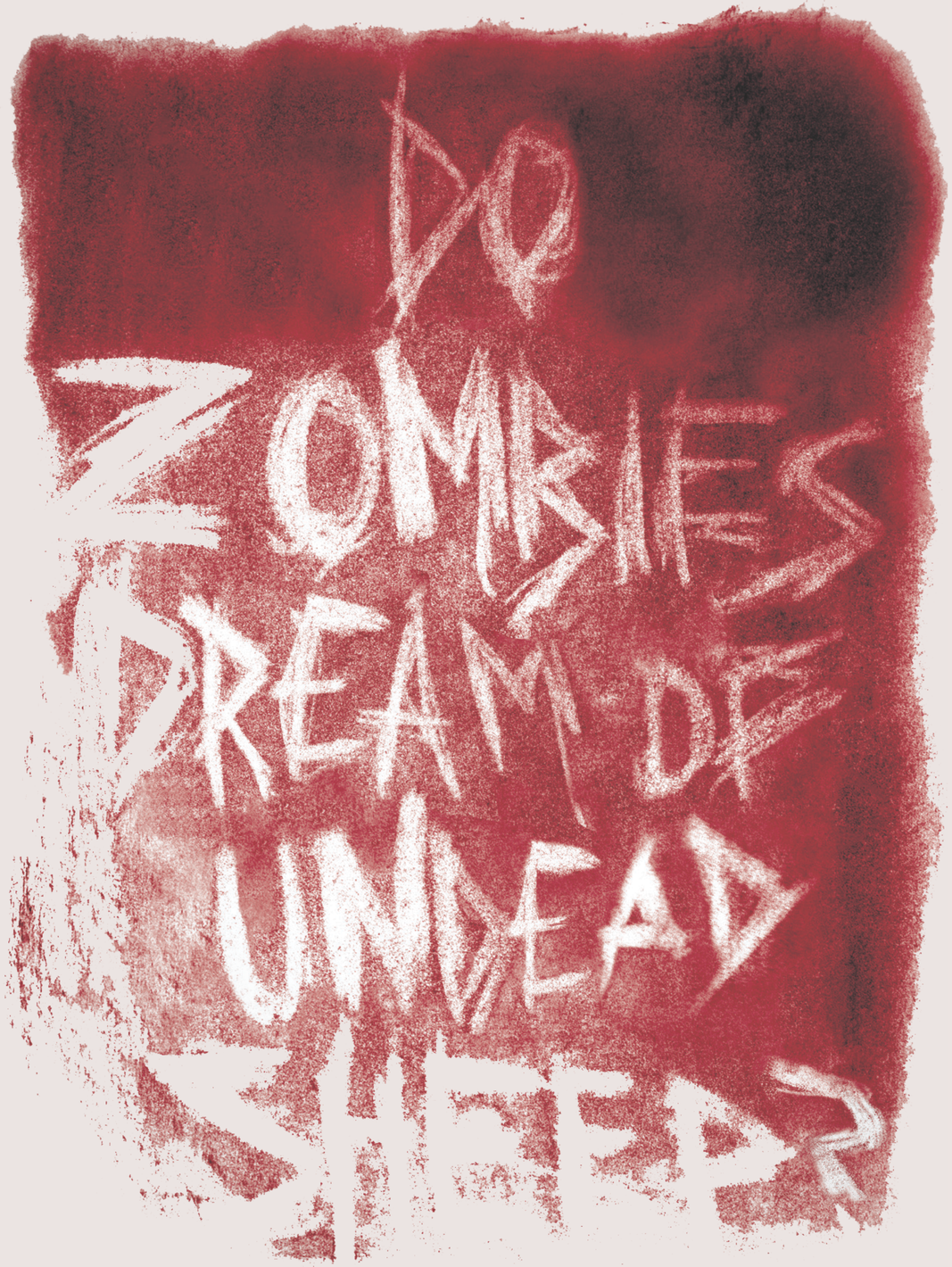
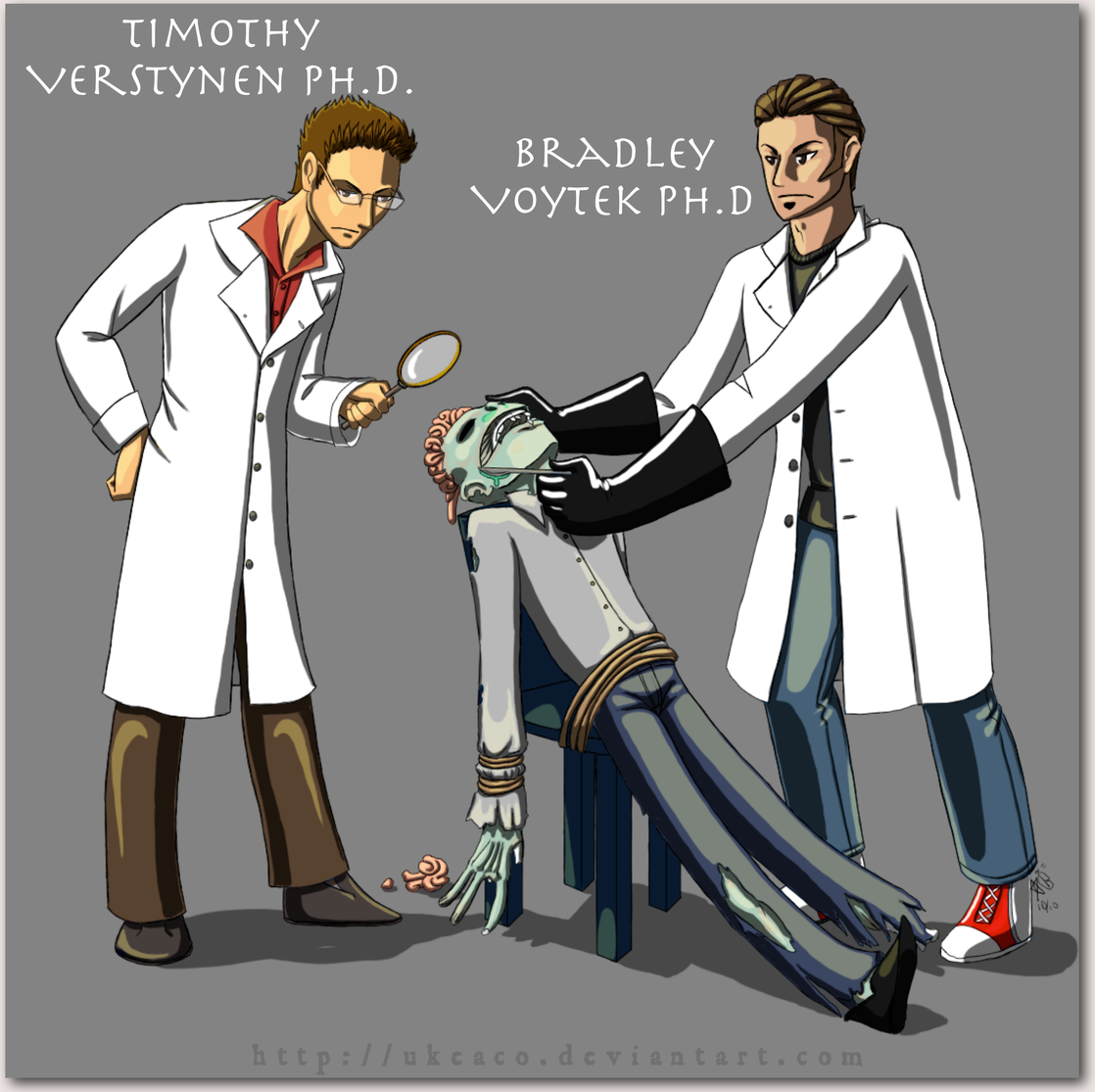


A NEUROSCIENTIFIC VIEW OF THE ZOMBIE BRAIN

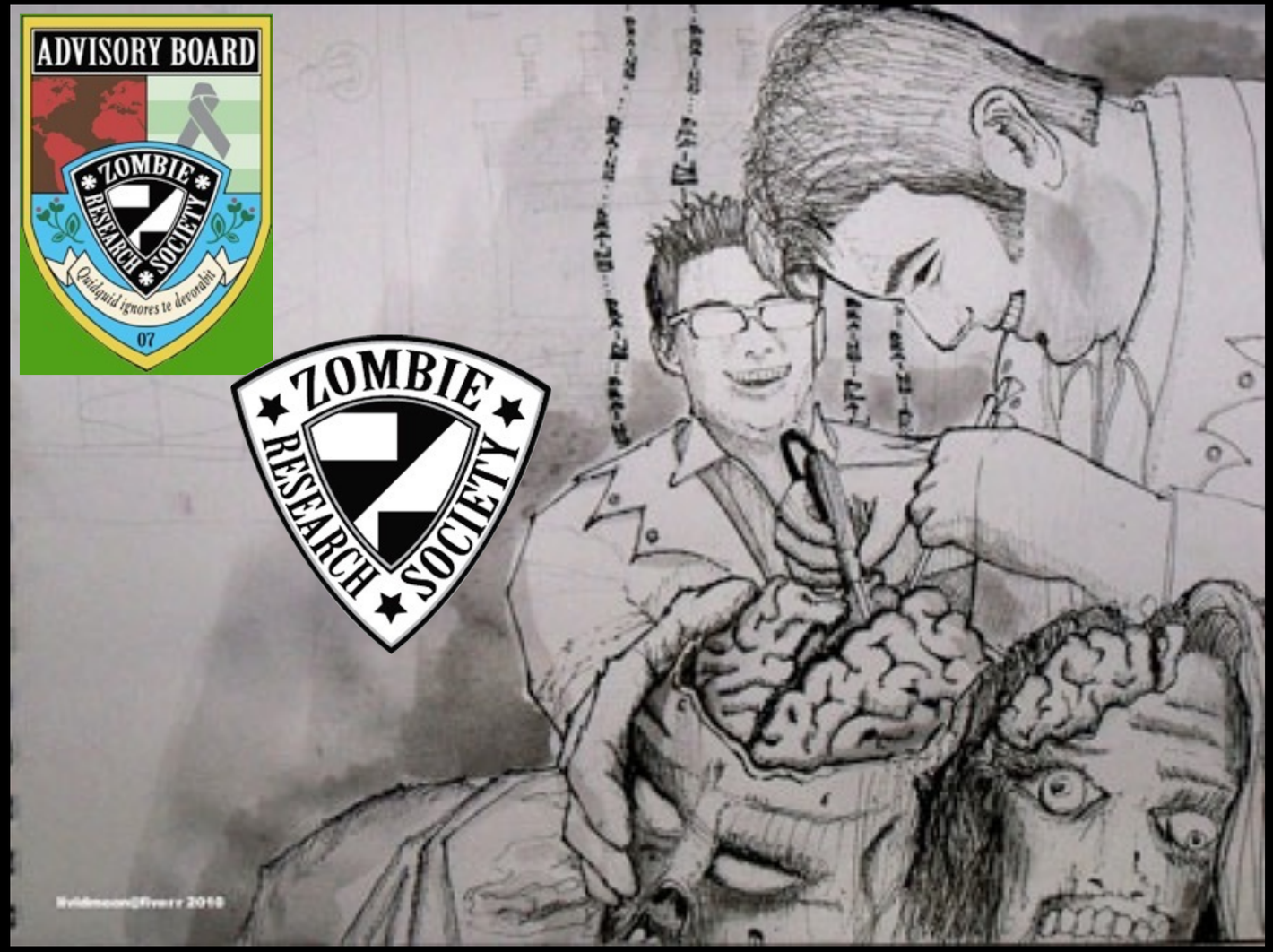


http://ukcaco.deviantart.com

Disclaimer:

In this talk there will be clips of zombie movies (some blood, some gore, etc.) and possible spoilers.

You've been warned!



lividmoon@fiverr.com

WHY ZOMBIE NEUROSCIENCE?

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How do you get general audiences more engaged in basic science?

WHY ZOMBIE NEUROSCIENCE?

LOL Cat Figures

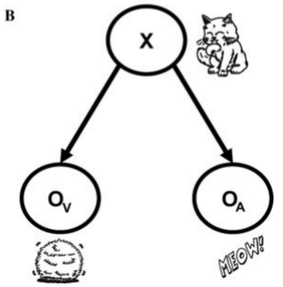

Figure 1. Cue combination. (A) Example of an indirect observation of a cat's position. You can see the bush moving and hear a "meow" sound, but you cannot directly observe the cat. (B) Graphical model of what is seen in A. The variable X (position of the cat) is unobserved, but it produces two observed variables: the moving bush, which provides a visual cue (O_v), and the "meow" sound, which provides an auditory cue (O_A). Cartoons made by Hugo M. Martins.

auditory cues are generated may be true or not, but it enables the construction of a simple normative model of behavior. The central assumptions about the world that give rise to each Bayesian model (in this case, the assumption of how cues are generated) can thus be effectively formalized in a graphical model.

In our example, we can say that the goal of our nervous system is to discover where the cat is, i.e., estimate the hidden variable, "position of the cat." Assuming that this variable generated the observed visual and auditory cues, the nervous system has to invert this generative process and estimate the hidden variable position of the cat by combining the visual and auditory cues.

Bayesian statistics provides a way of calculating how to optimally combine the cues, i.e., a way of maximally reducing the final uncertainty about the cat's position. The resulting estimate combines the cues, weighting them according to their reliability. If people combine cue information in a Bayesian way, the resulting estimate has generally lower uncertainty than estimates based on any of the cues alone.

This property of lower uncertainty in the final estimate is one of the crucial advantages of behavior that combines different pieces of knowledge in a way predicted by Bayesian models. Previously, it has been suggested that the nervous system could use a winner-take-all approach, taking only into account the most reliable cue (in this case, generally vision).[23] However, this would result in a final uncertainty generally higher than what would be obtained by employing Bayesian statistics.[4] Furthermore, an

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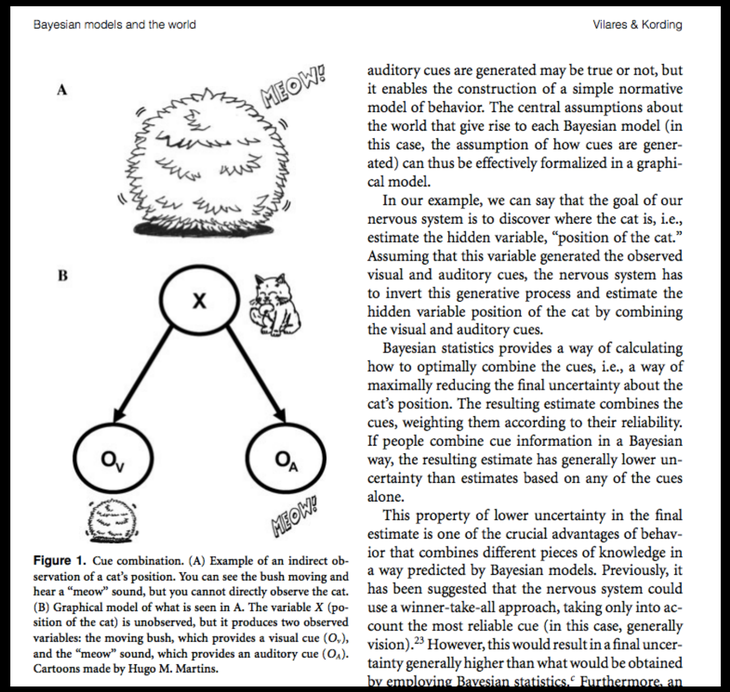

Bayesian models and the world — Vilares & Kording

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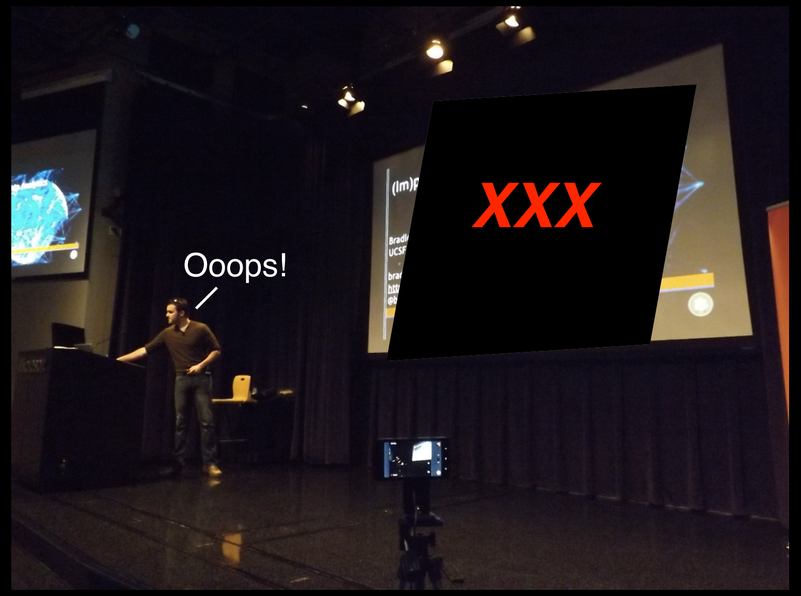
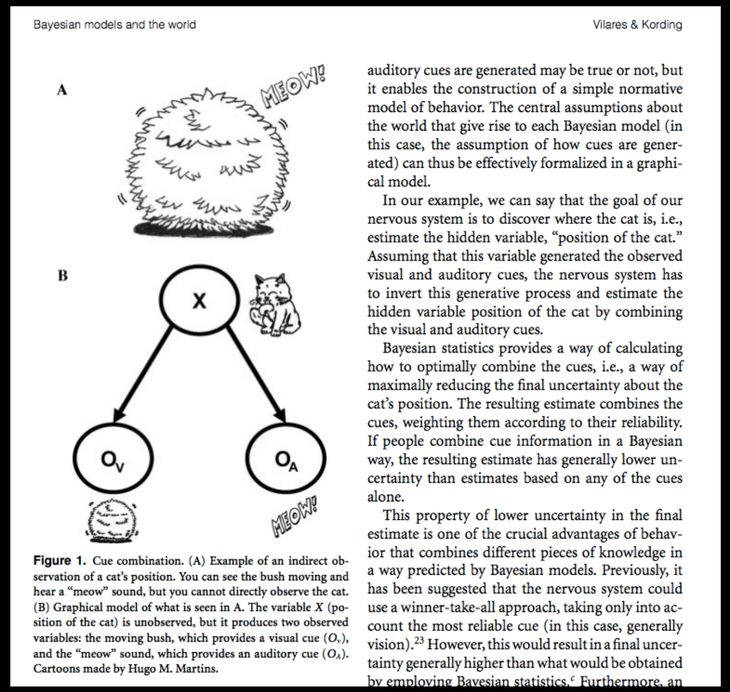
Leak Sex Tapes During Lectures



How do you get general audiences more engaged in basic science?

WHY ZOMBIE NEUROSCIENCE?

LOL Cat Figures



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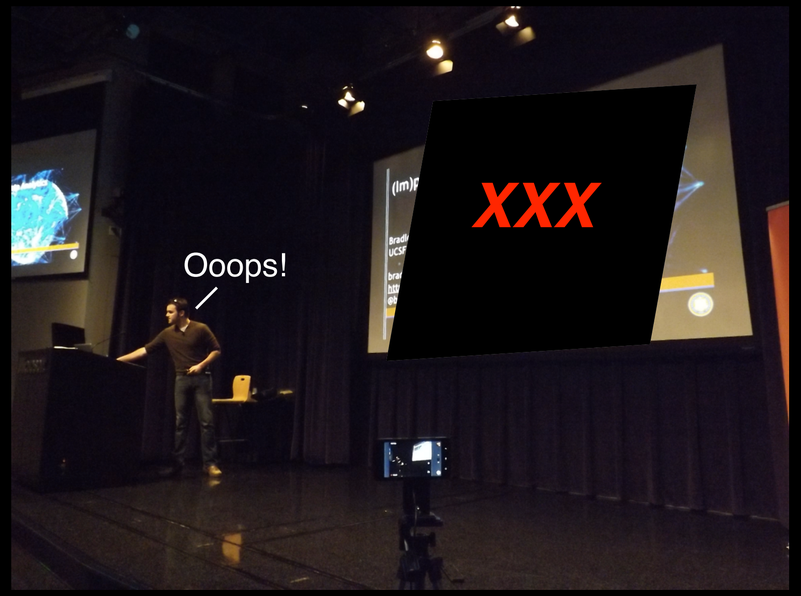
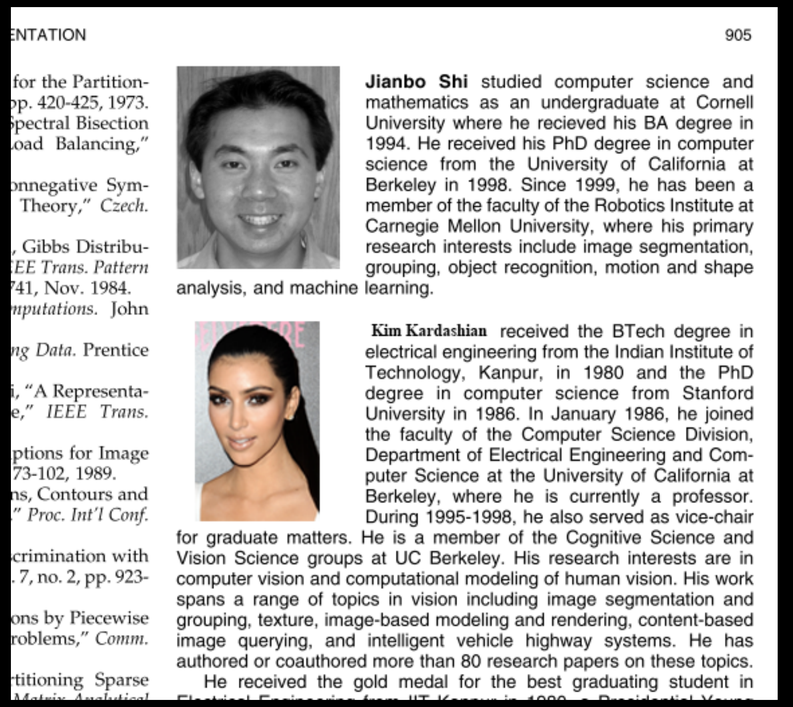


Add a Kardashian as a co-author



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Jianbo Shi studied computer science and mathematics as an undergraduate at Cornell University where he recieved his BA degree in 1994. He received his PhD degree in computer science from the University of California at Berkeley in 1998. Since 1999, he has been a member of the faculty of the Robotics Institute at Carnegie Mellon University, where his primary research interests include image segmentation, grouping, object recognition, motion and shape analysis, and machine learning.

Kim Kardashian received the BTech degree in electrical engineering from the Indian Institute of Technology, Kanpur, in 1980 and the PhD degree in computer science from Stanford University in 1986. In January 1986, he joined the faculty of the Computer Science Division, Department of Electrical Engineering and Computer Science at the University of California at Berkeley, where he is currently a professor. During 1995-1998, he also served as vice-chair for graduate matters. He is a member of the Cognitive Science and Vision Science groups at UC Berkeley. His research interests are in computer vision and computational modeling of human vision. His work spans a range of topics in vision including image segmentation and grouping, texture, image-based modeling and rendering, content-based image querying, and intelligent vehicle highway systems. He has authored or coauthored more than 80 research papers on these topics.

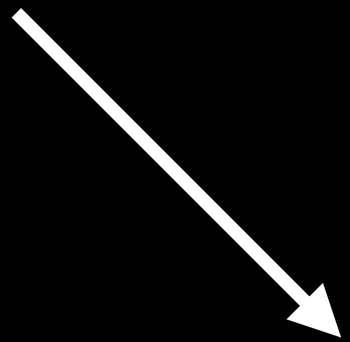
He received the gold medal for the best graduating student in

How do you get general audiences more engaged in basic science?

WHY ZOMBIE NEUROSCIENCE?

Why Zombie Neuroscience?

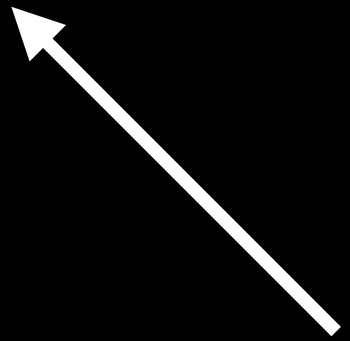
Pop Culture



Science

WHY ZOMBIE NEUROSCIENCE?

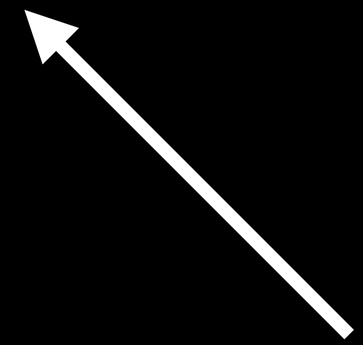
Pop Culture



Science

WHY ZOMBIE NEUROSCIENCE?

Pop Culture



Science

THE SCIENCE OF
SURVIVING THE ZOMBIE APOCALYPSE

The Spectrum of Zombie Symptoms

This is a zombie …

… engagement not recommended

The Spectrum of Zombie Symptoms

This is a zombie …

… engagement not recommended

Hyper Aggression

Memory Deficits

Reduced Impulse Control

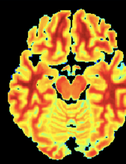
Language Disruption

Movement Dysfunction

Visual Recognition Impairments

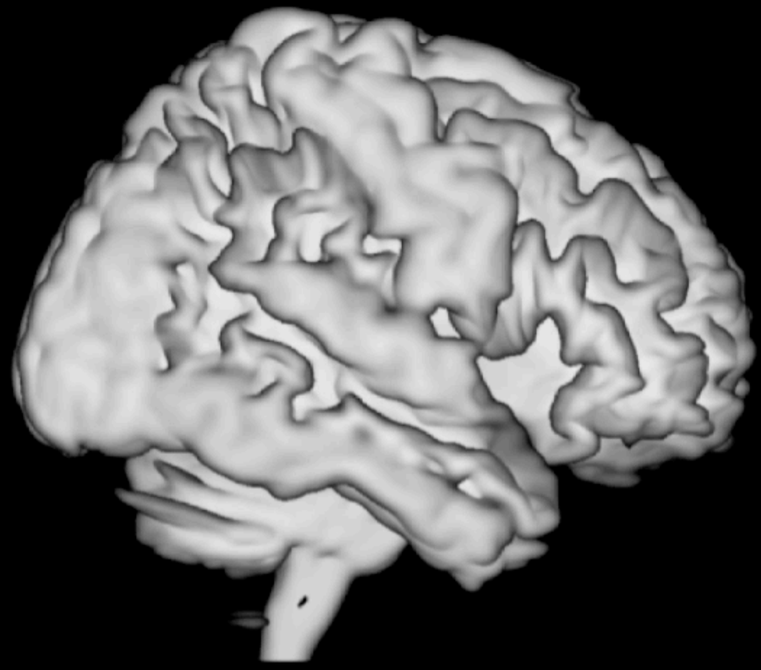
Attention Problems

The Zombie Brain

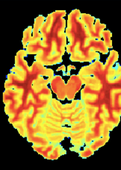


The Zombie Brain

Human

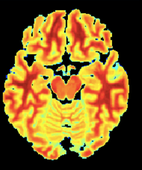


Zombie



Zombies as a clinical disorder

Consciousness Deficit Hypoactivity Disorder (CDHD): The loss of rational, voluntary and conscious behavior replaced by delusional/ impulsive aggression, stimulus-driven attention, and the inability to coordinate motor or lingustic behaviors.



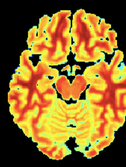
CDHD Symptom: Aggression

Night of the Living Dead

CDHD Symptom: Aggression

Reactive-Impulsive Aggression: "subtype of aggression [that] can result in sudden, heightened, enduring or inappropriate aggressive response...."

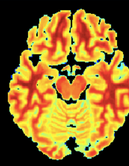
Nelson and Trainor, *Nature Reviews Neuroscience* 2007



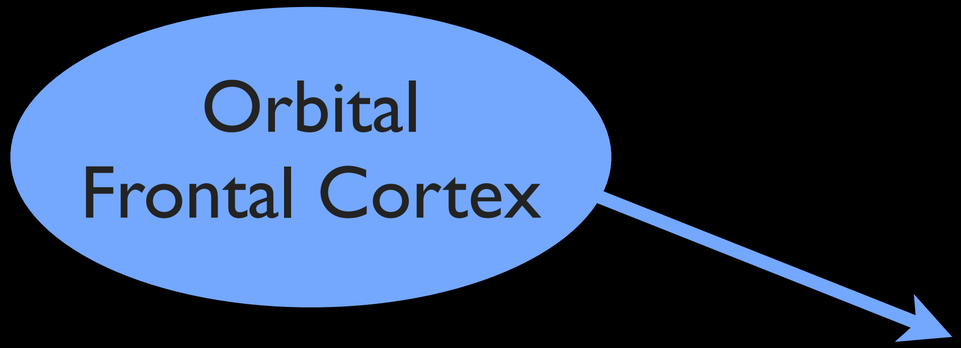
CDHD Symptom: Aggression

Orbital
Frontal Cortex

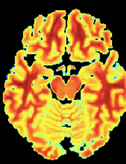
Nelson and Trainor, *Nature Reviews Neuroscience* 2007



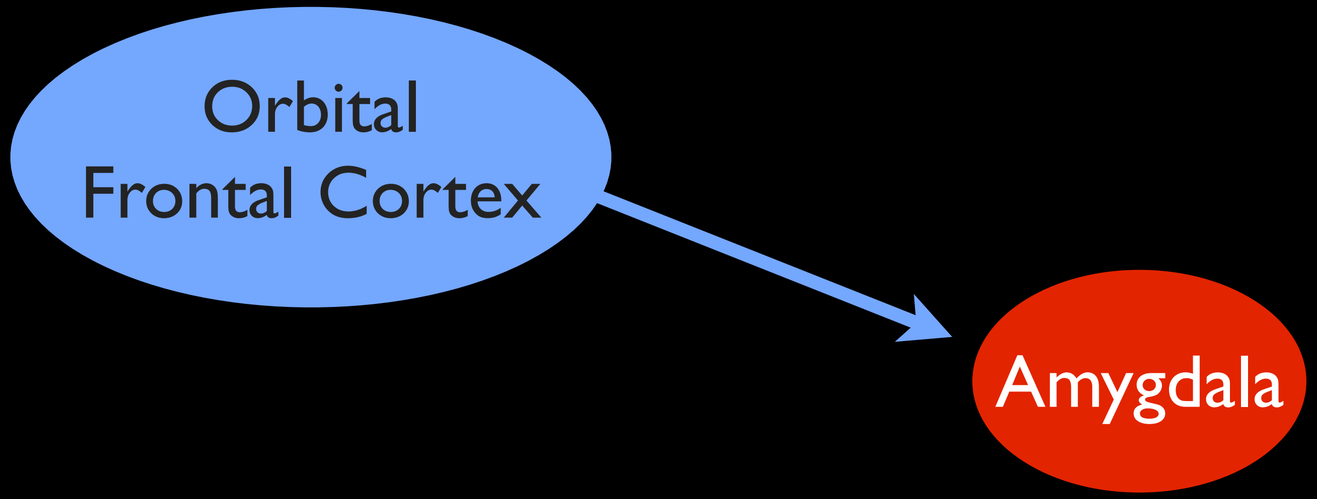
CDHD Symptom: Aggression



Nelson and Trainor, *Nature Reviews Neuroscience* 2007



CDHD Symptom: Aggression



Nelson and Trainor, *Nature Reviews Neuroscience* 2007

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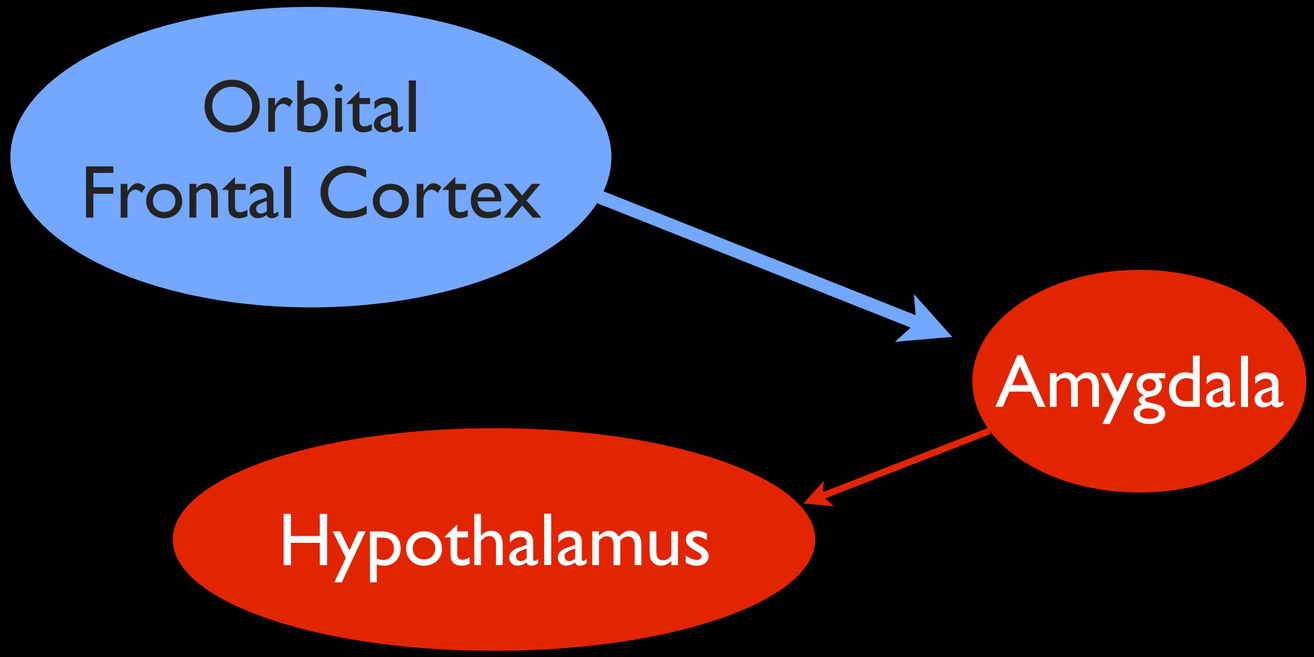

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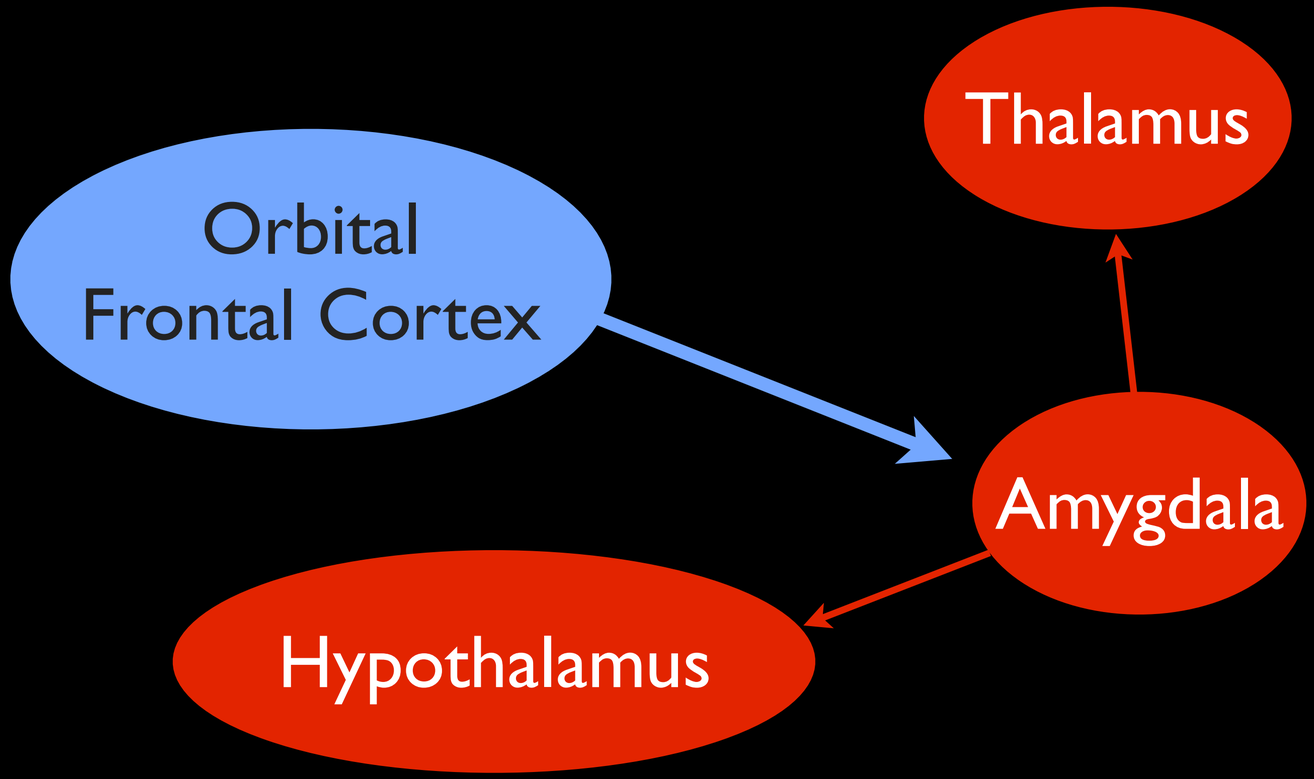

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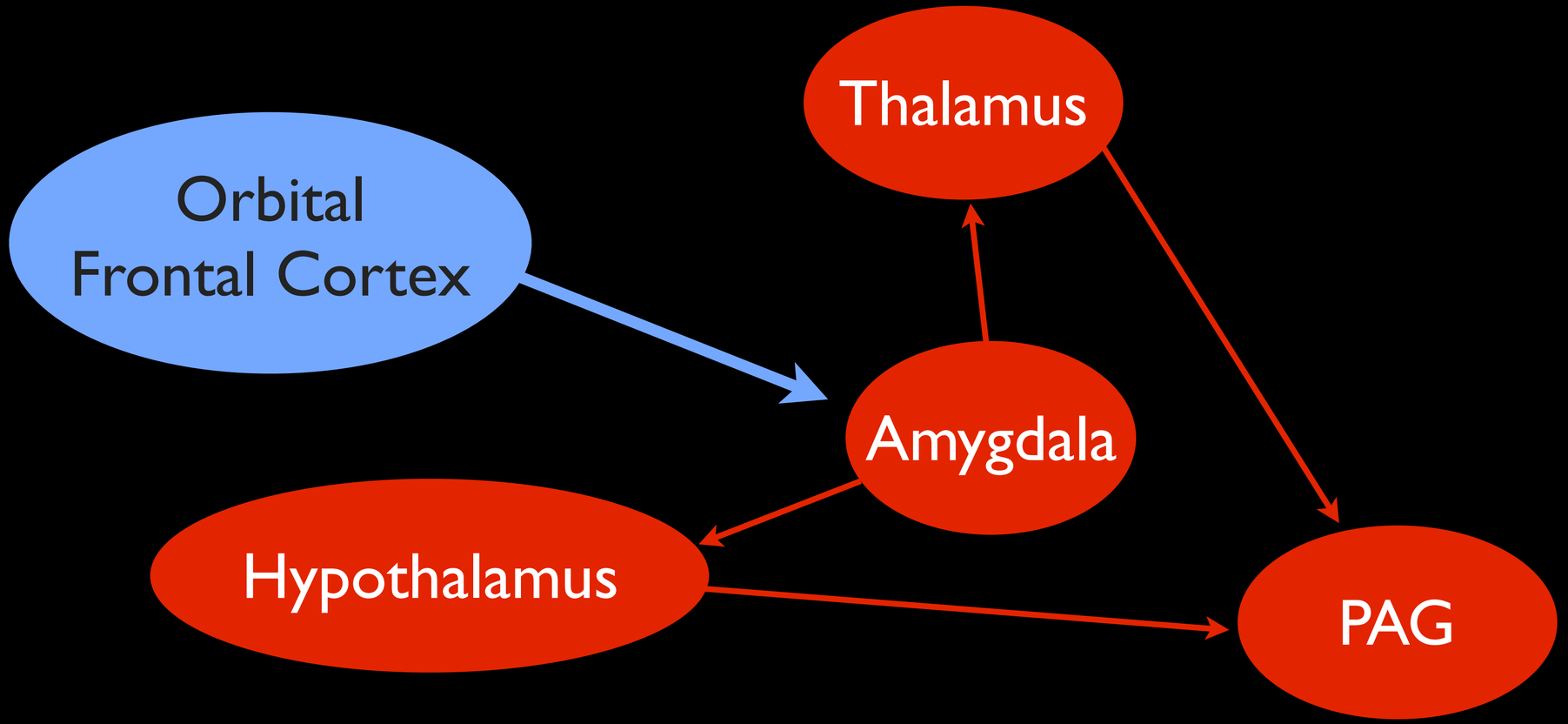

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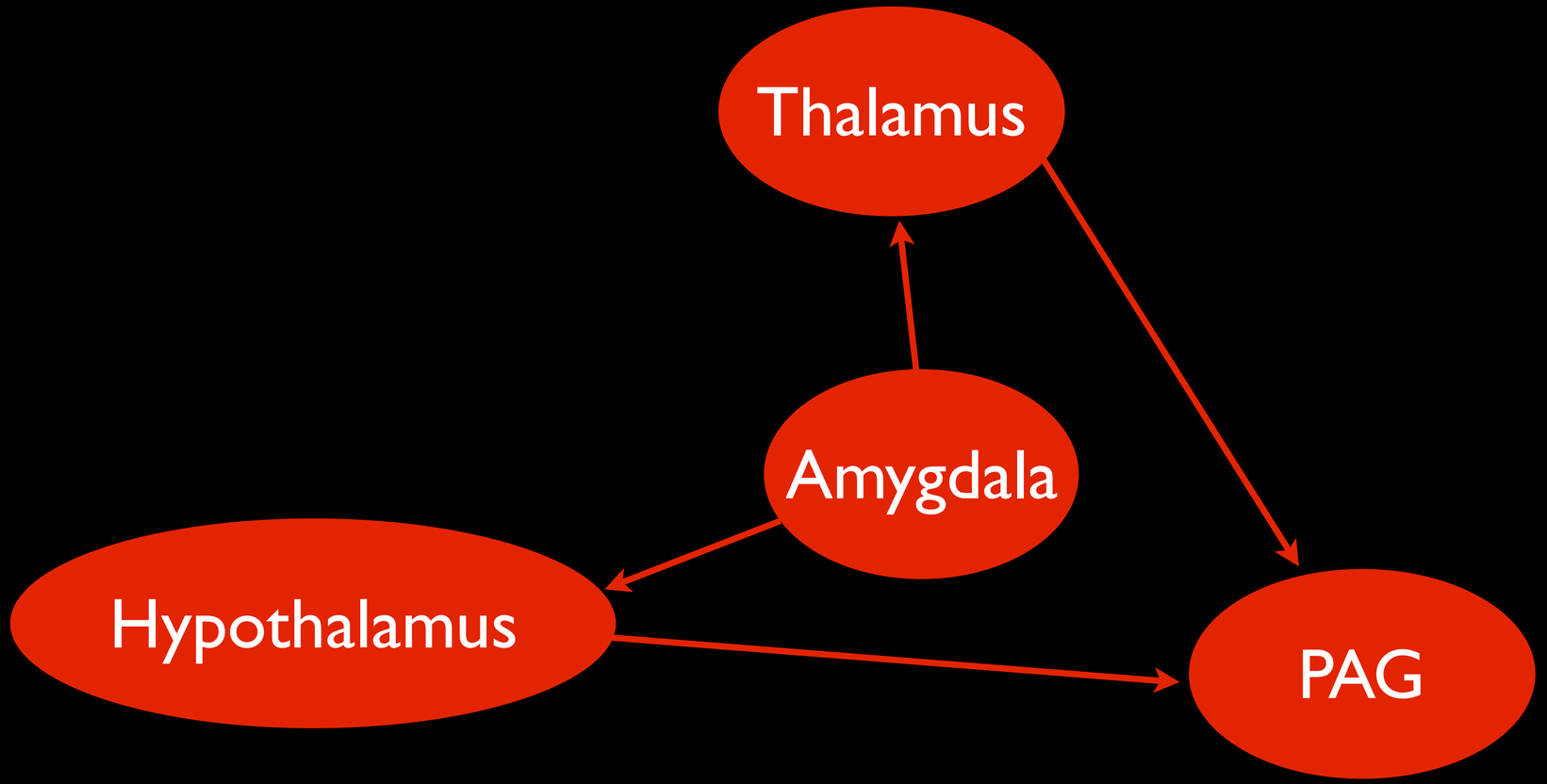

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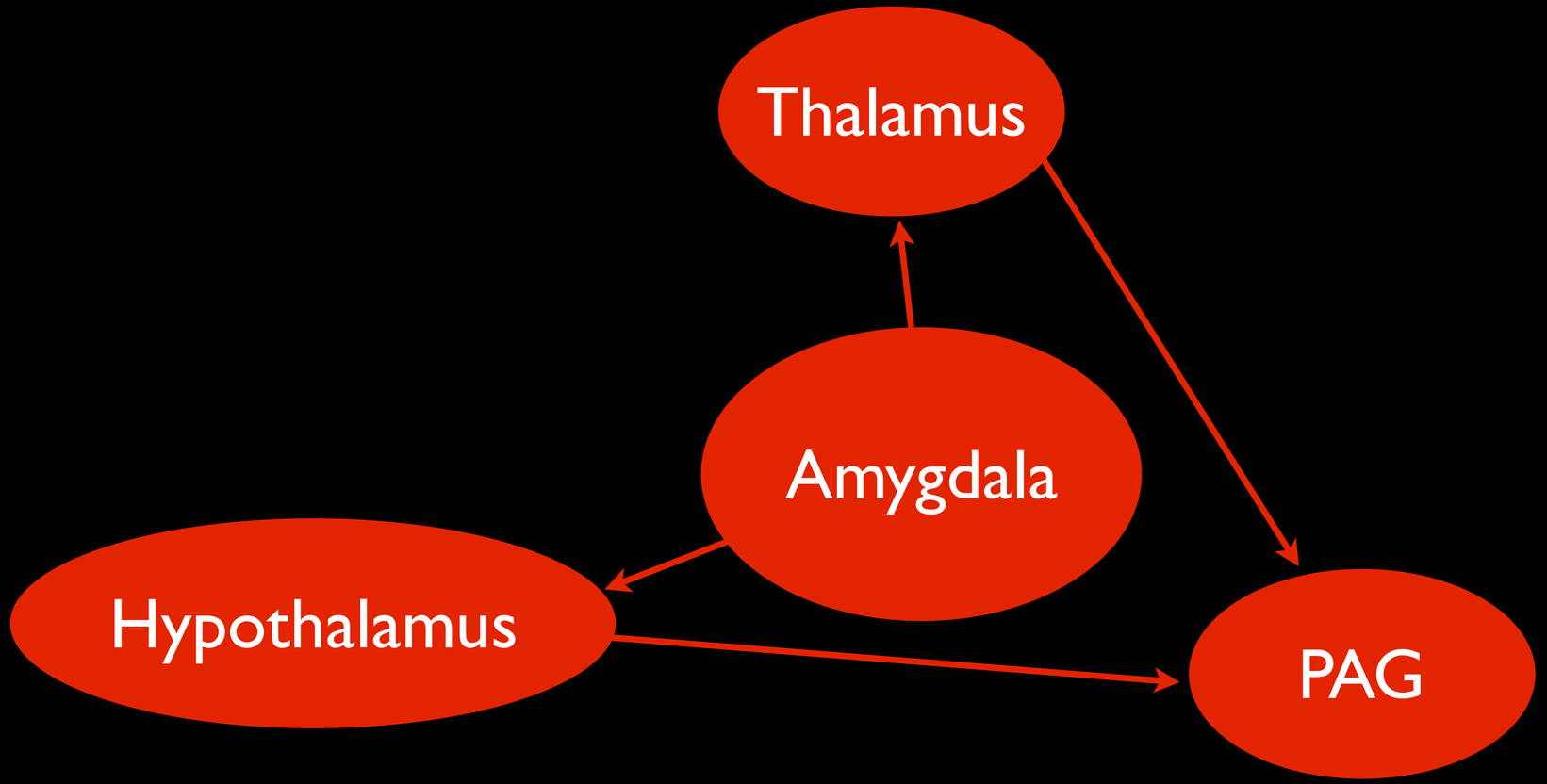

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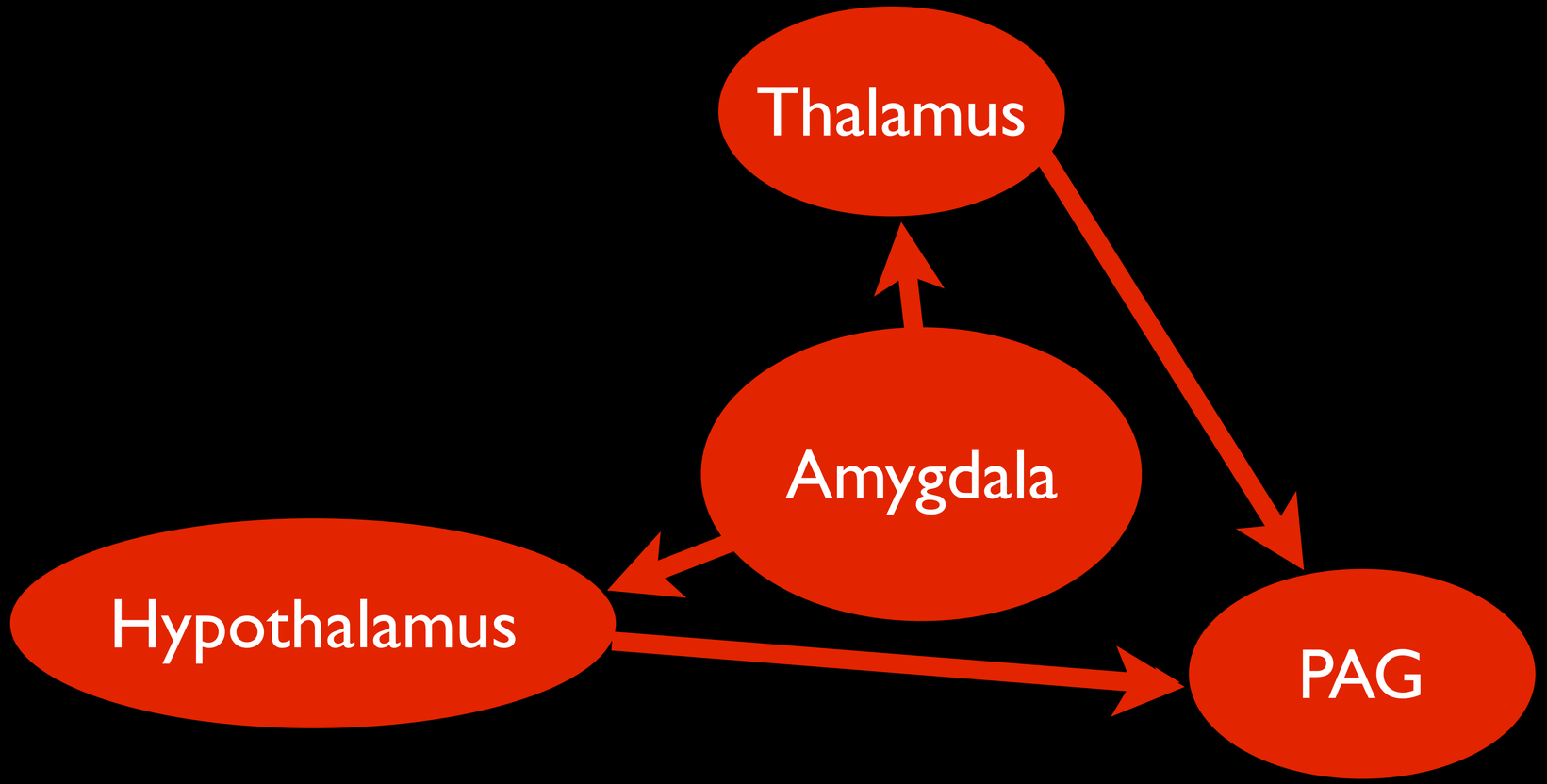

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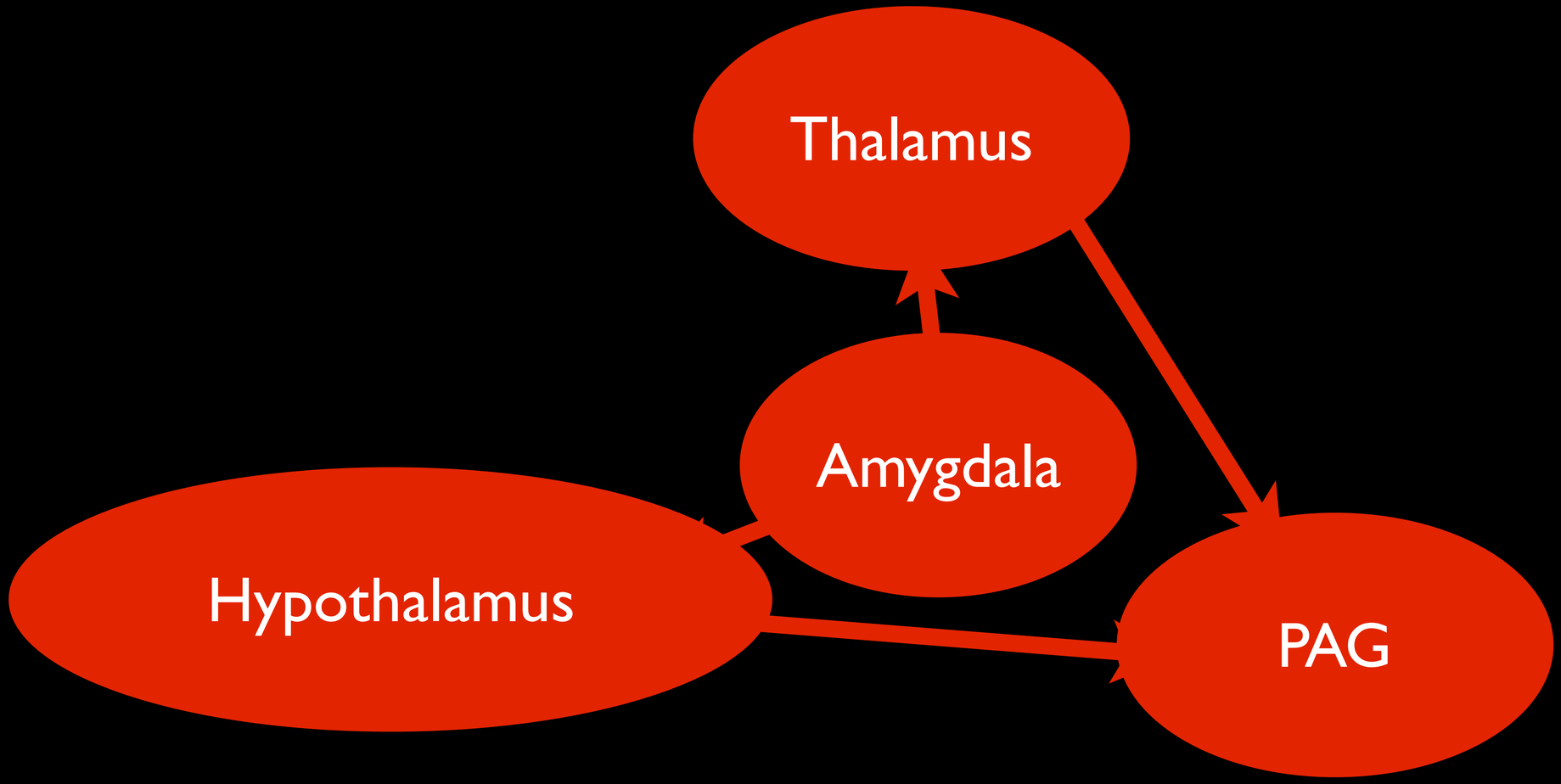

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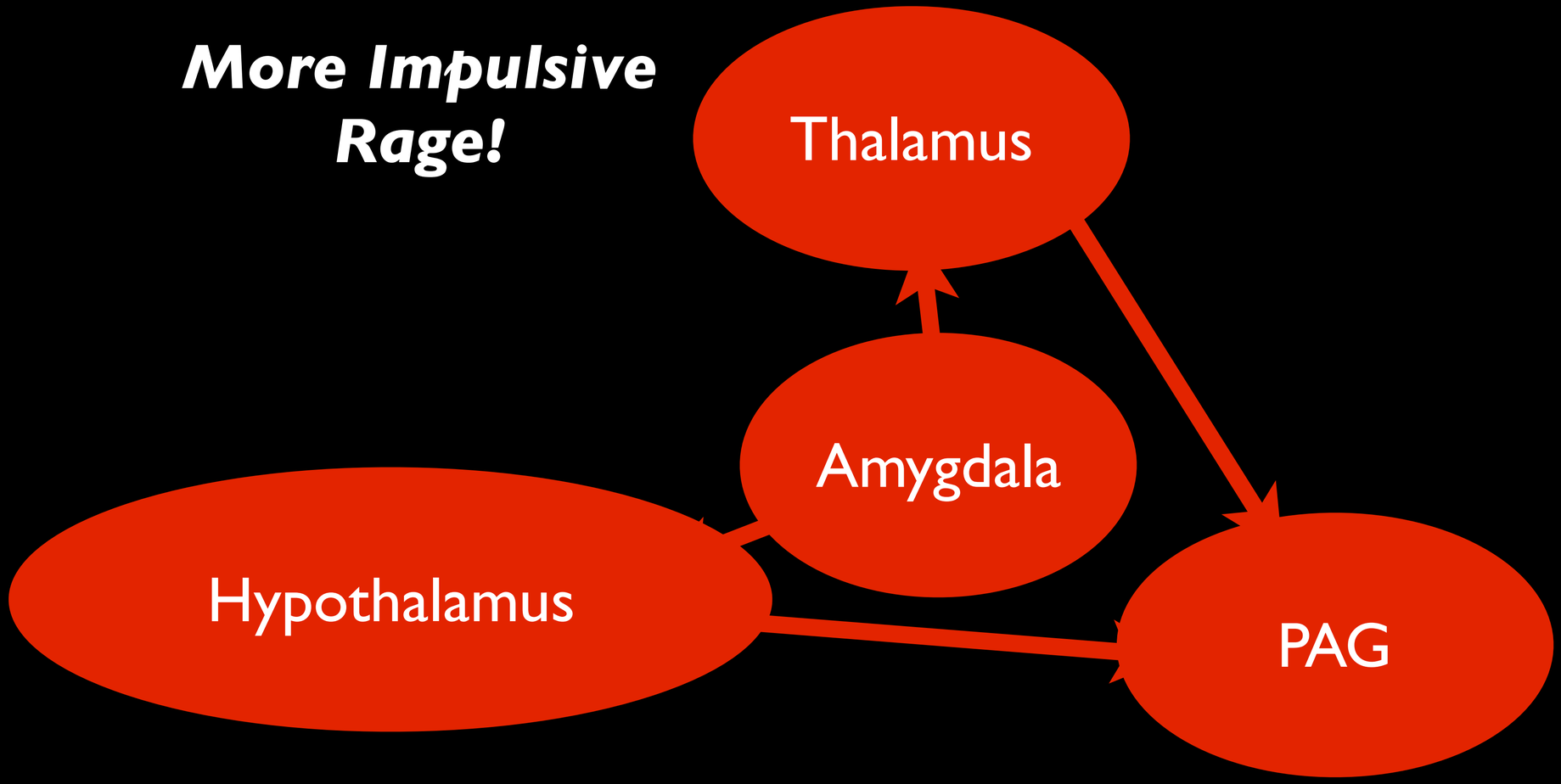
CDHD Symptom: Aggression

More Impulsive Rage!



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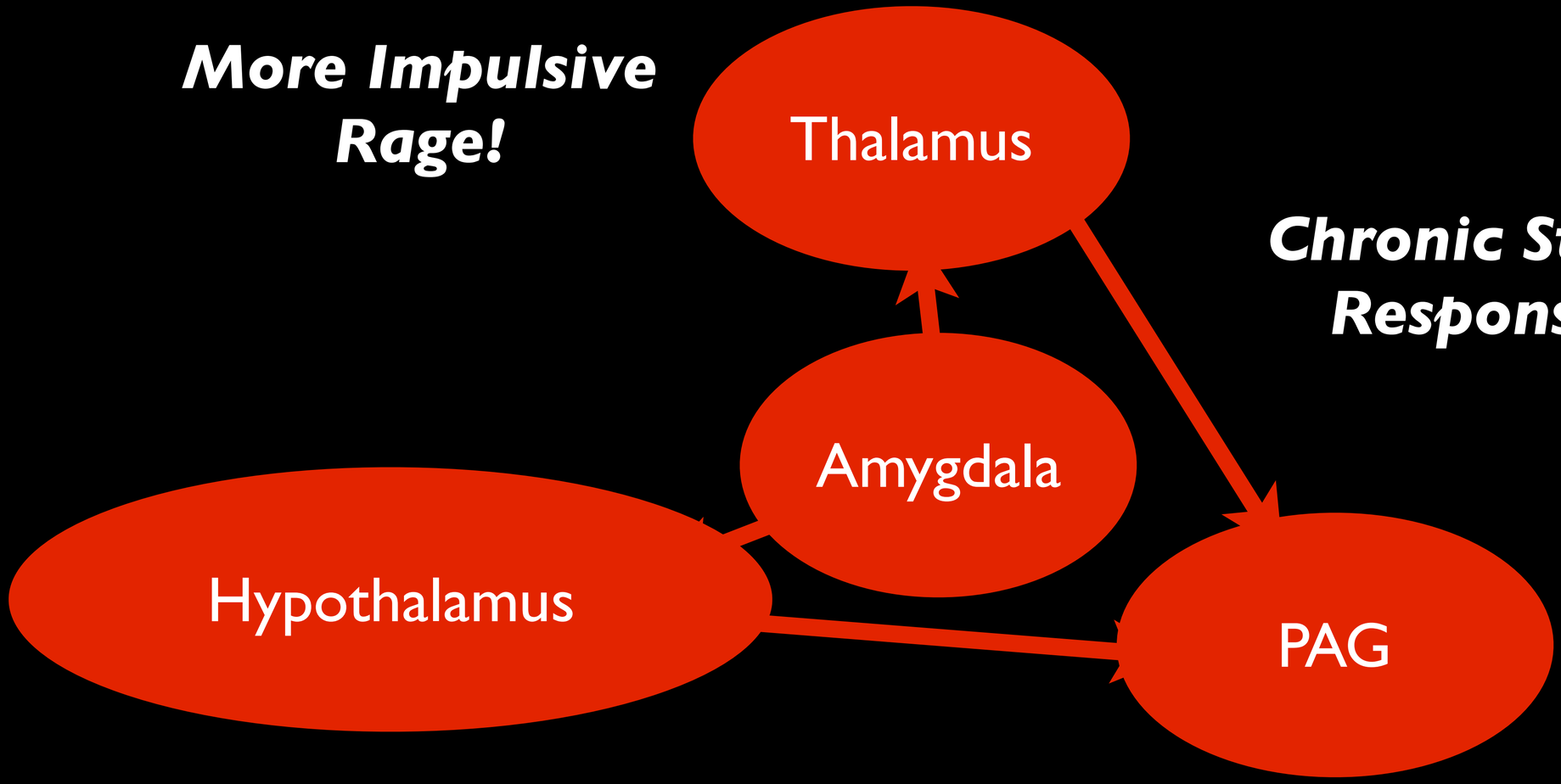
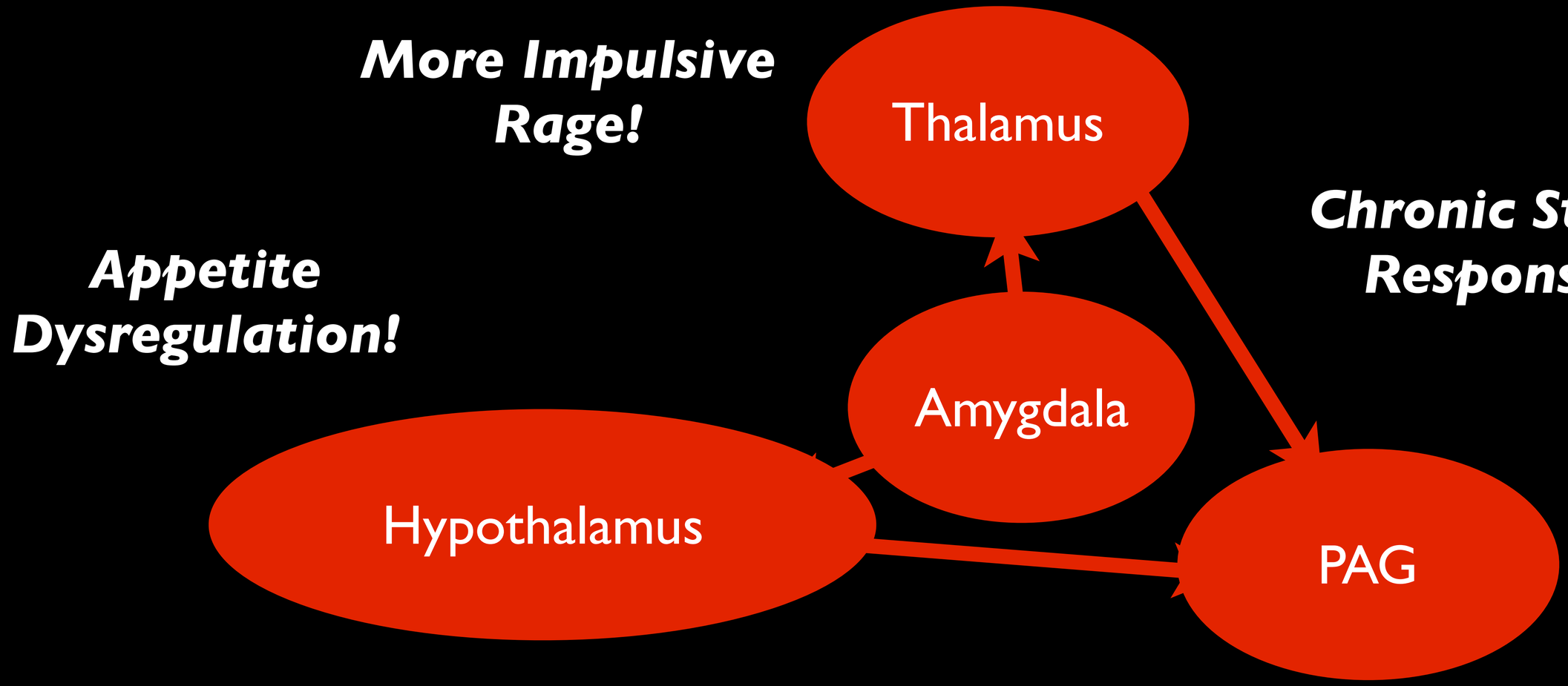


Chronic Stress Response!

Nelson and Trainor, *Nature Reviews Neuroscience* 2007

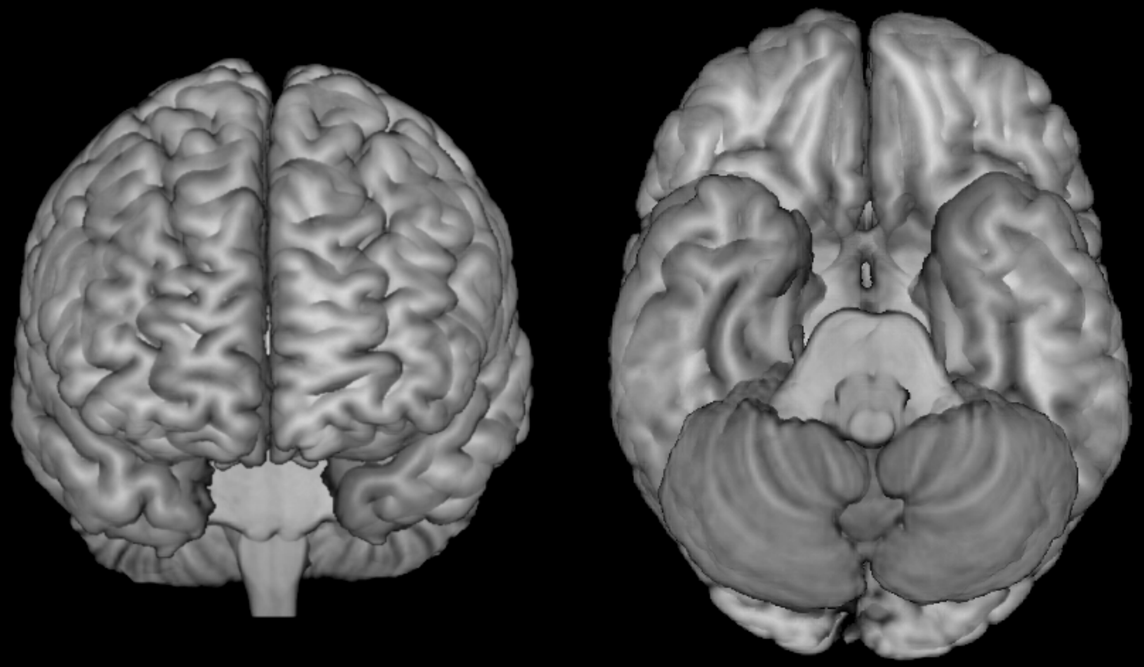
CDHD Symptom: Aggression



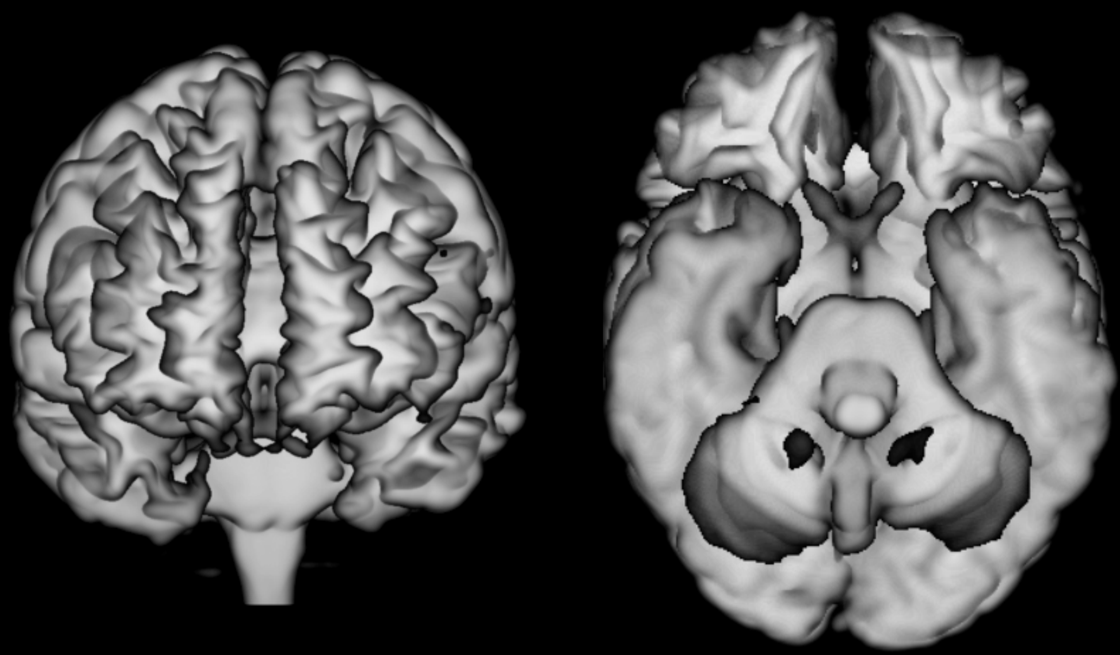
Nelson and Trainor, *Nature Reviews Neuroscience* 2007

CDHD Symptom: Aggression

Human

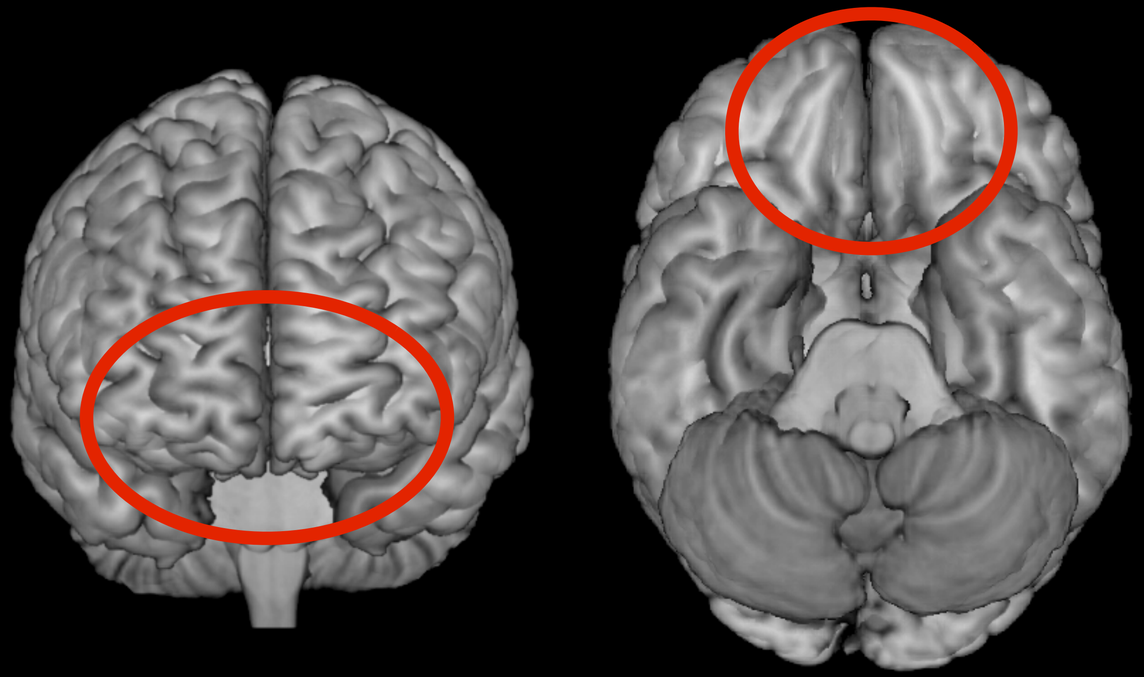


Zombie

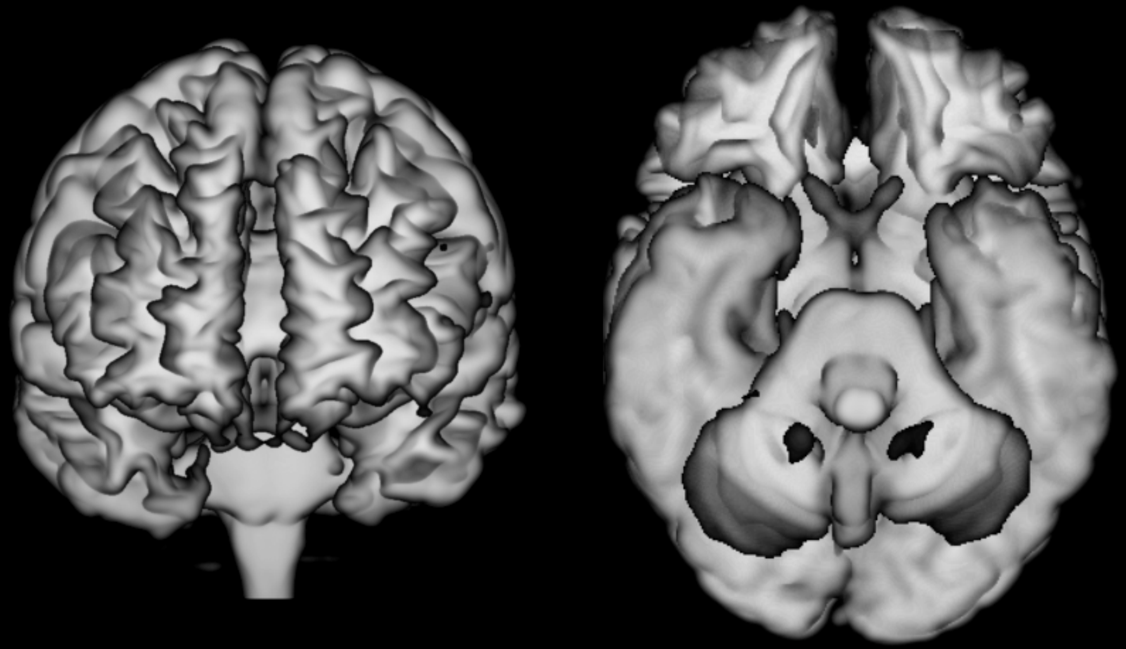


CDHD Symptom: Aggression

Human



Zombie



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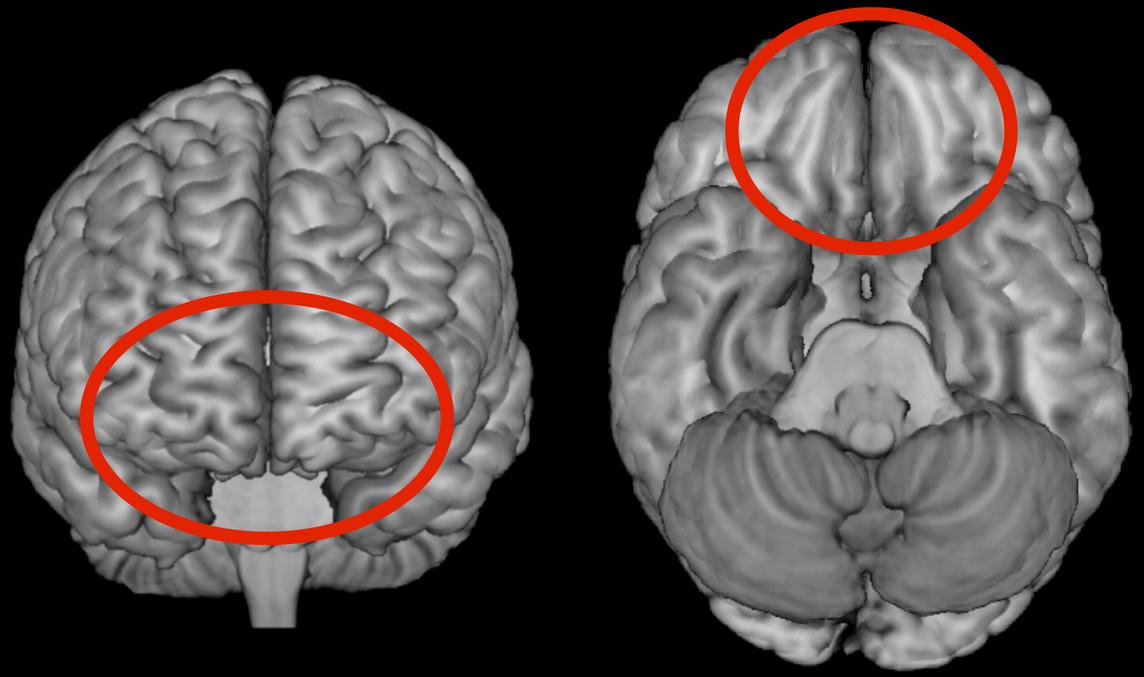
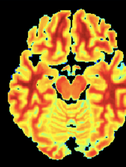


Zombie

Atrophy of the Orbital Frontal Areas!



CDHD Symptom: Aggression

Amygdala

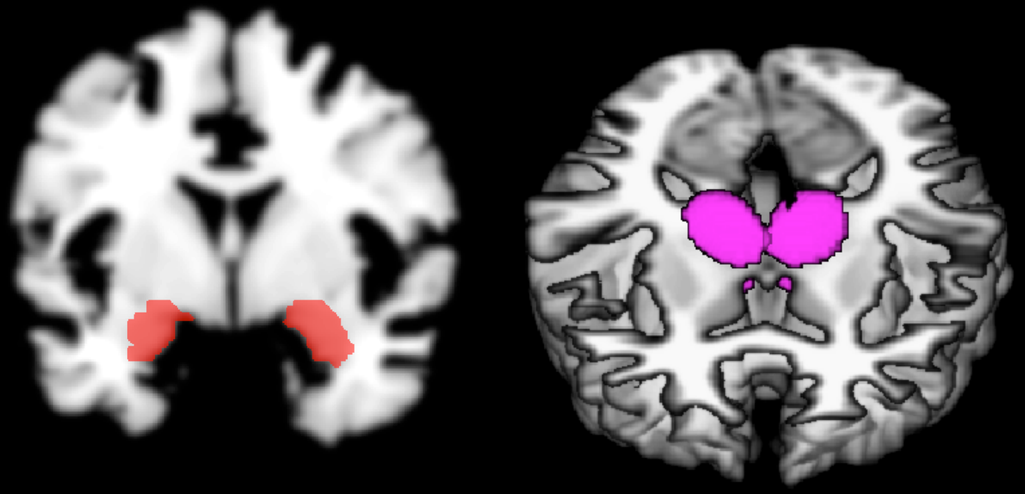
Thalamus

Voxel Based Morphometry

CDHD Symptom: Aggression

Amygdala

Thalamus



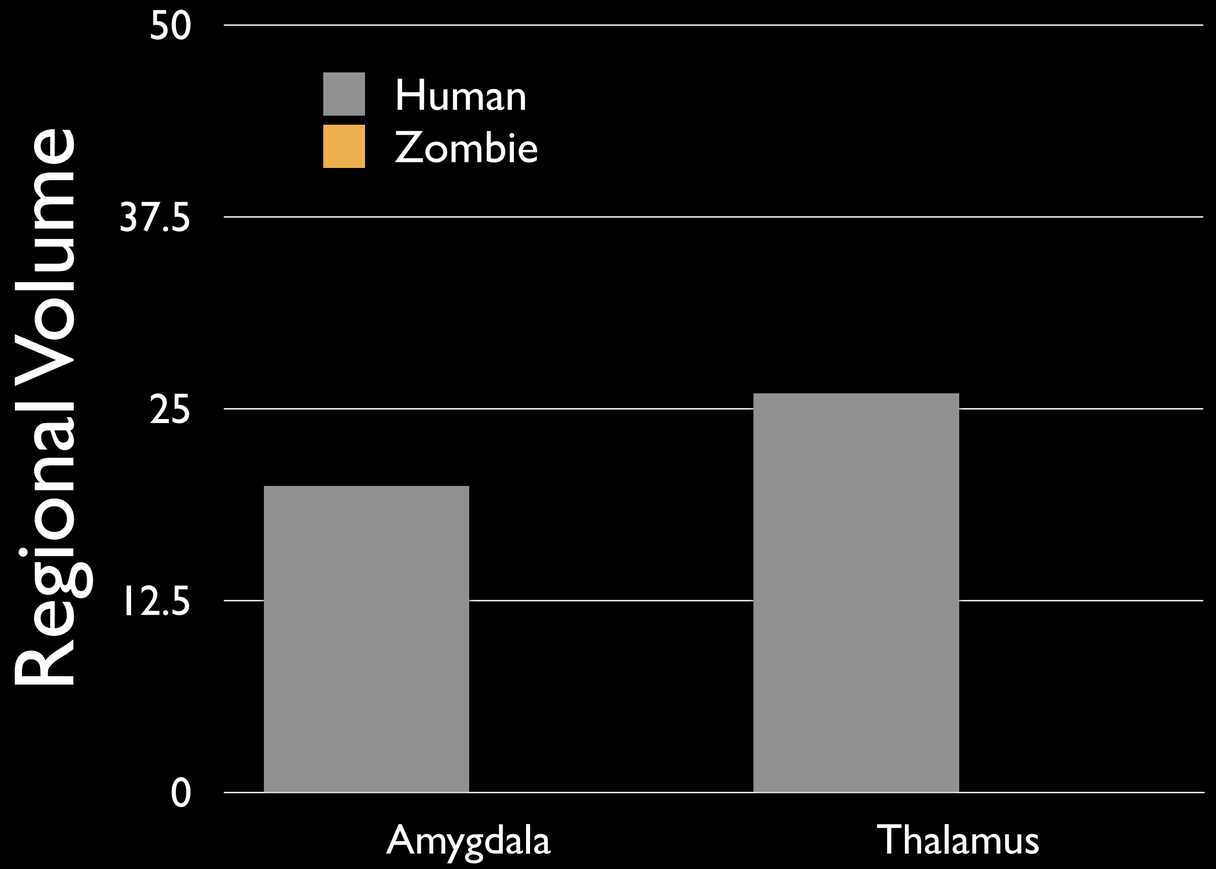
Voxel Based Morphometry

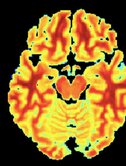
CDHD Symptom: Aggression

Amygdala

Thalamus

Voxel Based Morphometry

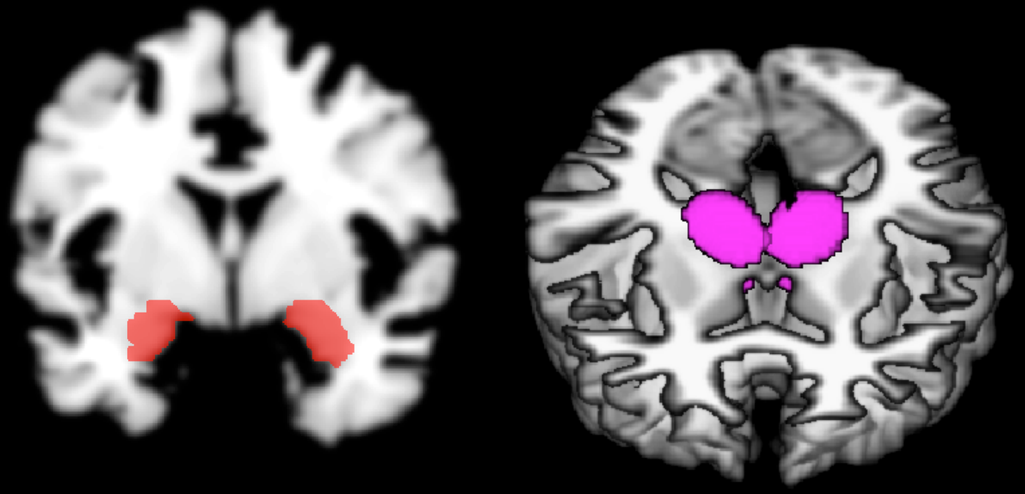




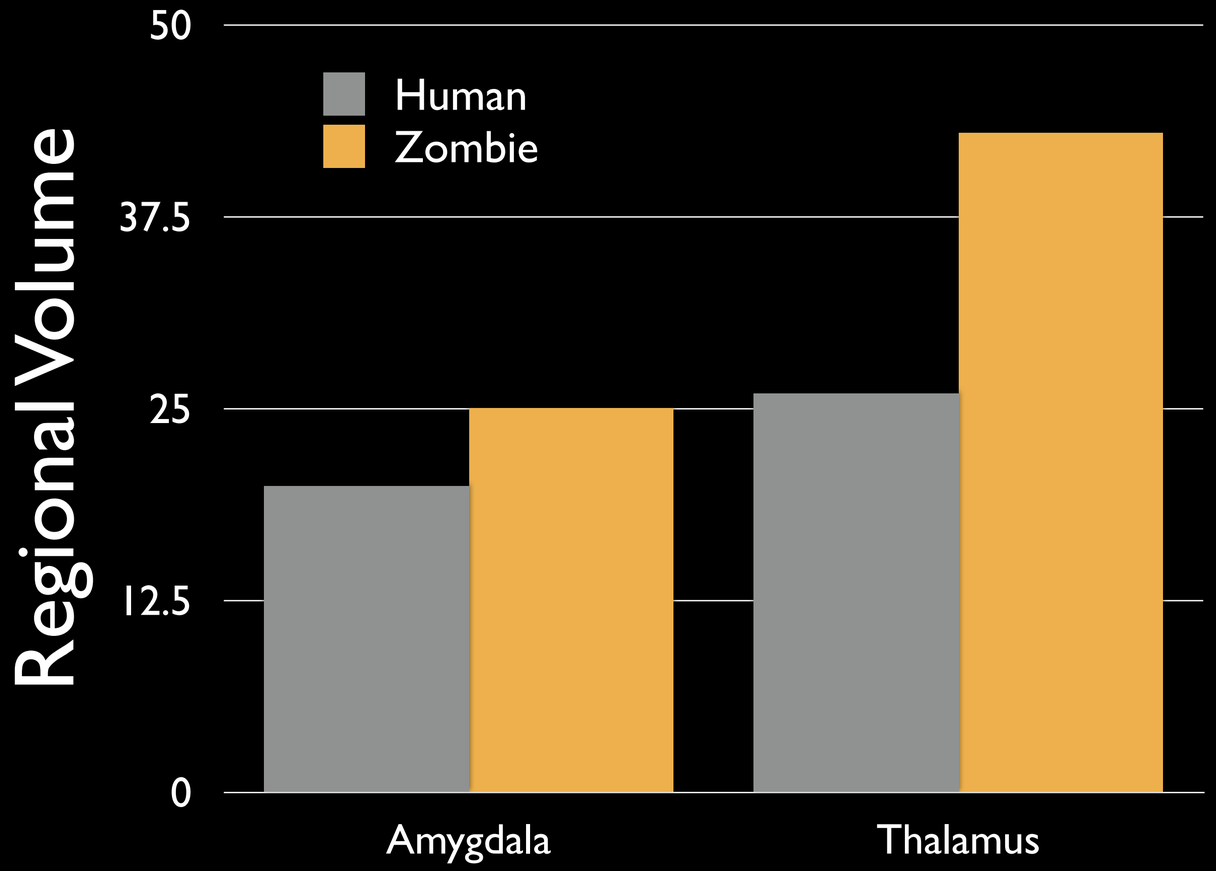
CDHD Symptom: Aggression

Amygdala

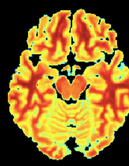
Thalamus



Voxel Based Morphometry



Enlarged Amygdala and Thalamus



CDHD Symptom: Visual Recognition

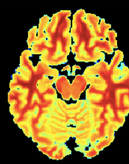
Zombieland

Shaun of the Dead

CDHD Symptom: Visual Recognition

Capgras Delusion: The false belief the people you know well have been replaced by imposters and typically seen as a threat.

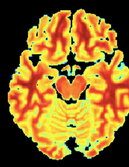
Capgras & Reboul-Lachaux, *Bulletin de la Société Clinique de Médicine Mentale* 1923



CDHD Symptom: Visual Recognition

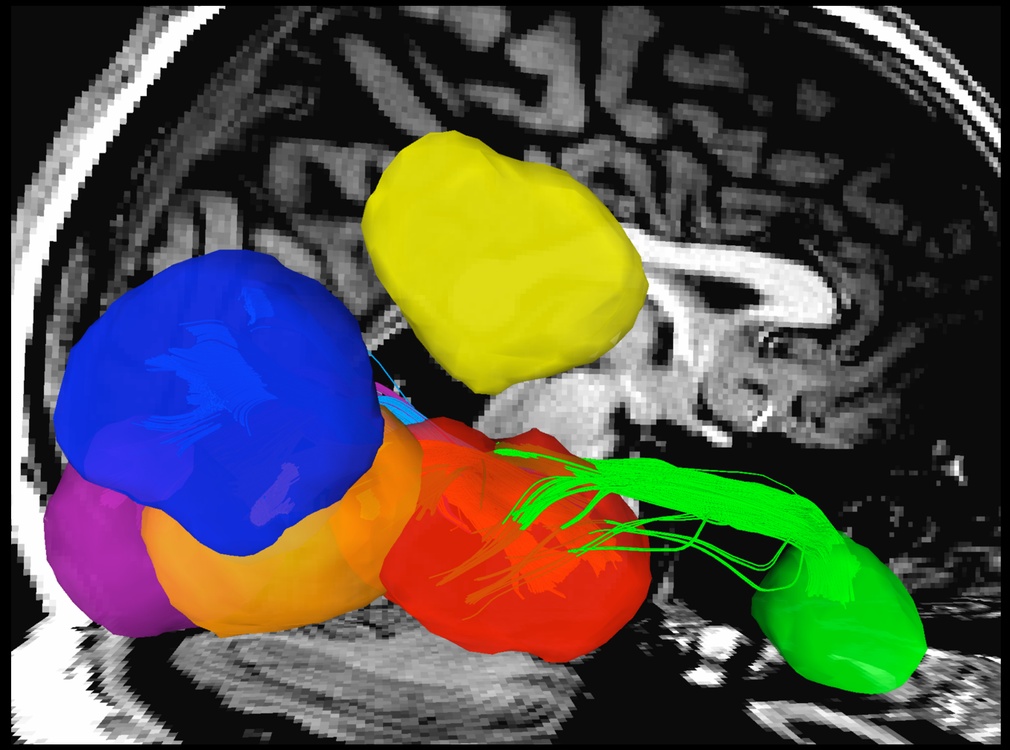
Prosopagnosia: The inability to link a person's identity to the visual image of their face.

CITE



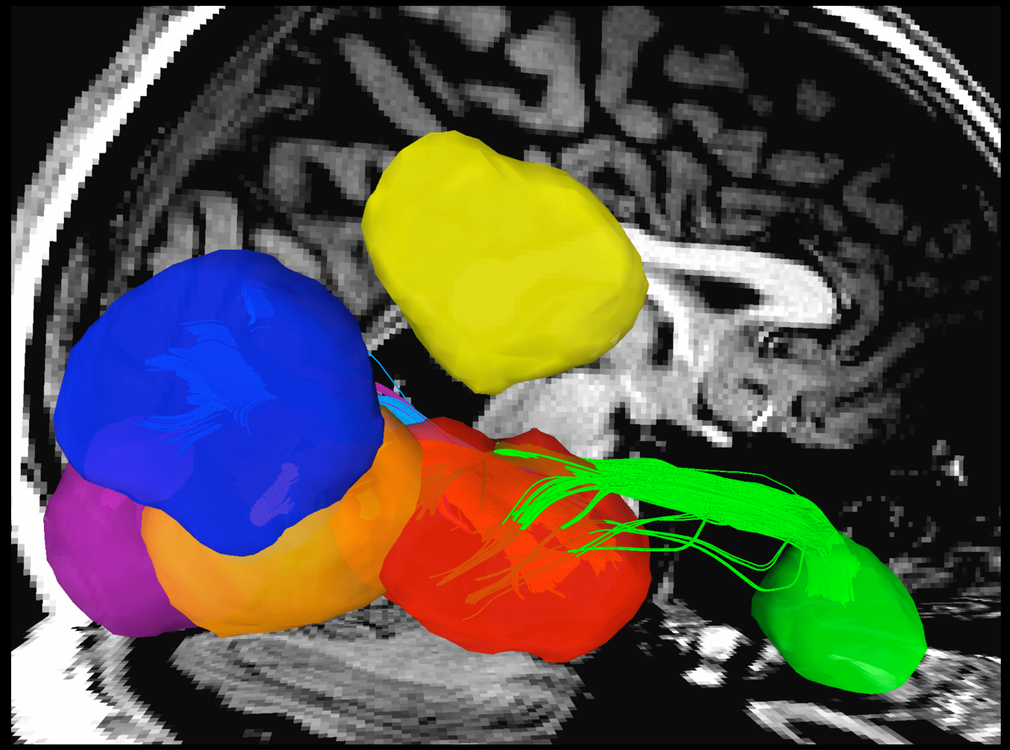
CDHD Symptom: Visual Recognition

"core" face network



CDHD Symptom: Visual Recognition

"core" face network



Courtesy of John Pyles and Mike Tarr

CDHD Symptom: Visual Recognition

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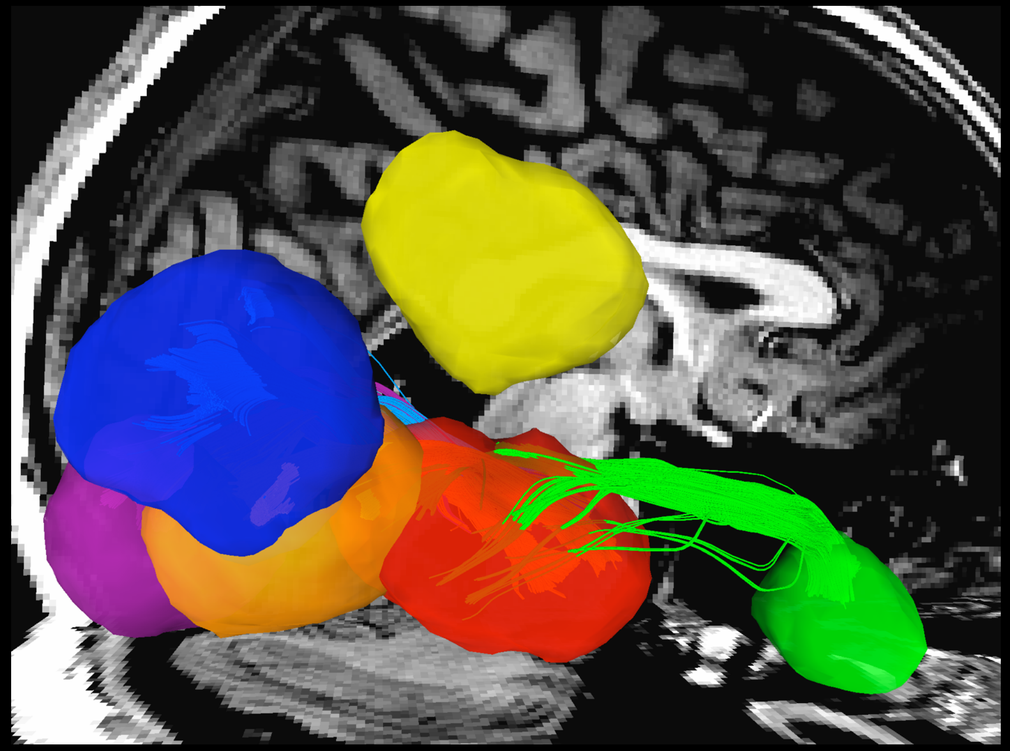
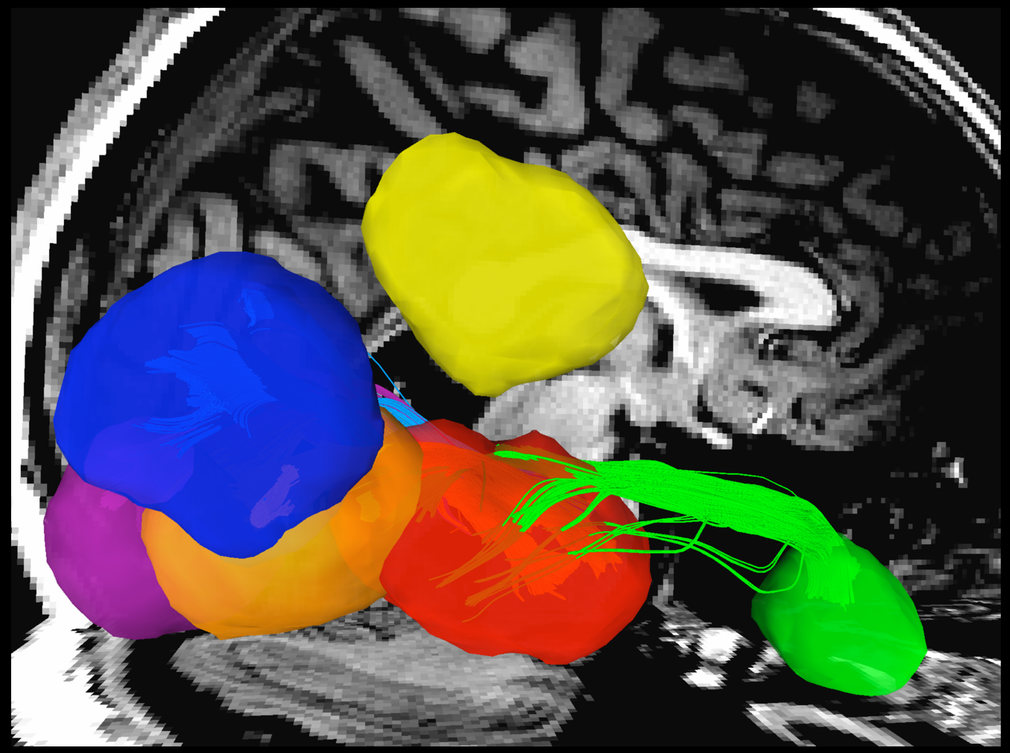


Courtesy of John Pyles and Mike Tarr

CDHD Symptom: Visual Recognition

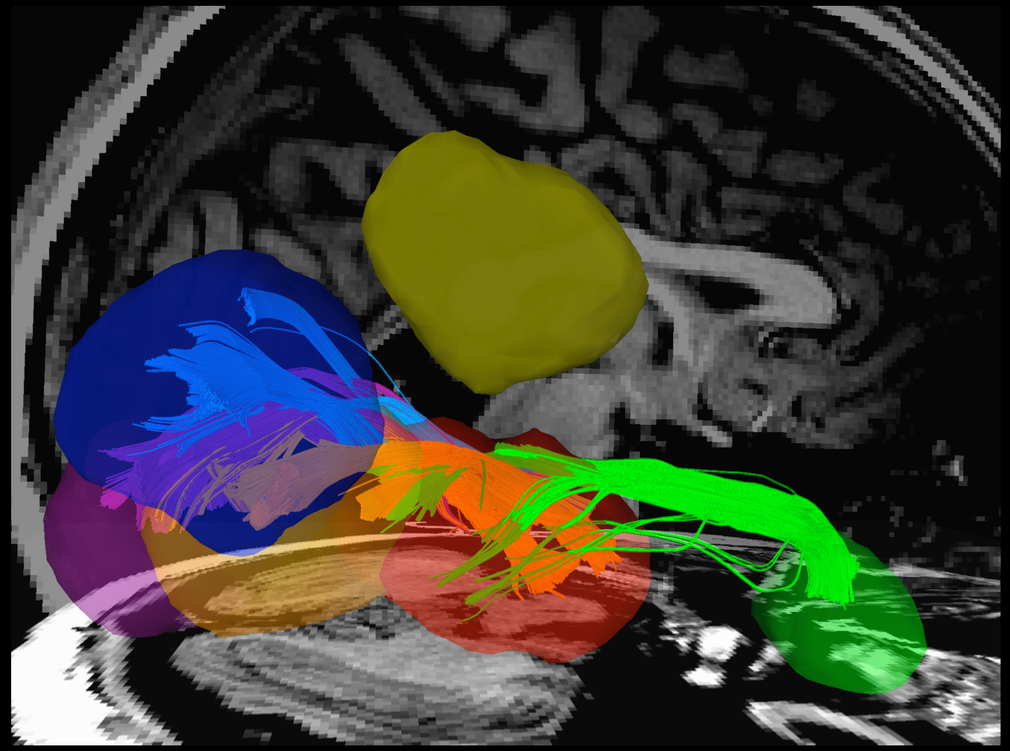
"core" face network



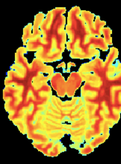
Courtesy of John Pyles and Mike Tarr

CDHD Symptom: Visual Recognition

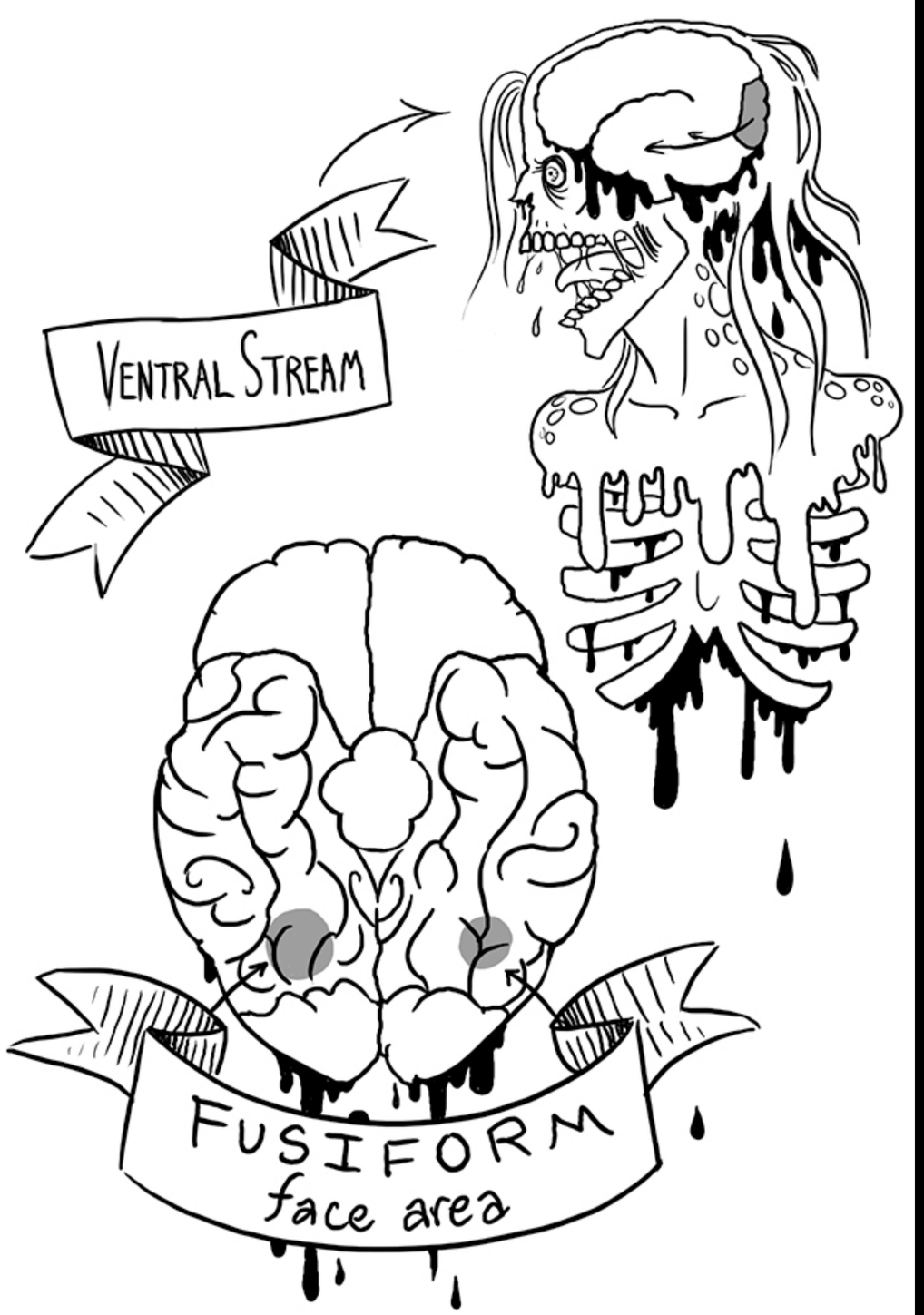
"core" face network

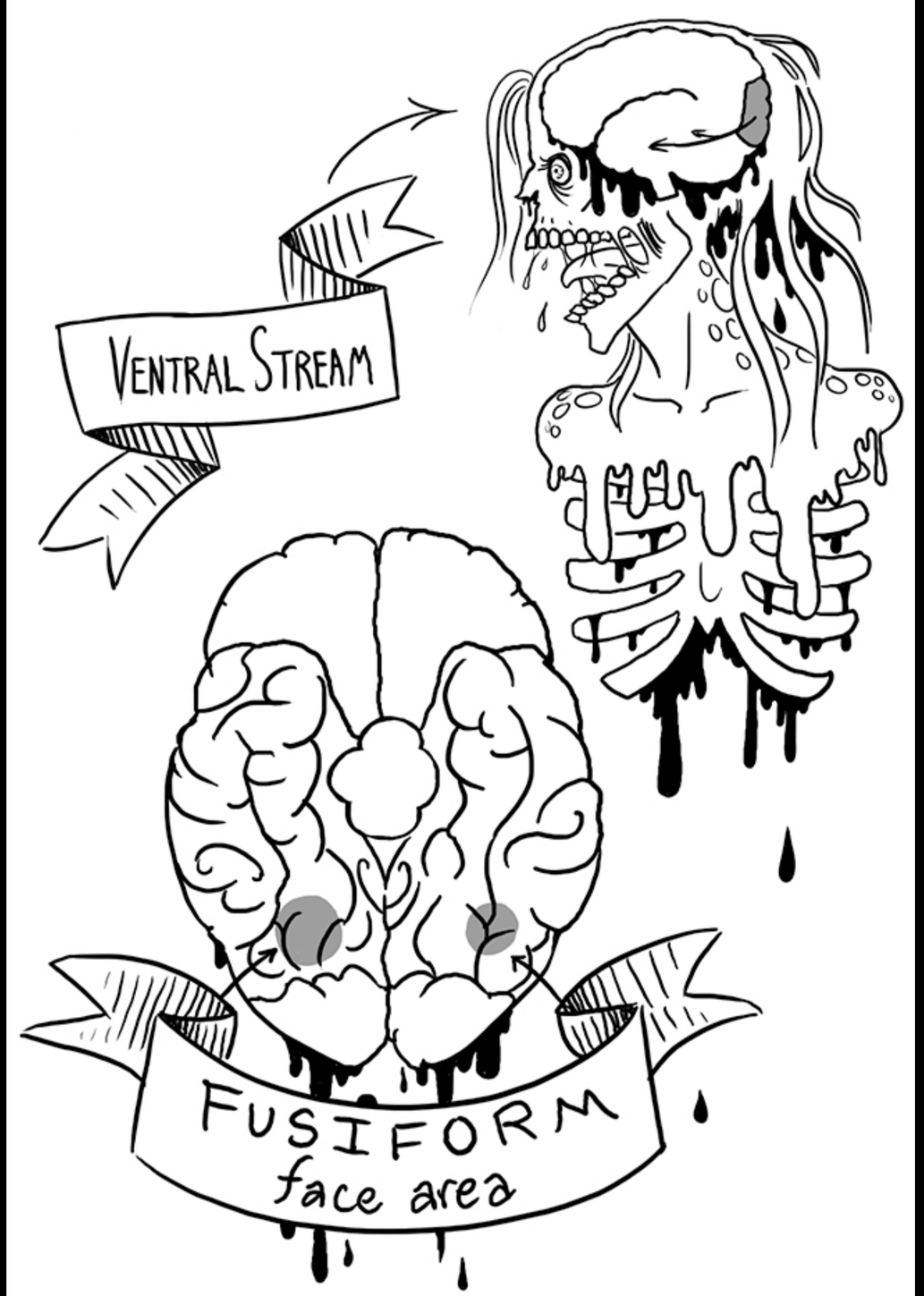


Courtesy of John Pyles and Mike Tarr



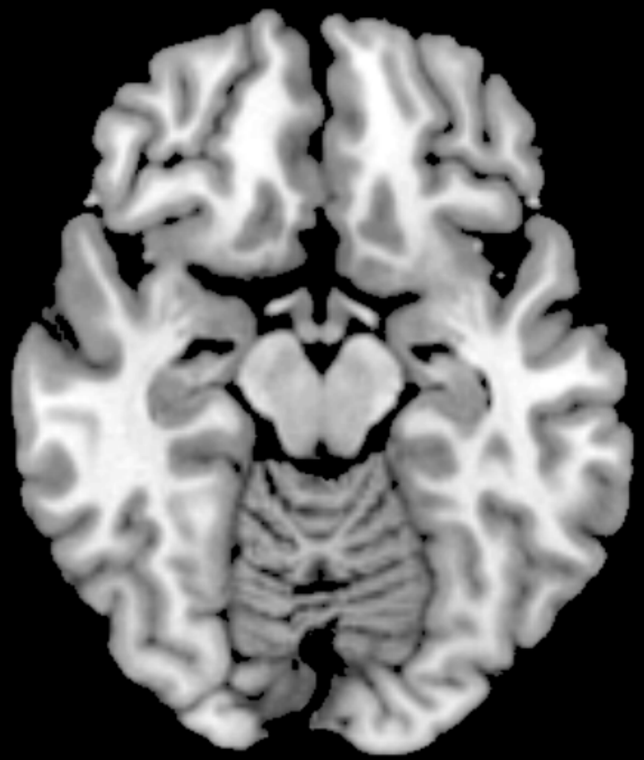
The “What” Pathway

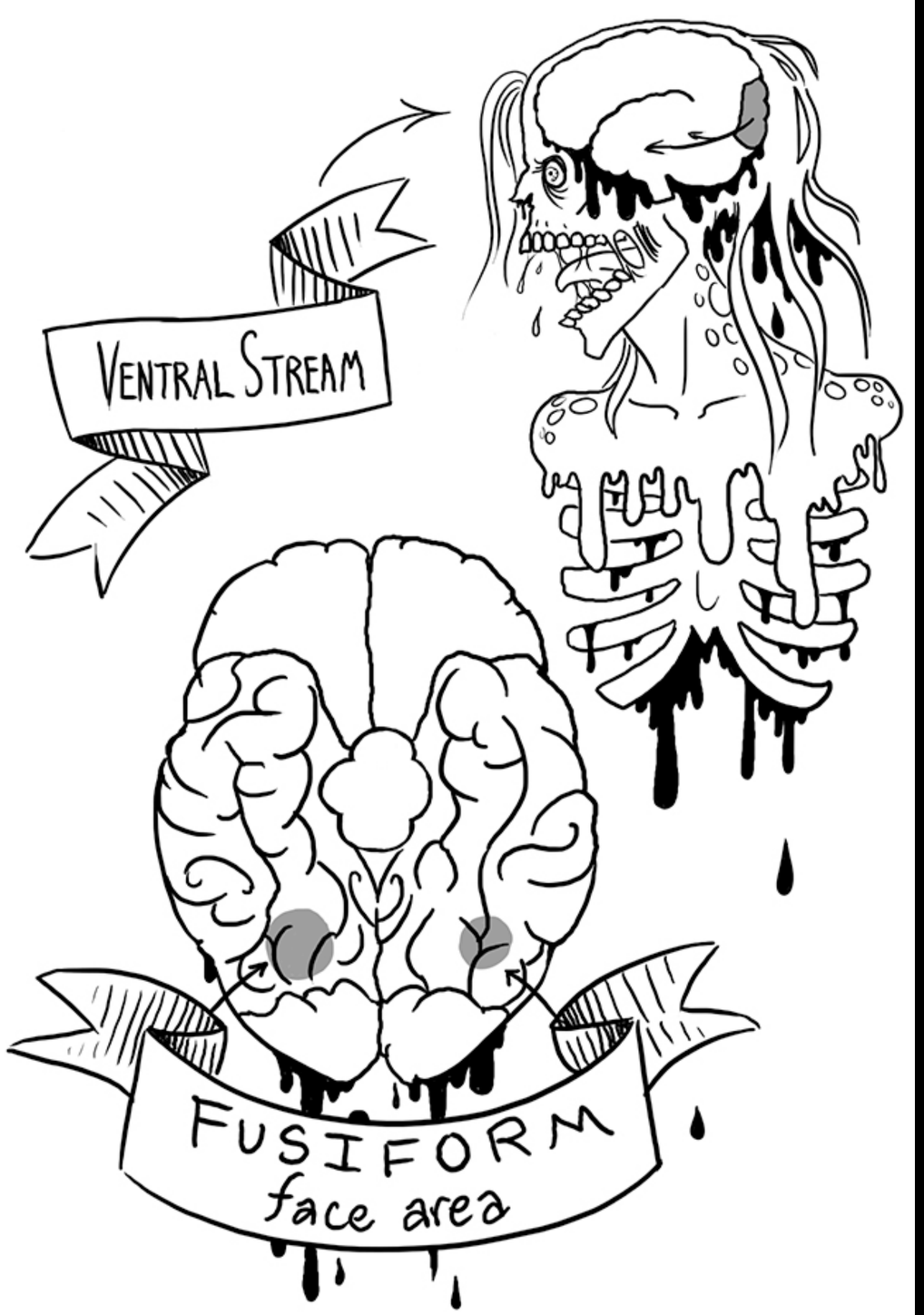




The “What” Pathway

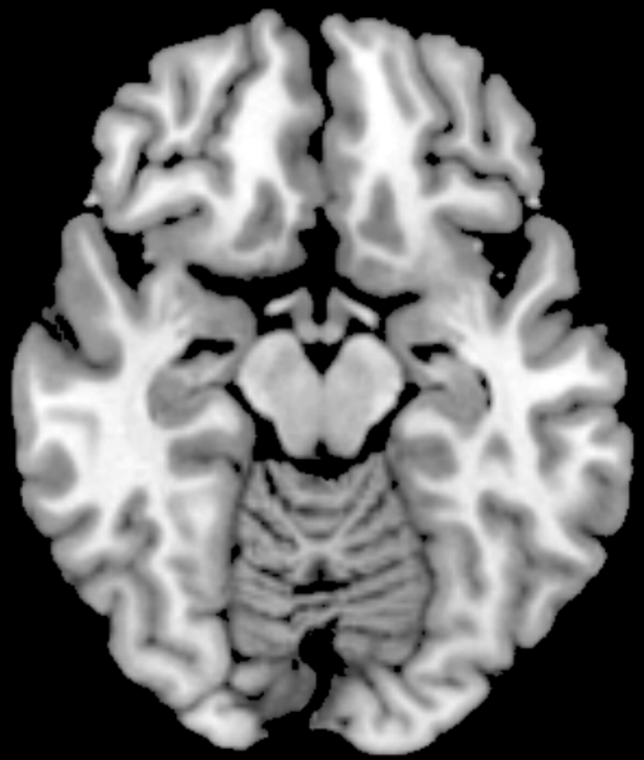
Human



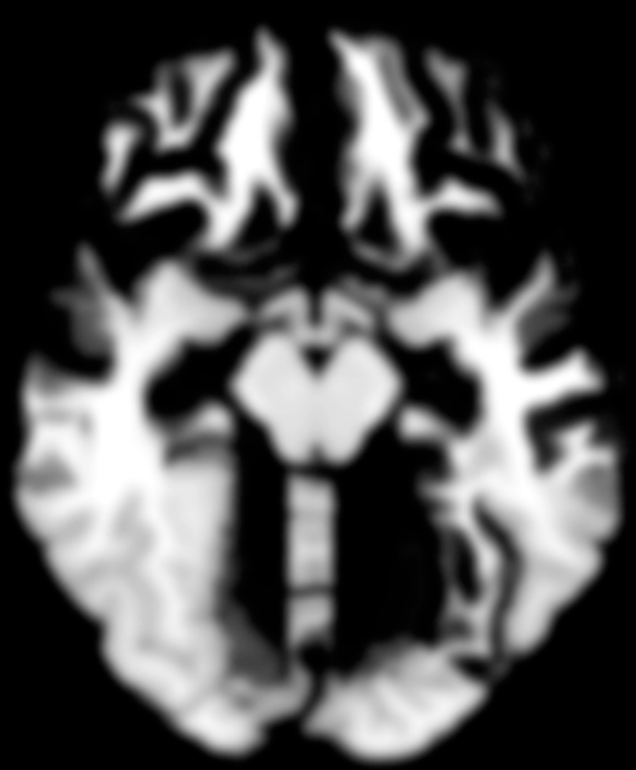


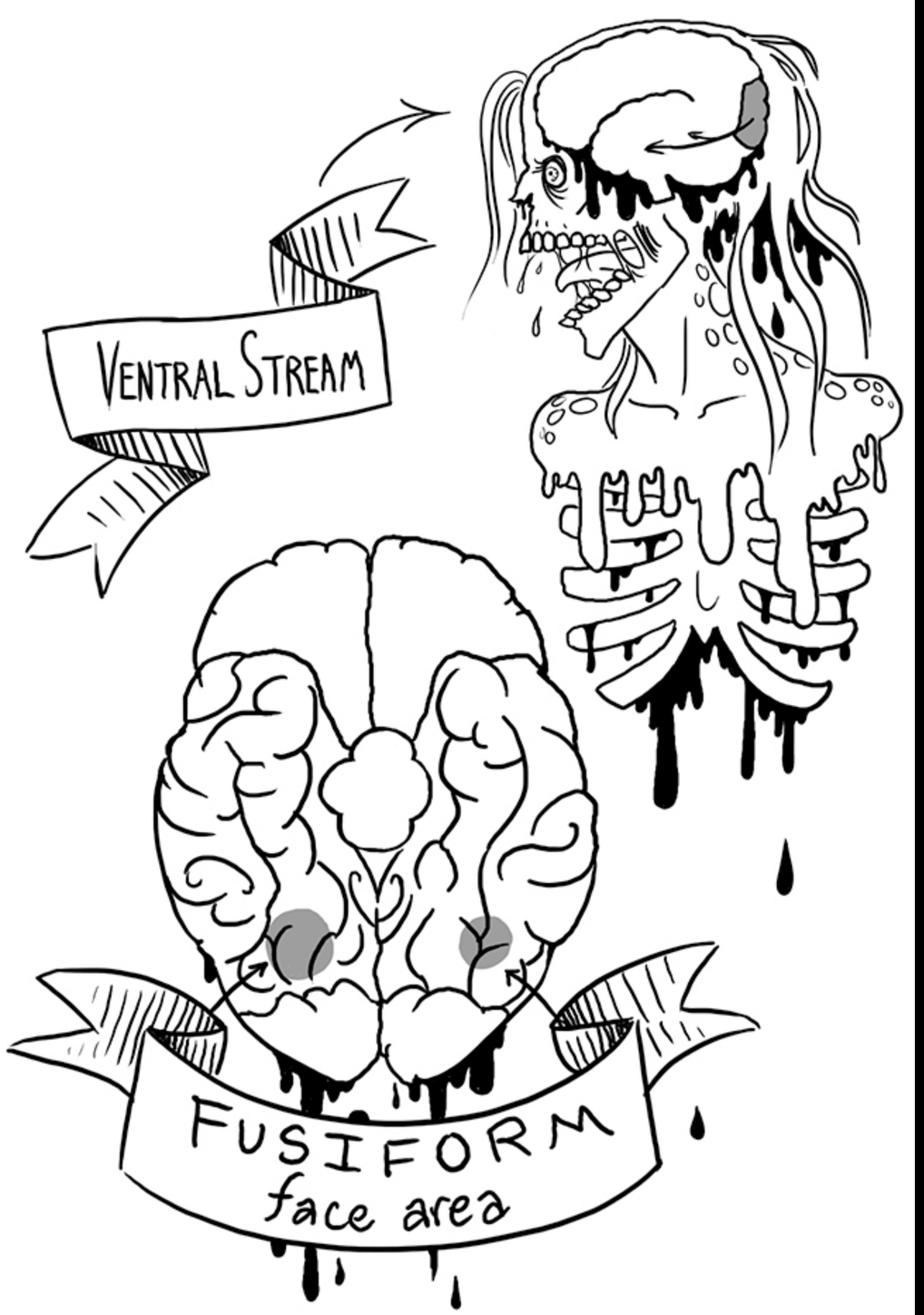
The "What" Pathway

Human



Zombie

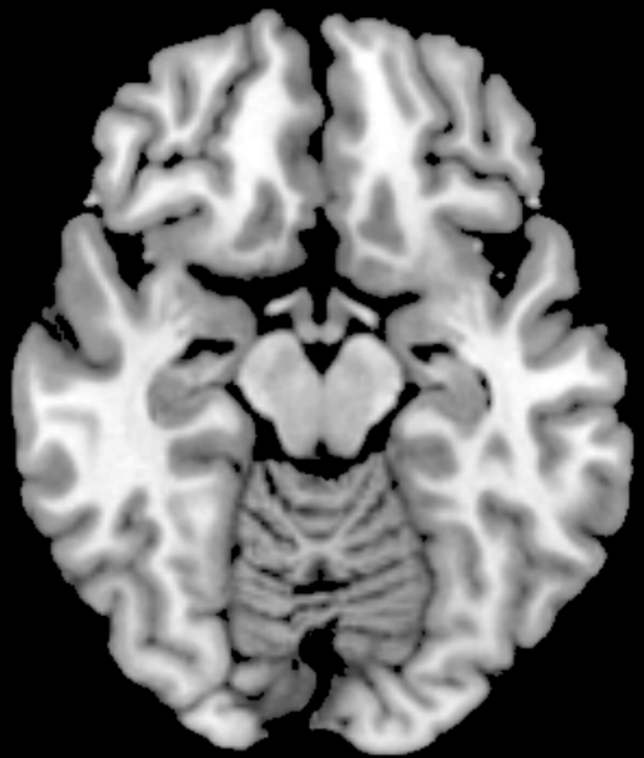


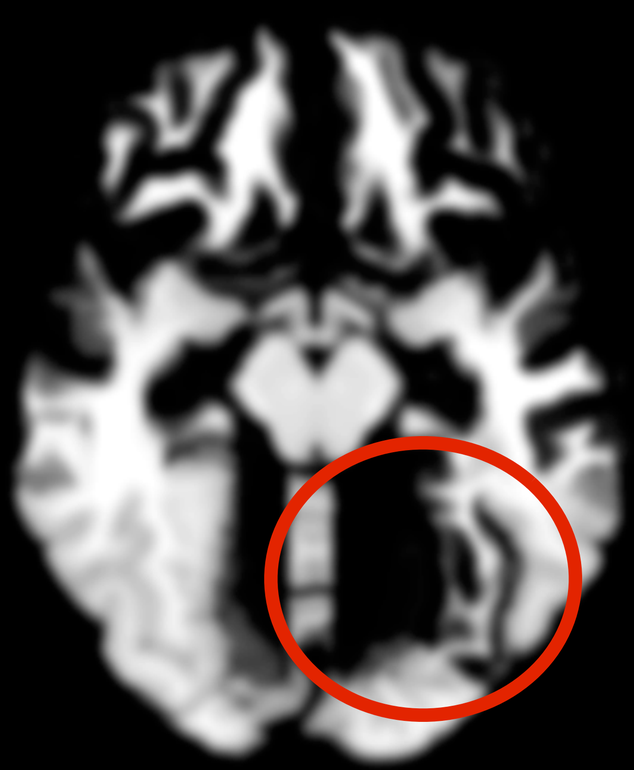


The "What" Pathway

Human

Zombie





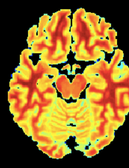
CDHD Symptom: Language Deficits

Return of the Living Dead

CDHD Symptom: Language Deficits

Aphasia: The inability to produce ("Broca's aphasia") or difficulty in comprehending ("Wernicke's aphasia") language.

Dronker and colleagues, *Cognition* 2004



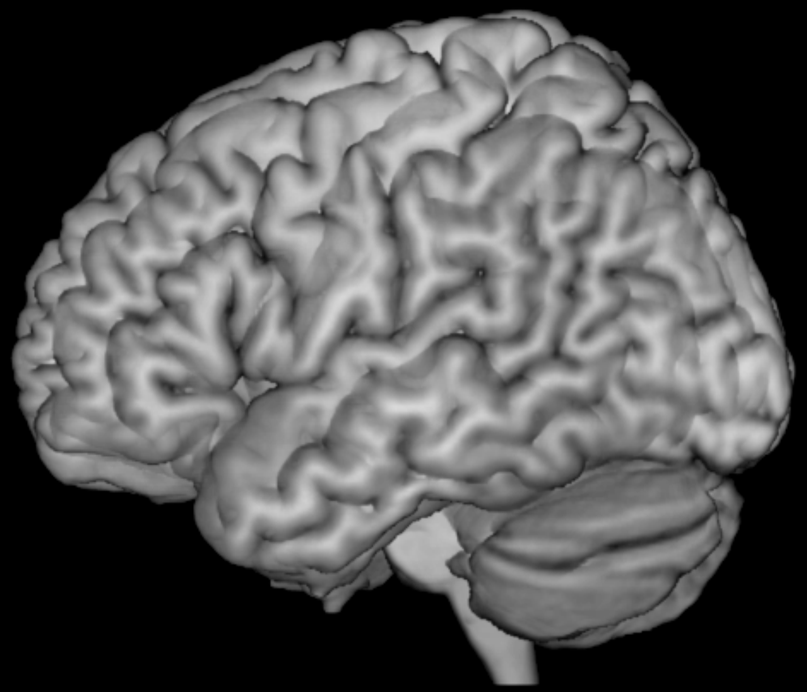
- **<u>Broca's Area</u>**: Region in the frontal lobe linked to language production.

- **<u>Broca's Area</u>**: Region in the frontal lobe linked to language production.
- **<u>Wernicke's Area</u>**: Region where the temporal and parietal lobes meet linked to language comprehension.

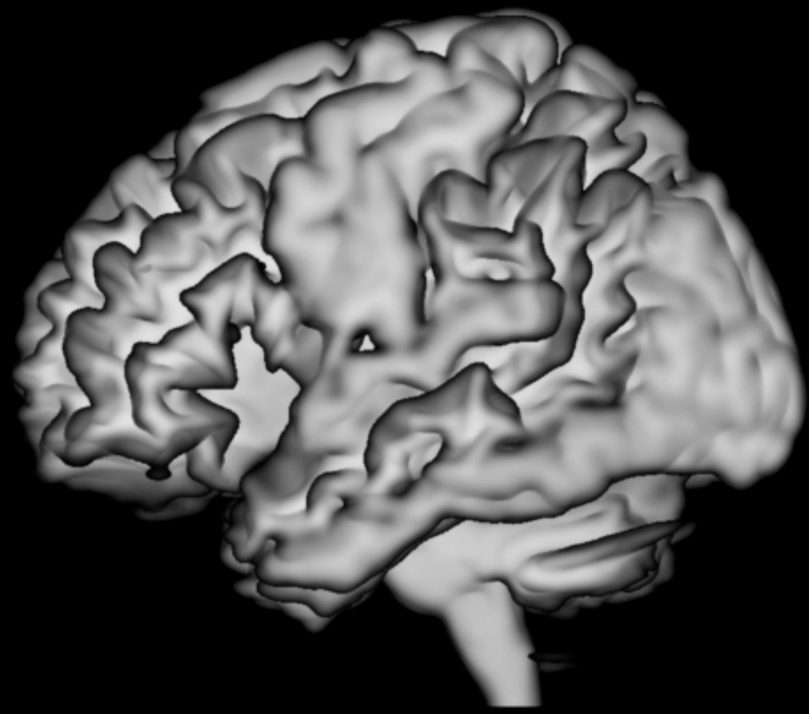
- **Broca's Area**: Region in the frontal lobe linked to language production.
- **Wernicke's Area**: Region where the temporal and parietal lobes meet linked to language comprehension.
- **Arcuate Fasiculus**: Large bundle of fibers that connect Wernicke's & Broca's areas together.

CDHD Symptom: Language Deficits

Human



Zombie

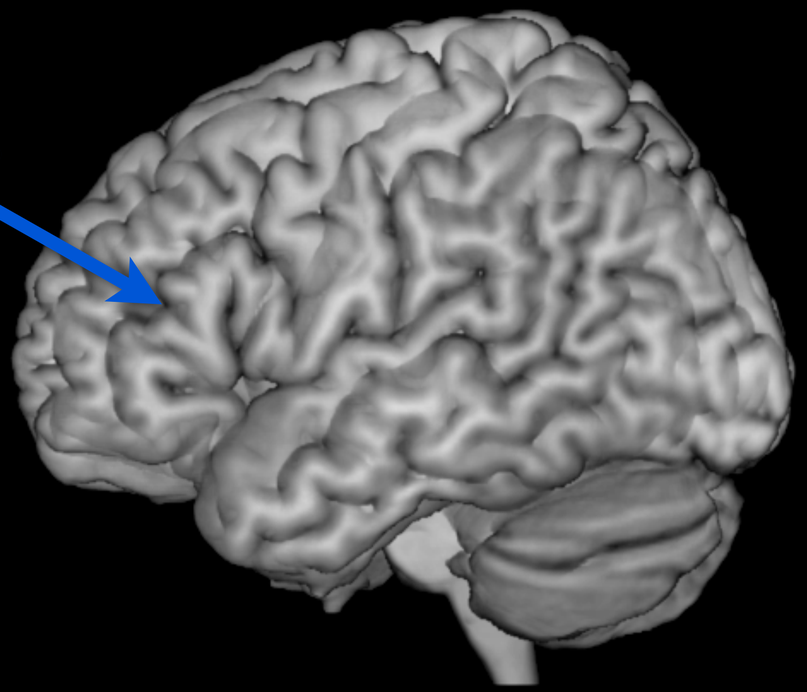


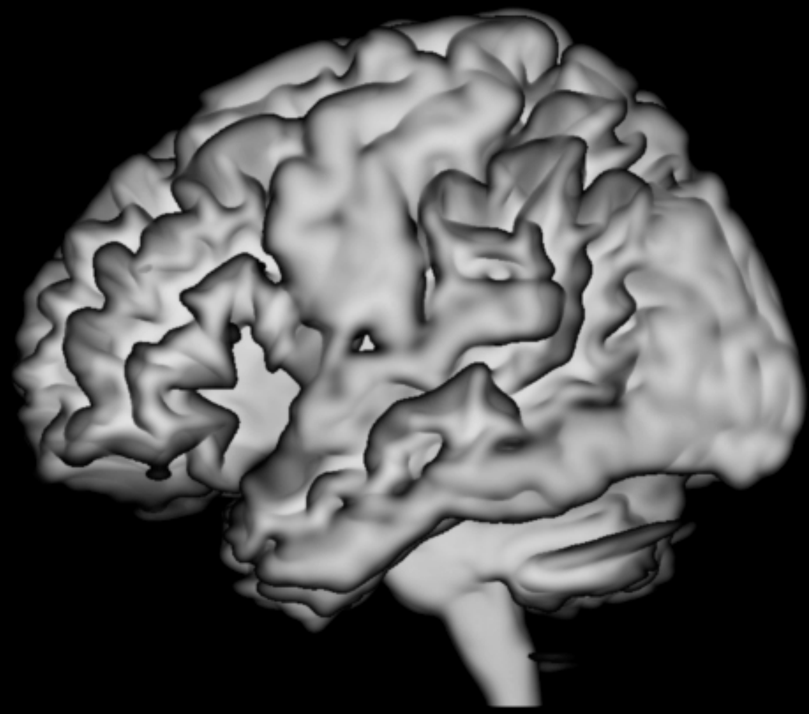
CDHD Symptom: Language Deficits

Human

Zombie

Broca's

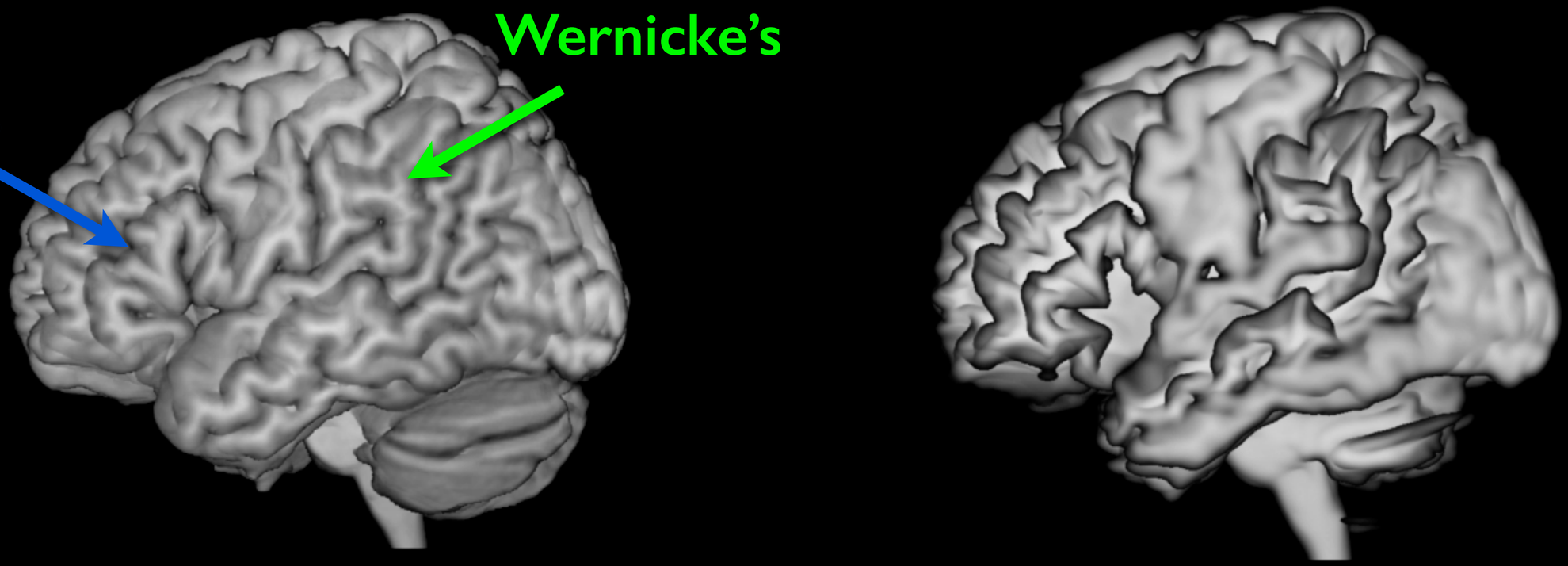




CDHD Symptom: Language Deficits

Human

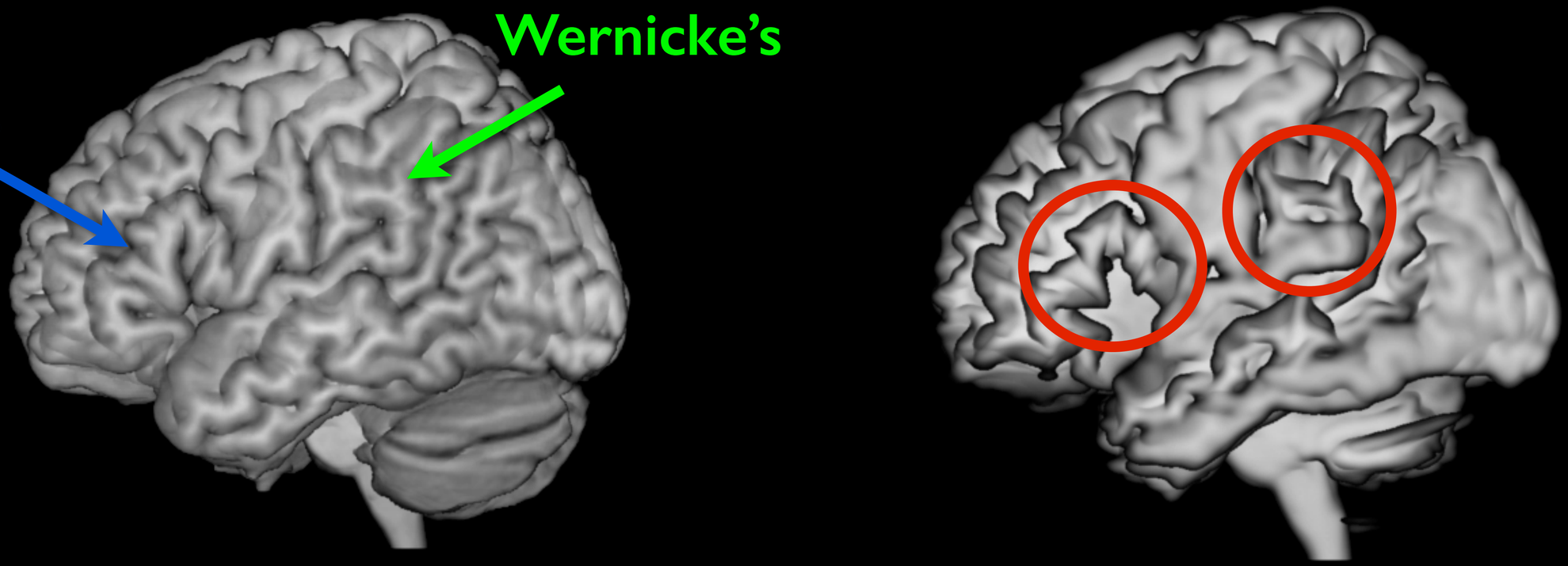
Zombie



CDHD Symptom: Language Deficits

Human

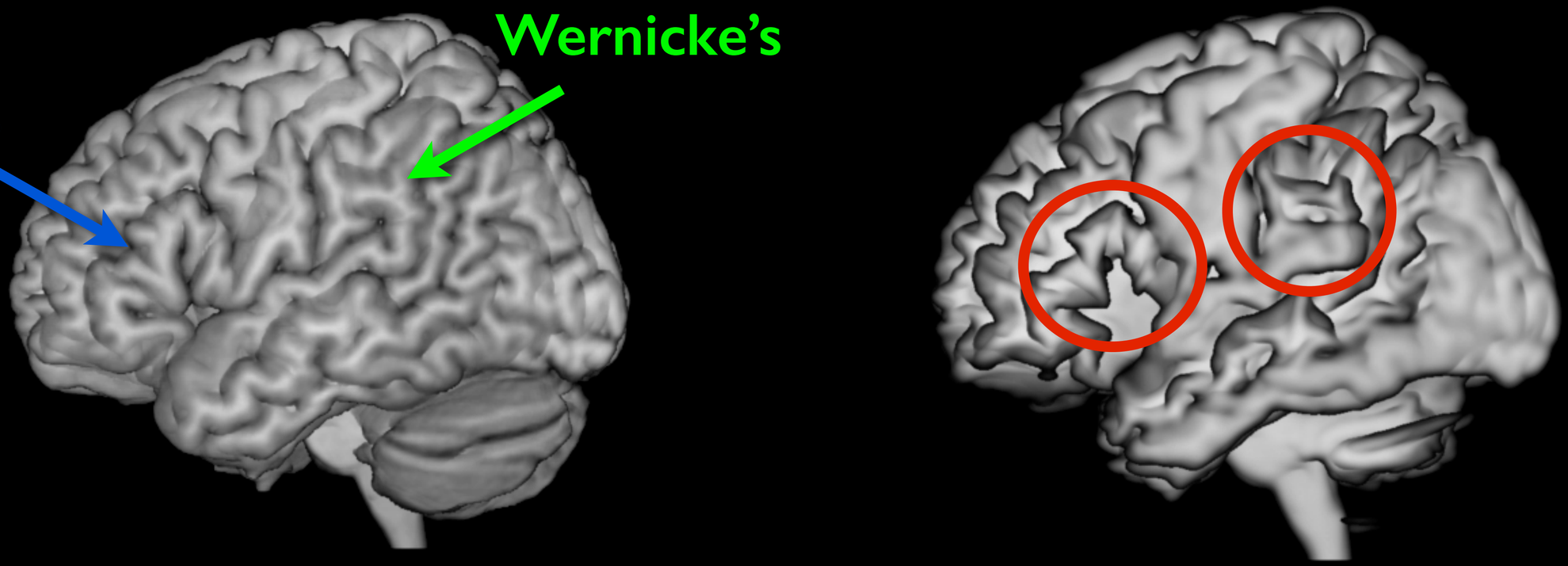
Zombie



CDHD Symptom: Language Deficits

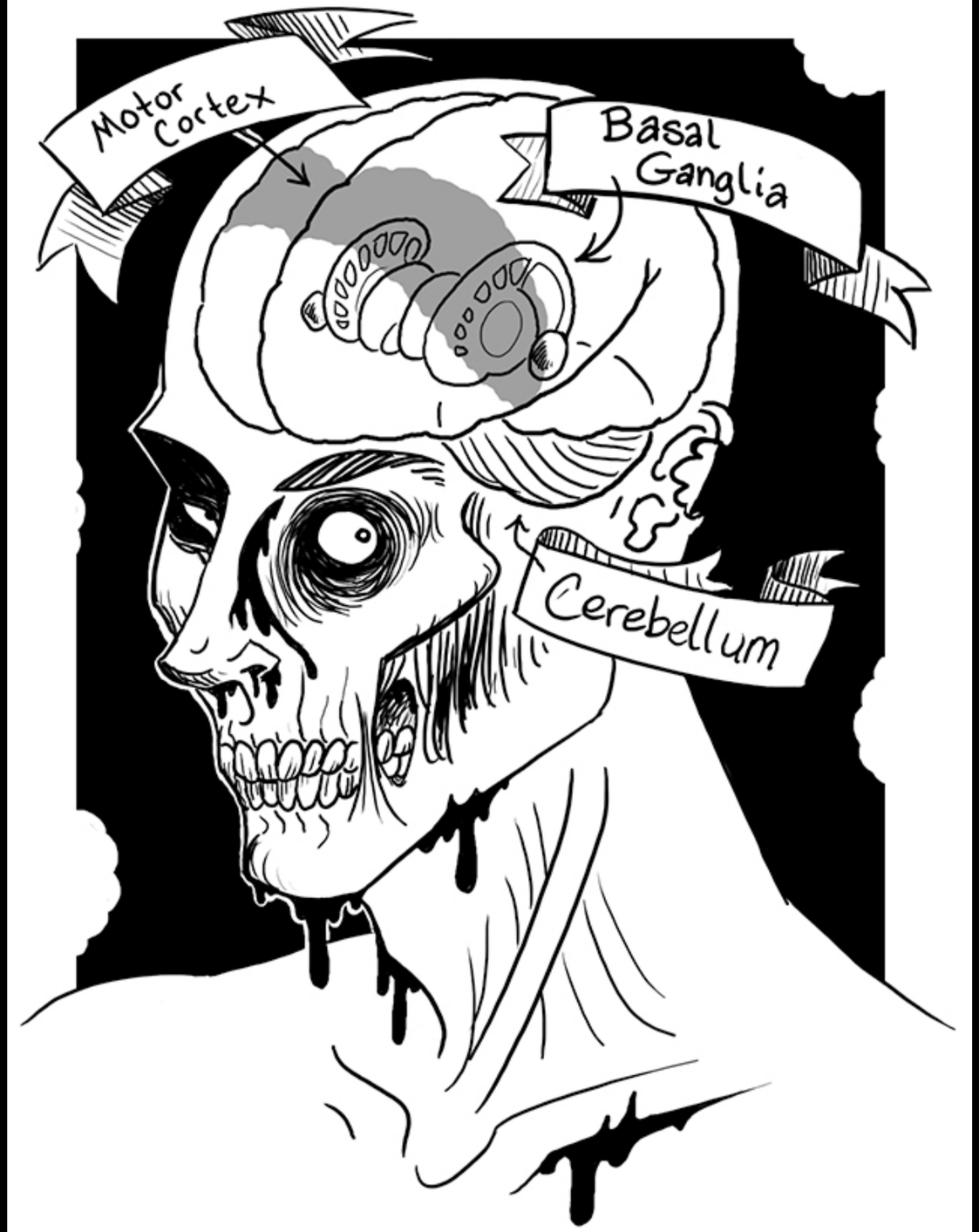
Human

Zombie

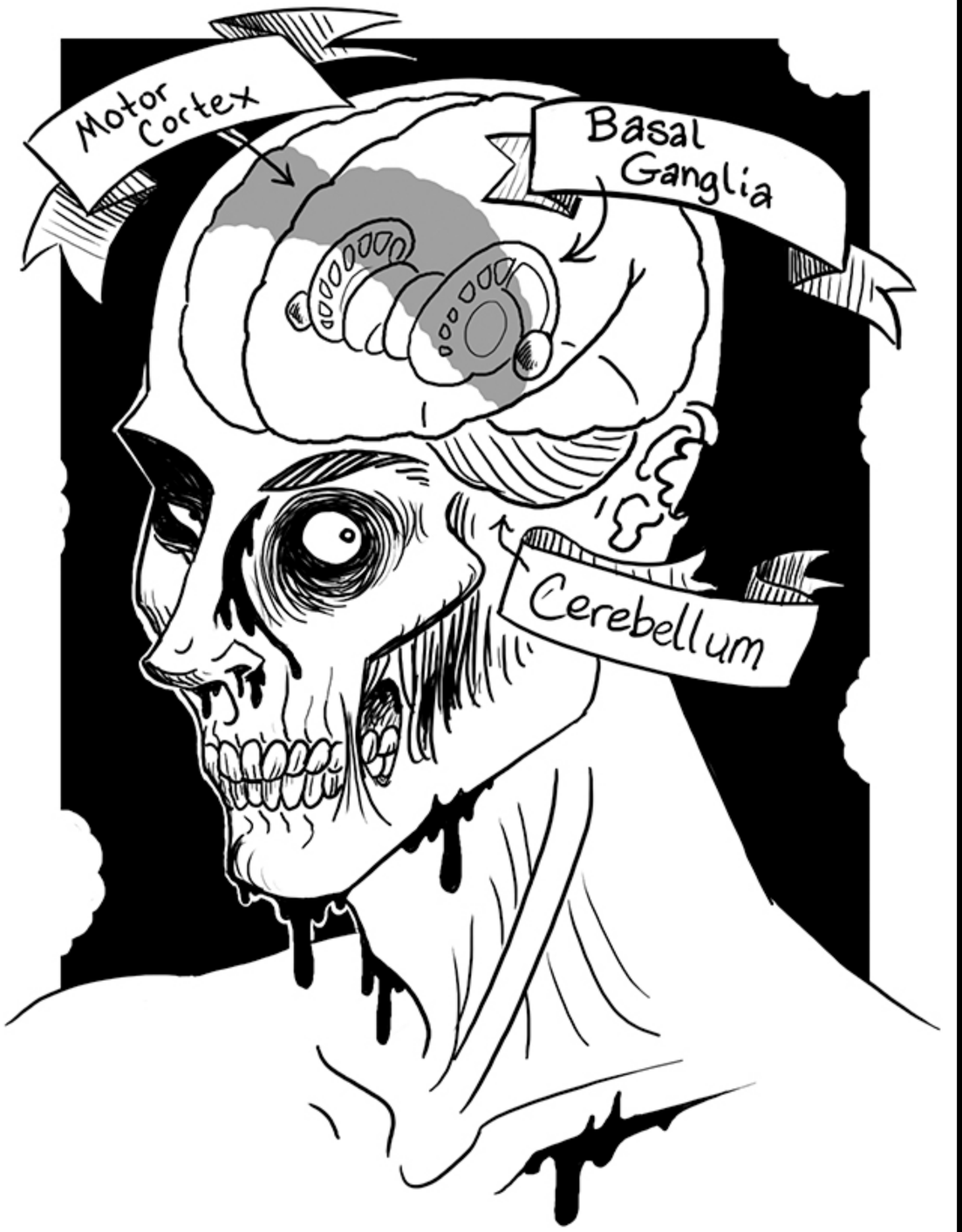


Near complete loss of cortical language areas

CDHD Symptom: Movement

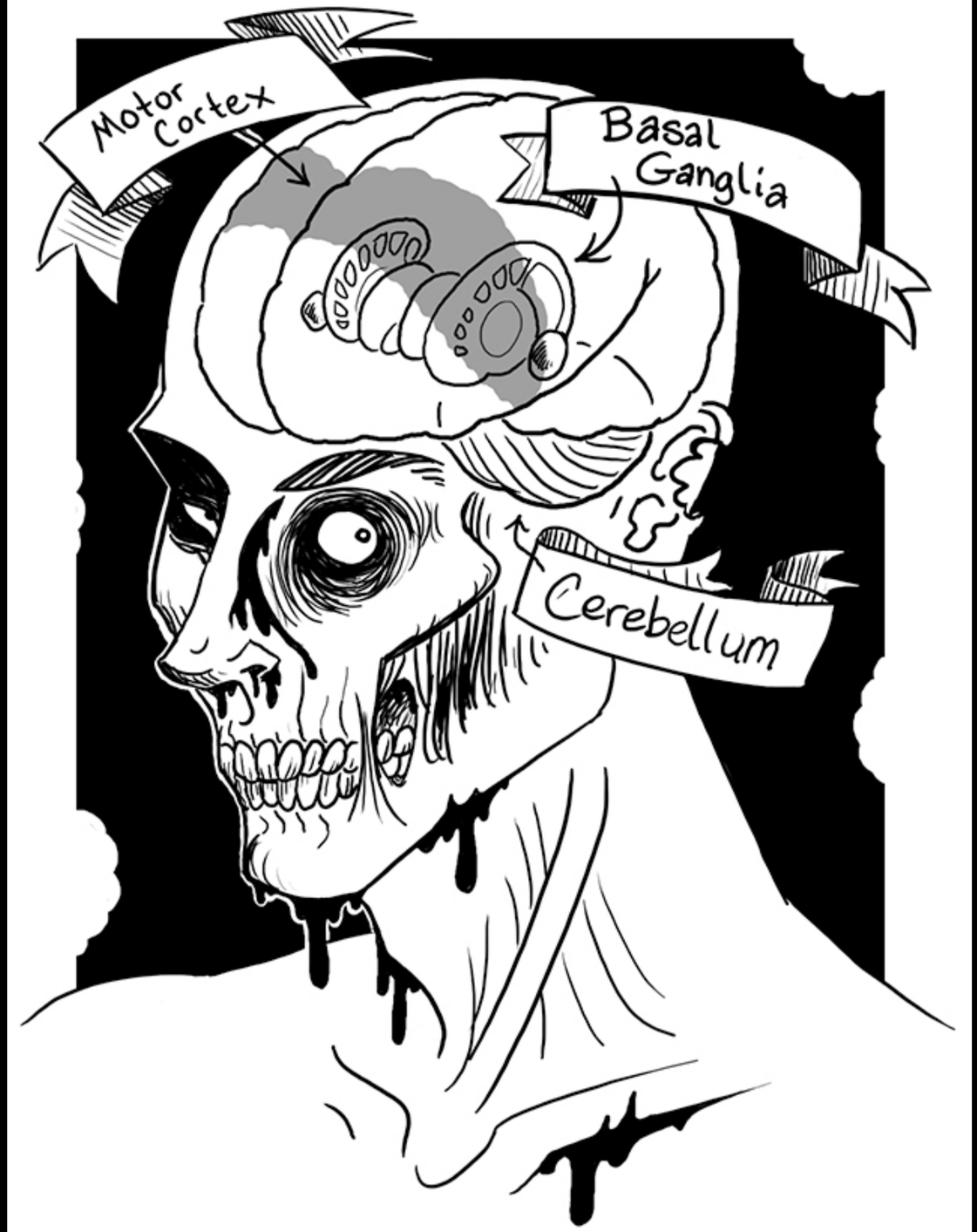


- **<u>Cortical Motor Areas</u>**: Sensory integration, movement planning, and execution.



- **<u>Cortical Motor Areas</u>**: Sensory integration, movement planning, and execution.

- **<u>Basal Ganglia</u>**: Movement gaiting, inhibitory control.



- **Cortical Motor Areas**: Sensory integration, movement planning, and execution.

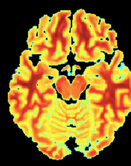
- **Basal Ganglia**: Movement gaiting, inhibitory control.

- **Cerebellum**: Timing, coordination, and error correction.

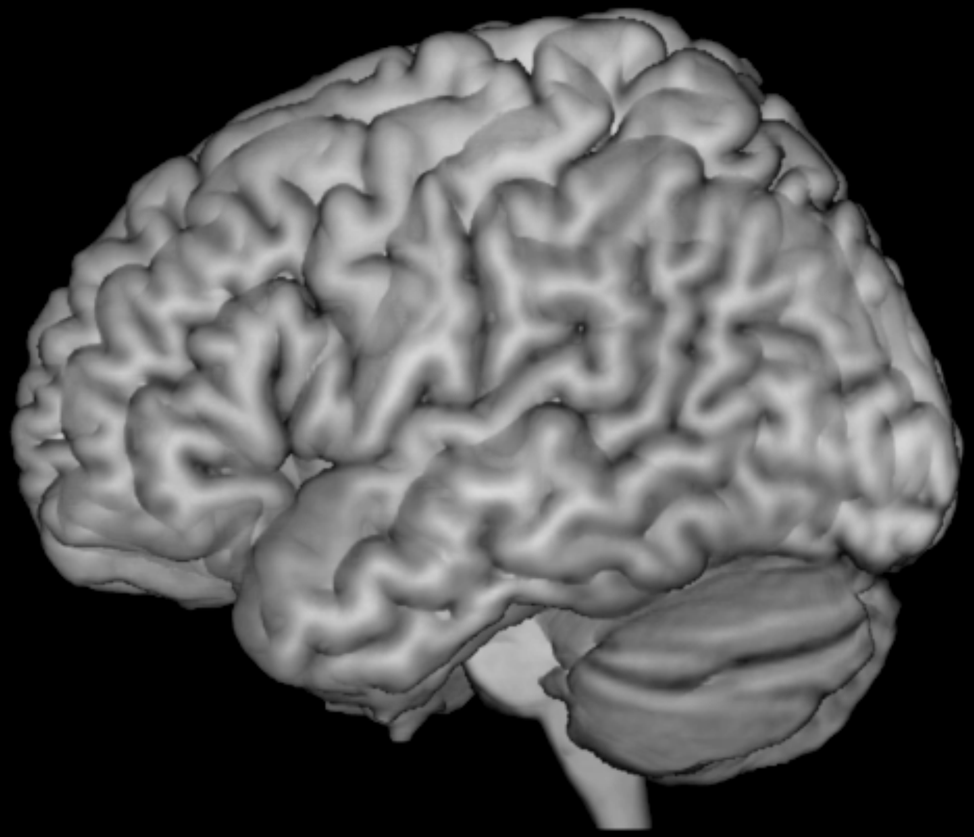
CDHD Symptom: Movement

Spinocerebellar Ataxia: Inability to produce smooth, coordinated actions. Usually resulting in lumbering movements, balance problems and tremors.

Manto and Marmolino, *Curr. Opinion in Neurology* 2007



CDHD Symptom: Movement

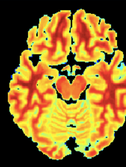


The human cerebellum

CDHD Symptom: Movement

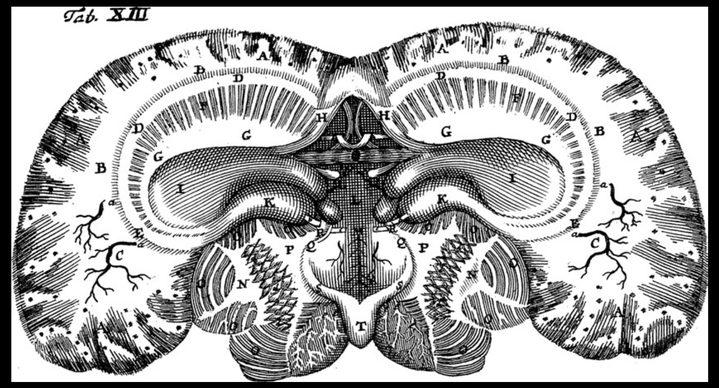
The human cerebellum

History of the Cerebellum



History of the Cerebellum

Cerebellum as source of the libido!



- Phrenologists

History of the Cerebellum

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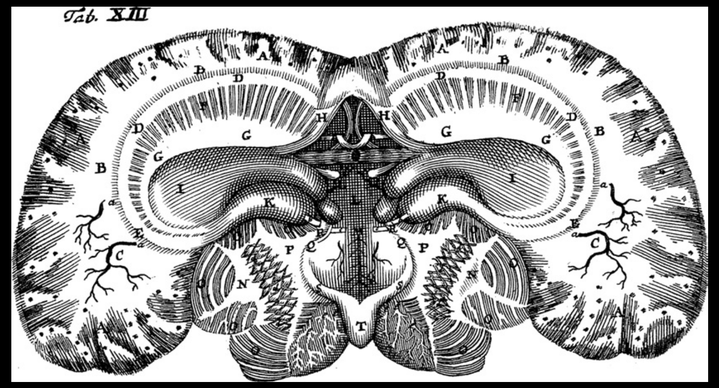

- Phrenologists

Pierre Flourens (1794-1867)

History of the Cerebellum

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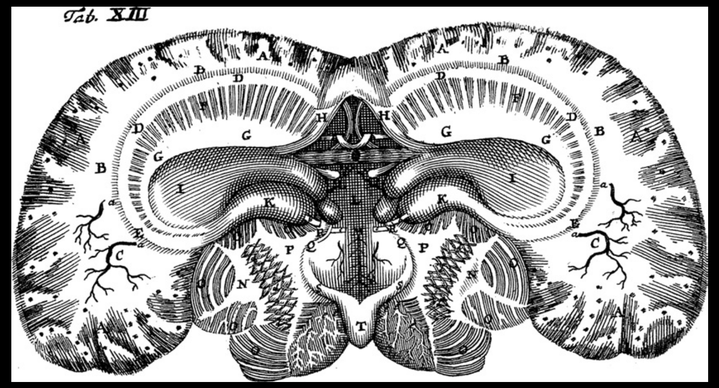


- Phrenologists

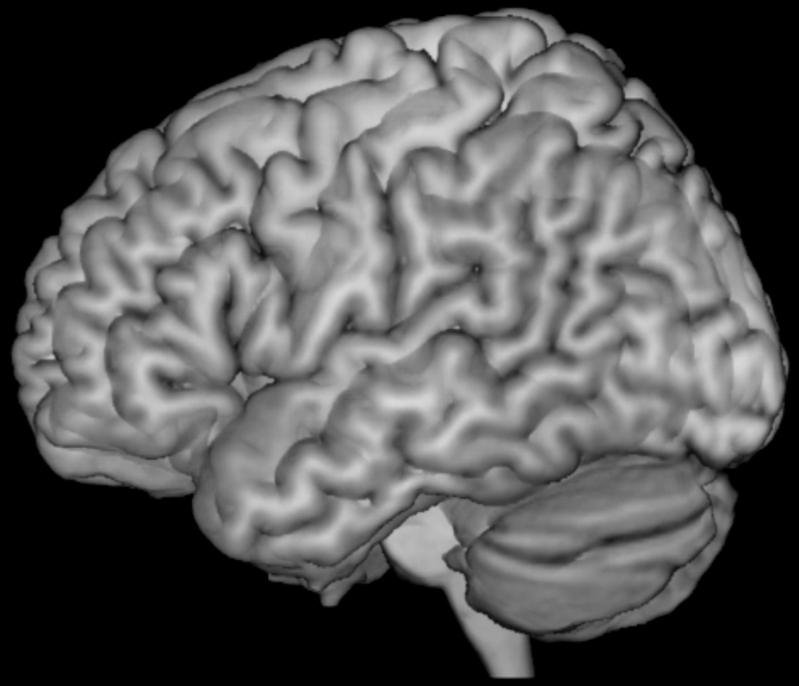
Pierre Flourens (1794-1867)

"Flourens dismissed as unfounded the claims for the sexual functions of the cerebellum. He removed the cerebellum of a mature rooster. The animal was still deeply interested in the hens, but motor dysfunction made it difficult for him to express his feelings towards them."

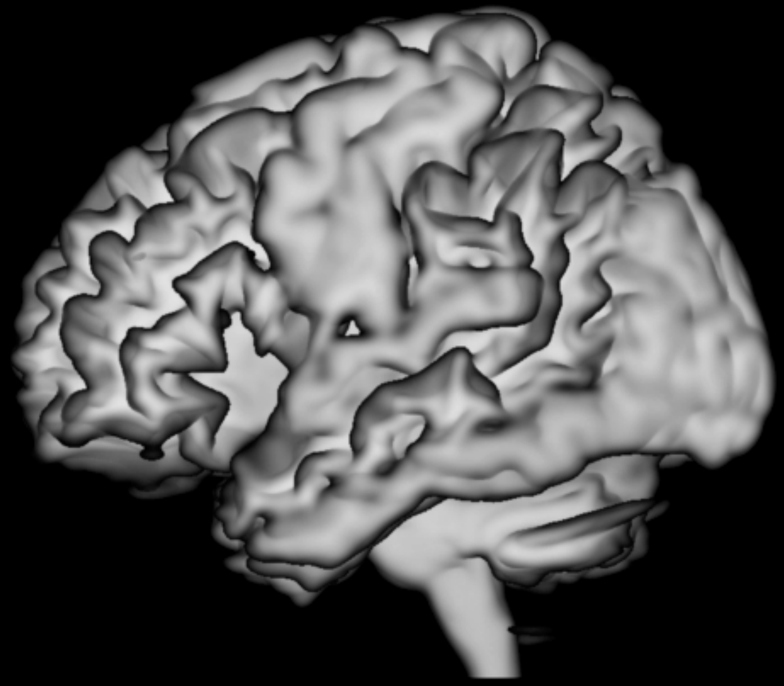
-Glickstein et al. *Neuroscience* 2009

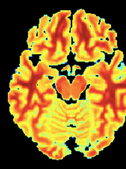
CDHD Symptom: Movement

Human



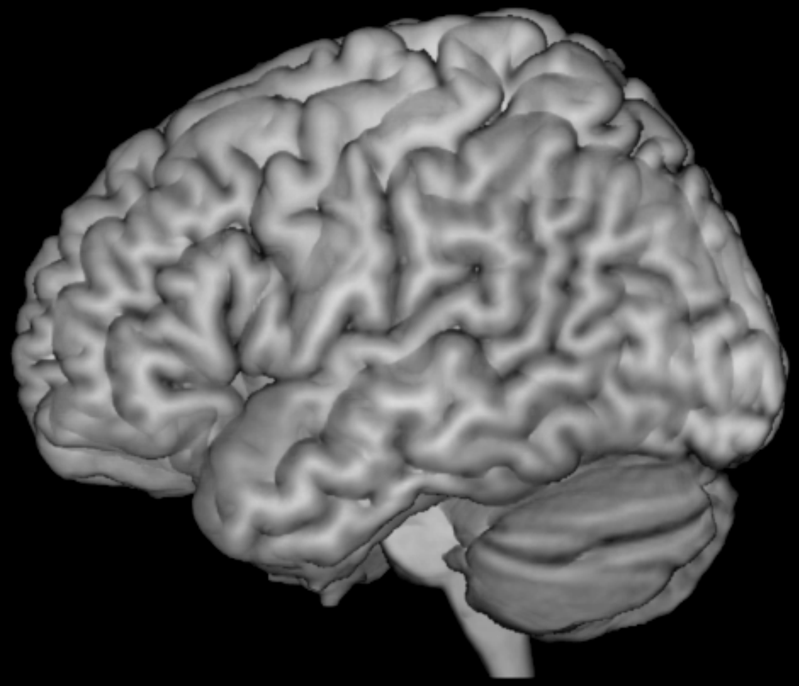
Zombie



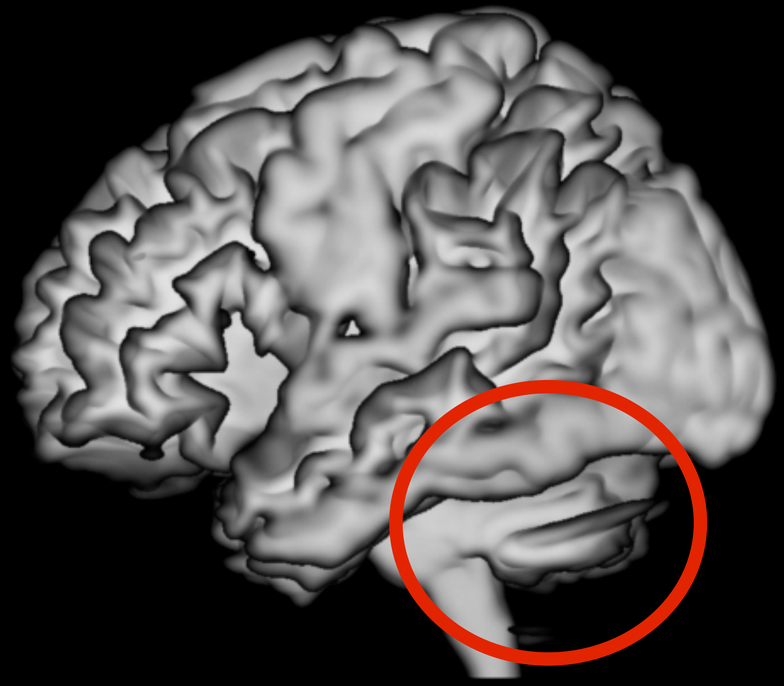


CDHD Symptom: Movement

Human

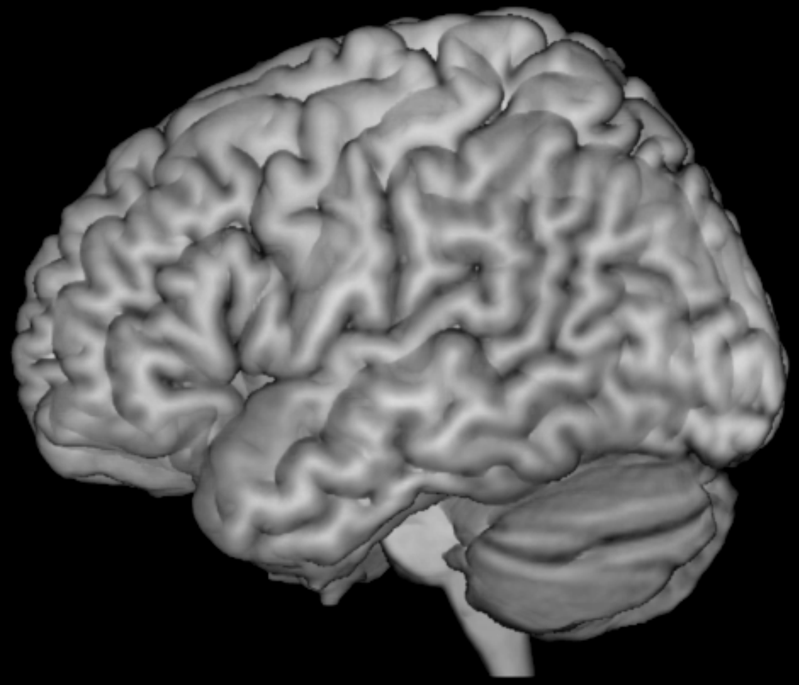


Zombie

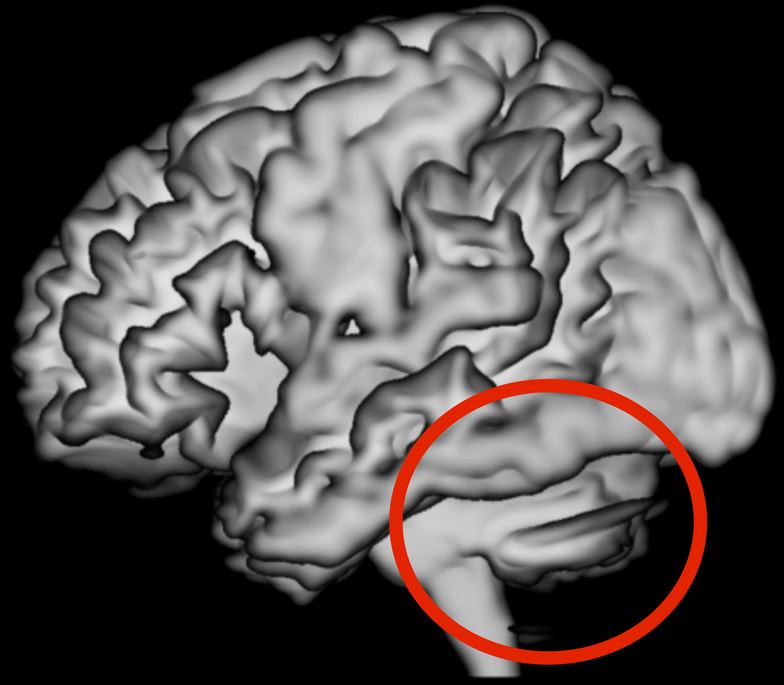


CDHD Symptom: Movement

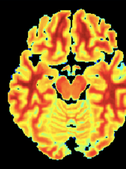
Human



Zombie



Cerebellum is almost completely gone in zombies!



CDHD Symptom: Movement

Slow Zombie

CDHD Symptom: Movement

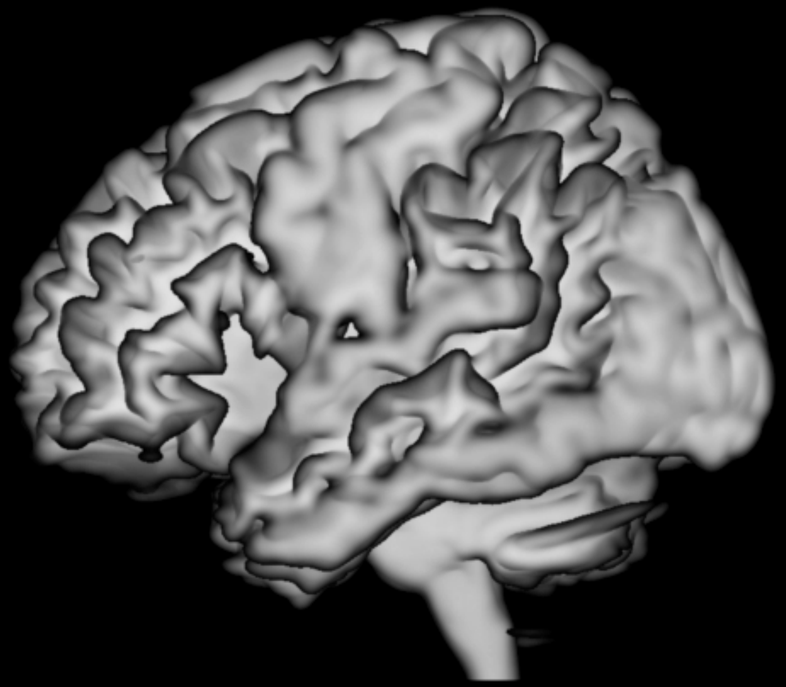
Slow Zombie

Fast Zombie

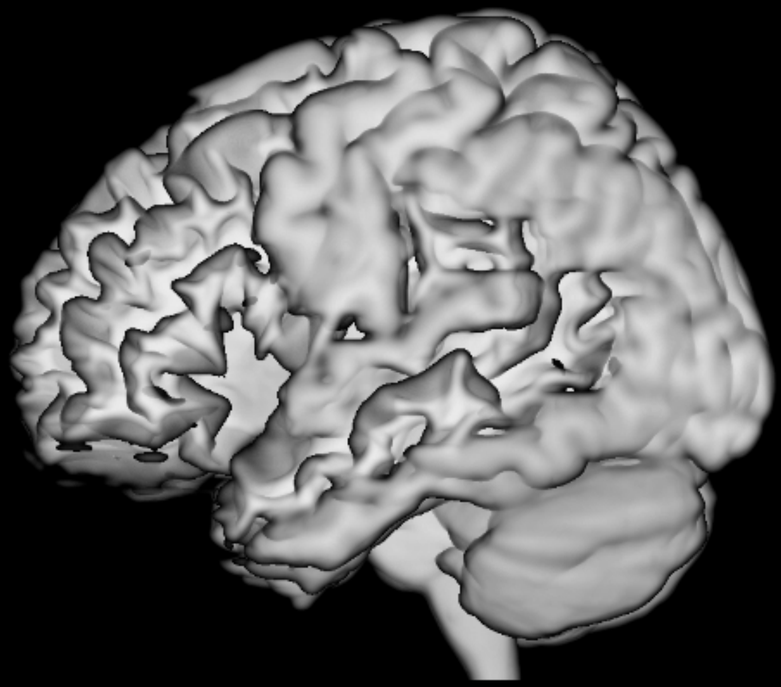
2 Subtypes of the CDHD!

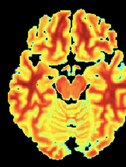
CDHD Symptom: Movement

Slow Zombie



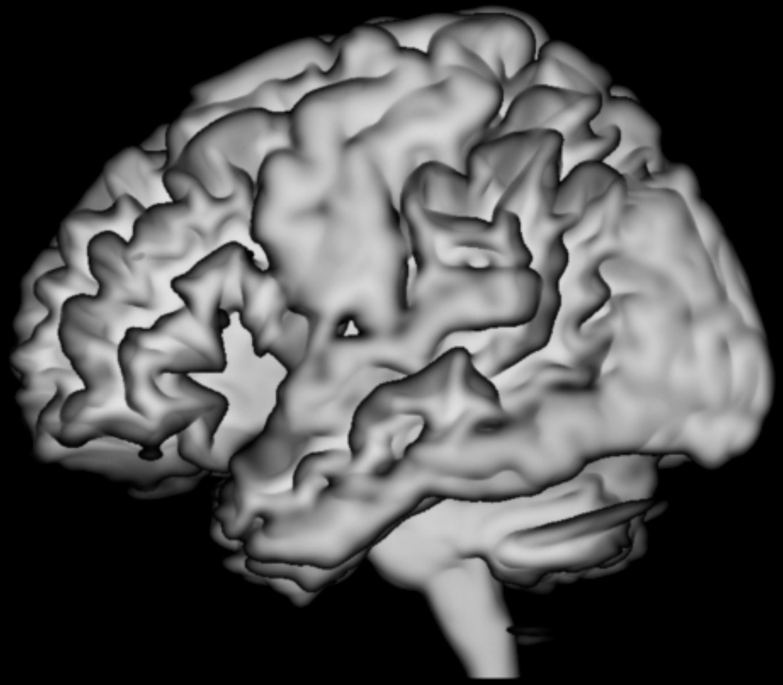
Fast Zombie





CDHD Symptom: Movement

Slow Zombie

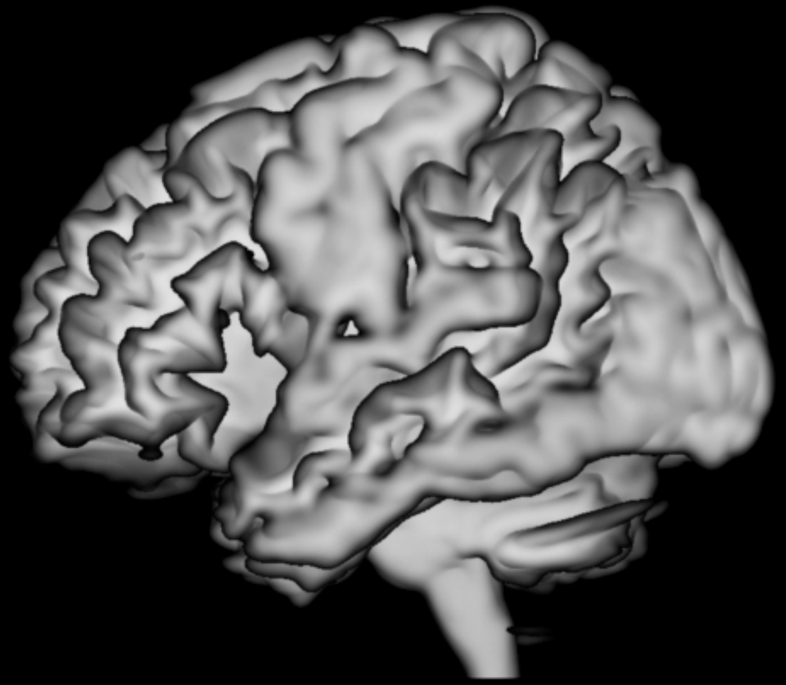


Fast Zombie

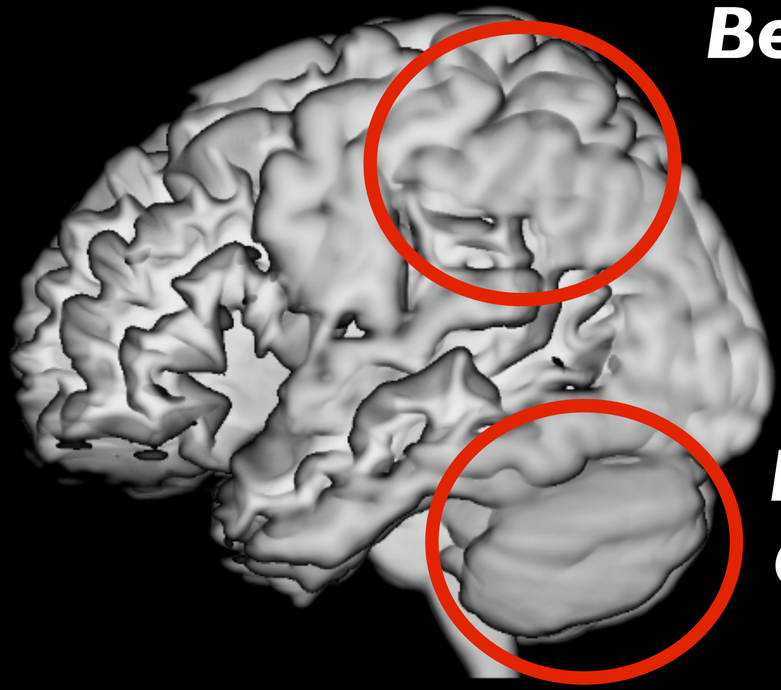
Better Motor Coordination

CDHD Symptom: Movement

Slow Zombie



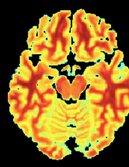
Fast Zombie



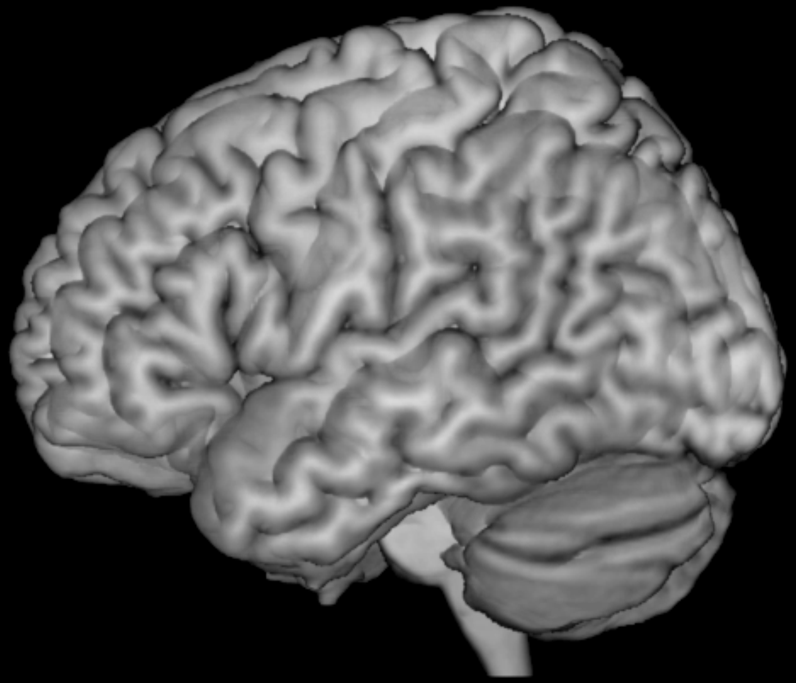
Better Spatial Abilities

Better Motor Coordination

Coordination and spatial attention areas are intact!



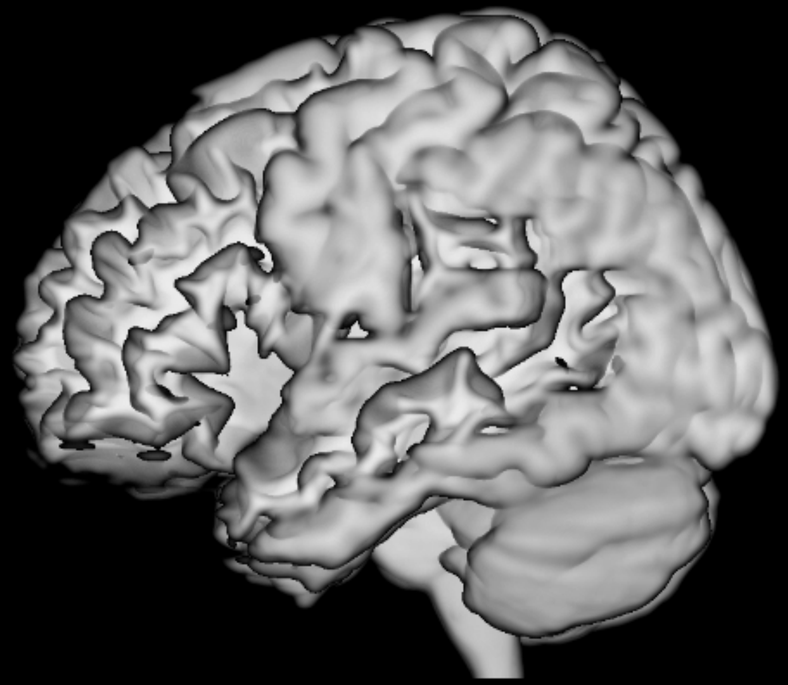
Origin of the Fast CDHD variant



time

Death

Origin of the Fast CDHD variant

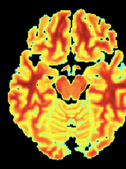


Fast
Zombie

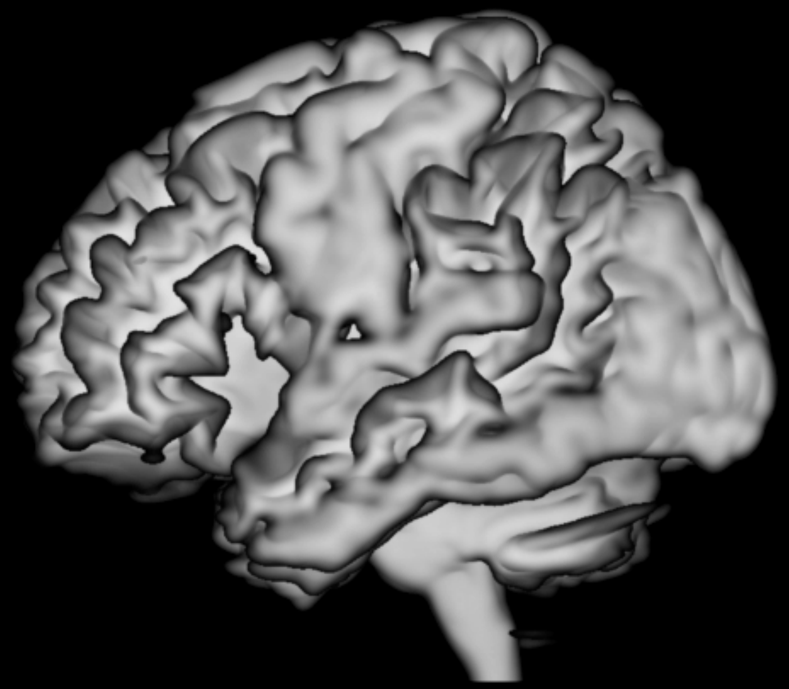
time

Death

Early



Origin of the Fast CDHD variant



Fast Zombie

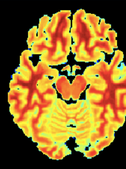
Slow Zombie

time

Death

Early

Late



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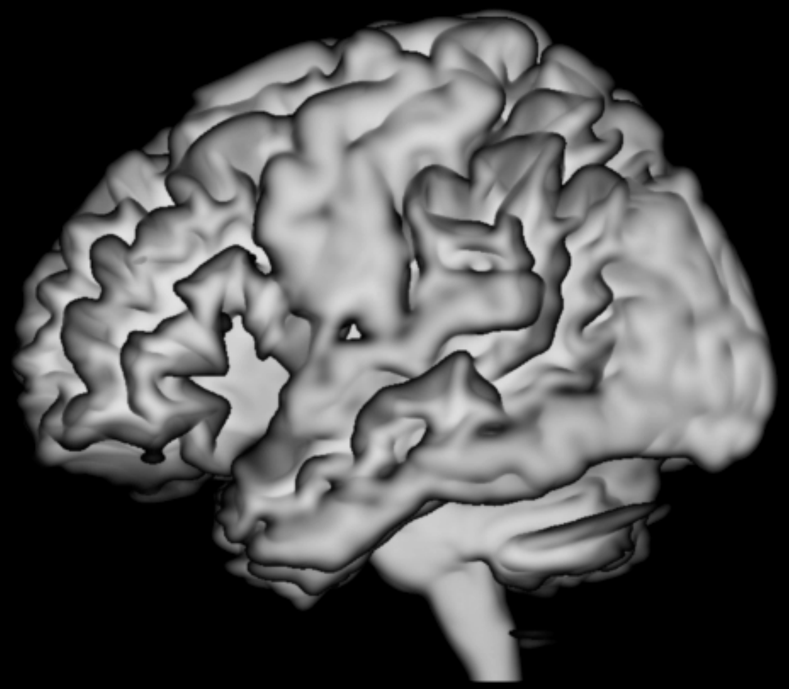
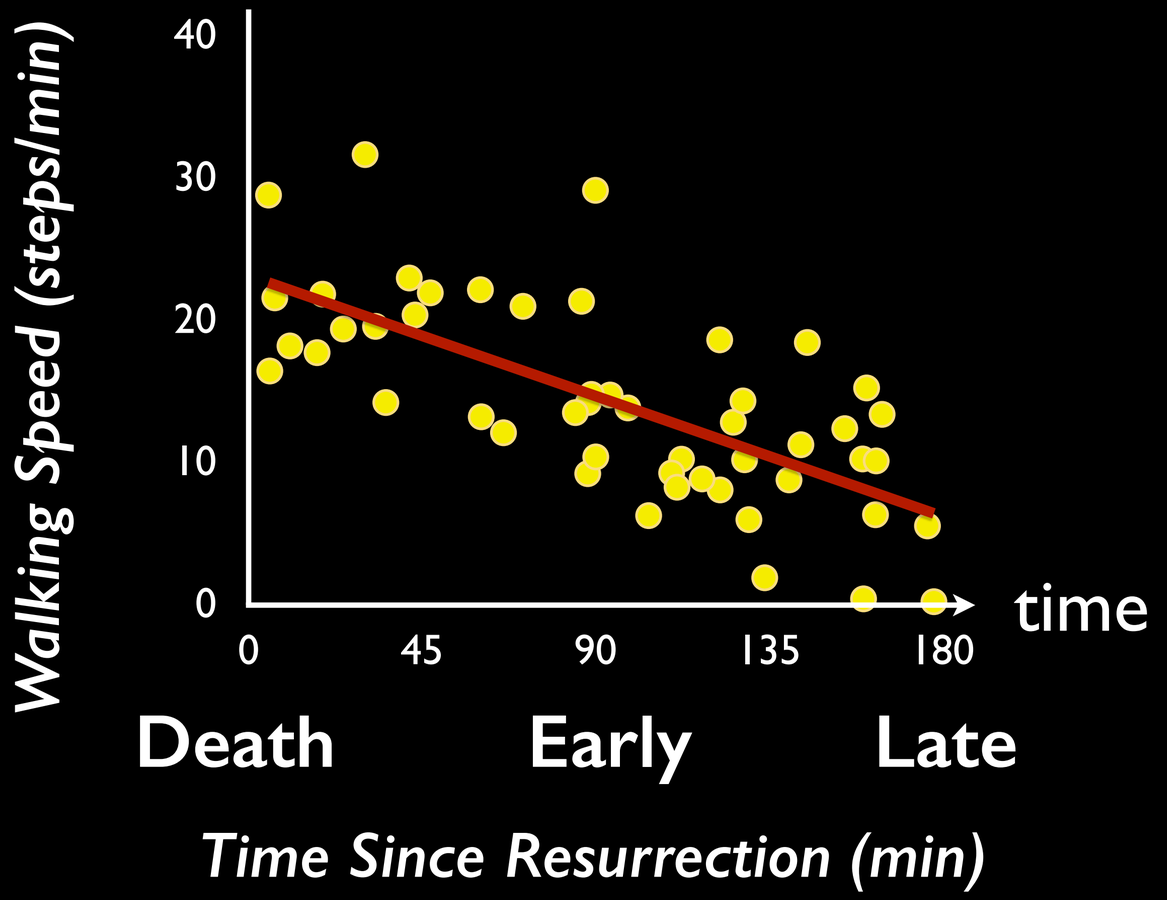
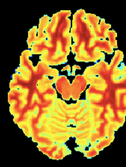
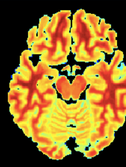




Severity of CDHD symptoms depends on incubation period



What might cause CDHD?



What might cause CDHD?

Zombie Funghi
(ants)

What might cause CDHD?

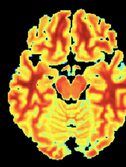
Zombie Funghi
(ants)

What might cause CDHD?

Zombie Funghi (ants)

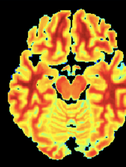
Zombie Funghi (moths)

What might cause CDHD?



What might cause CDHD?

Emerald Cockroach Wasp



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Emerald Cockroach Wasp

Delivers venom to the cockroach brain, guiding the victim back to its nest where the wasp lays its eggs in the roach. Subsequent offspring spawn from the roach and use the victim for food.

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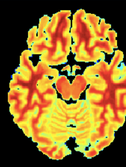
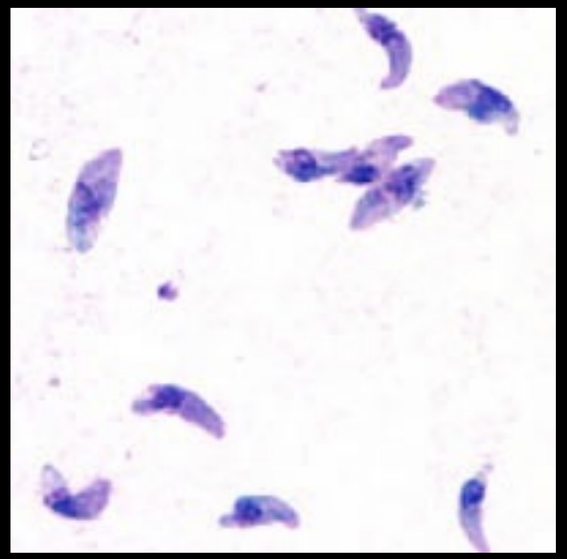
Nature is a cruel... CRUEL mistress

What might cause CDHD?



What might cause CDHD?

Toxoplasma gondii



Parasitic single-cell organism

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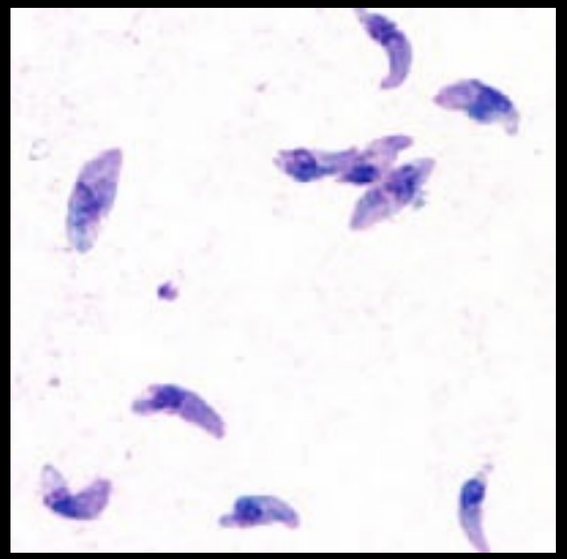
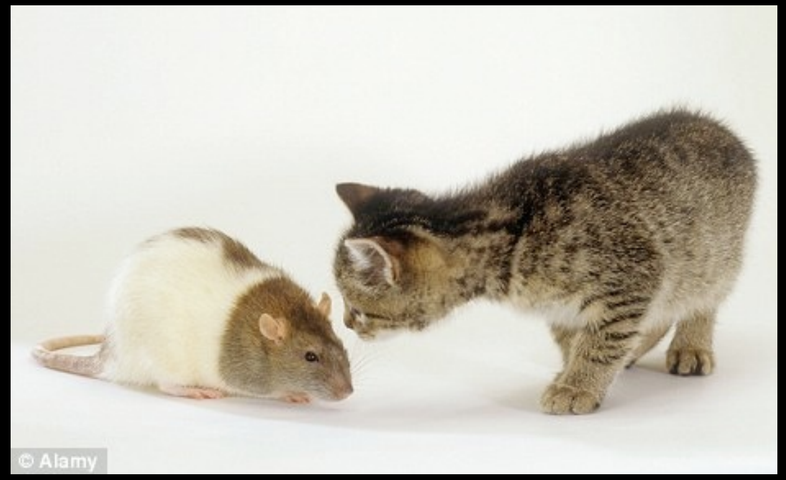
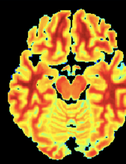


Parasitic single-cell organism

"It's okay to be afraid"



Berdoy & colleagues, *Proc. R. Soc. Lond. B.* 2000



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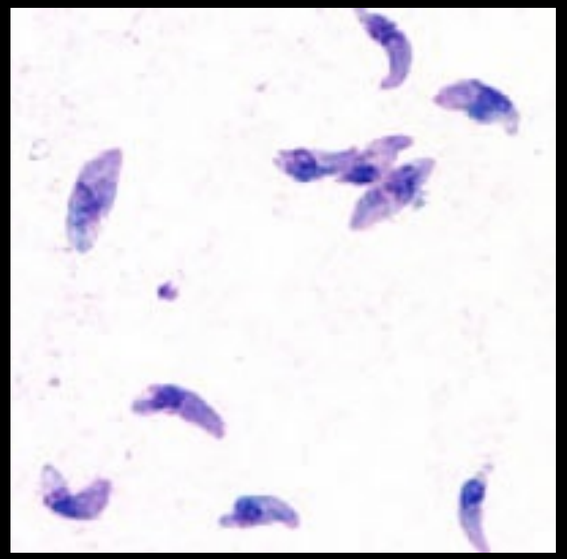

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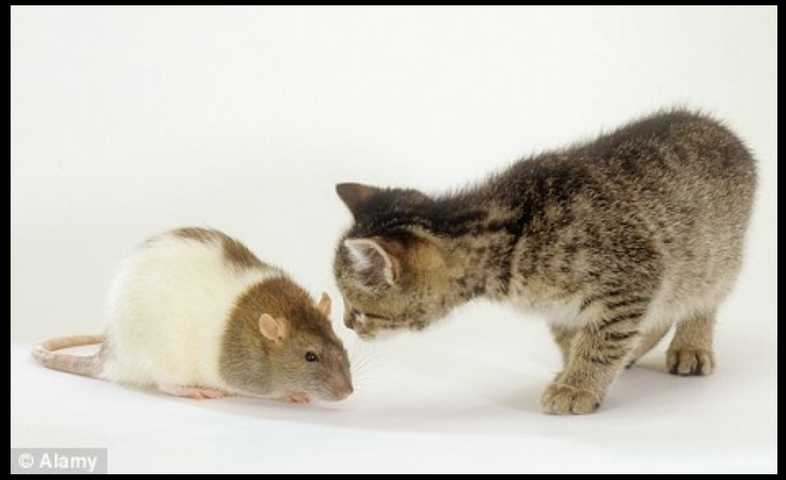
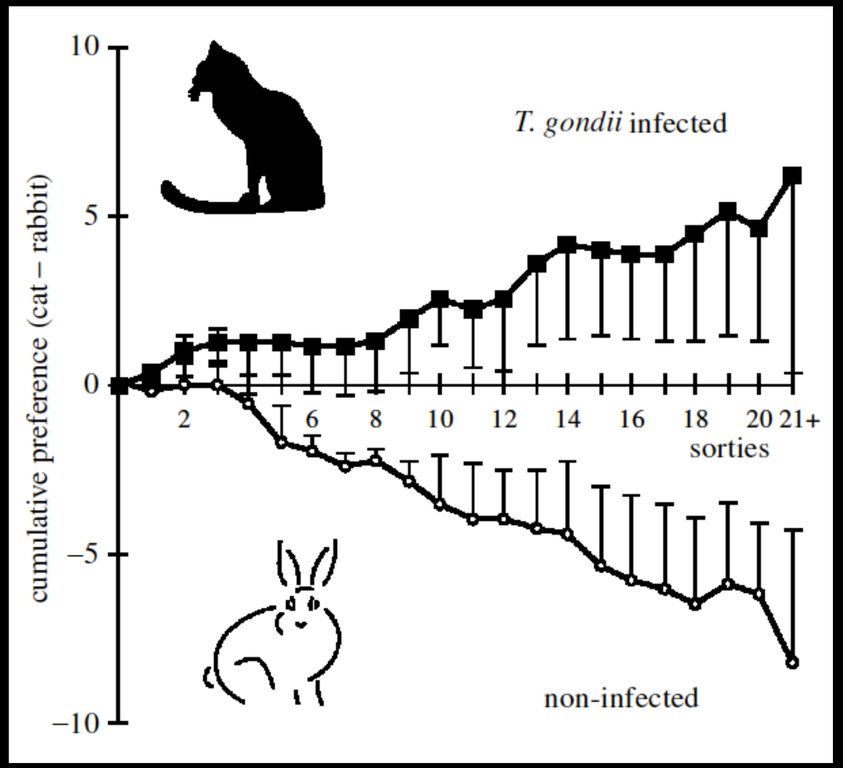
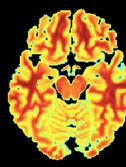




Complete loss of fear response

Berdoy & colleagues, *Proc. R. Soc. Lond. B.* 2000

What might cause CDHD?



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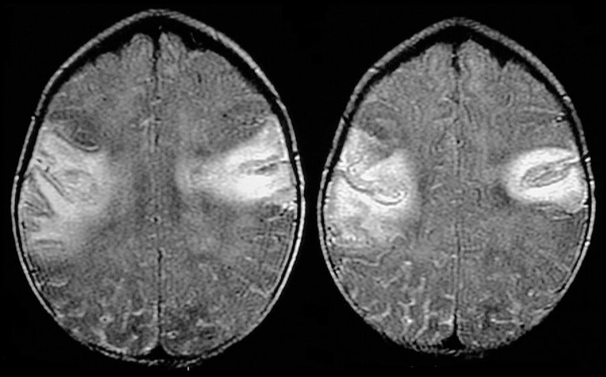
Virus



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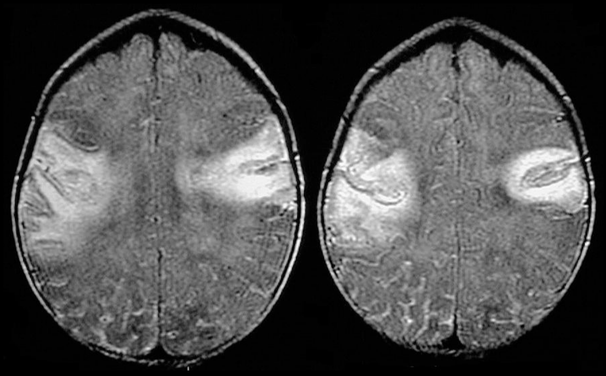
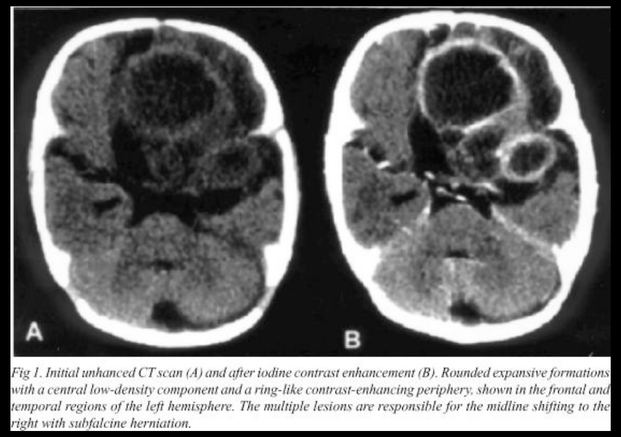


Bacteria



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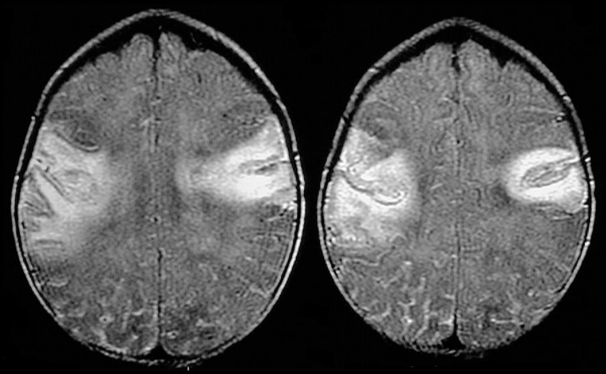

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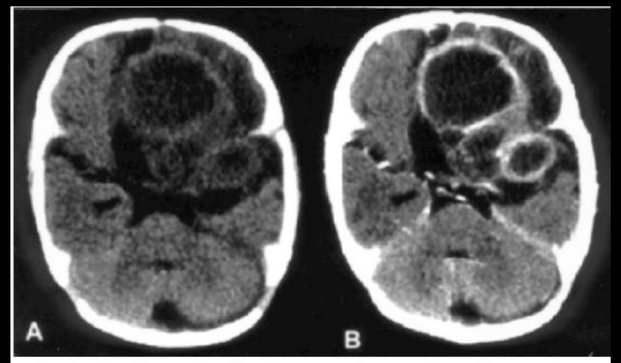

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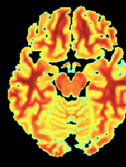
Prions

Fig 2. Axial DWI (TR/TE 9999/92.6), approximately at the same level as the previous image, depicts unequivocal hyperintense signal in the frontal, temporal and occipital cortices bilaterally. The basal ganglia and thalamus are spared.



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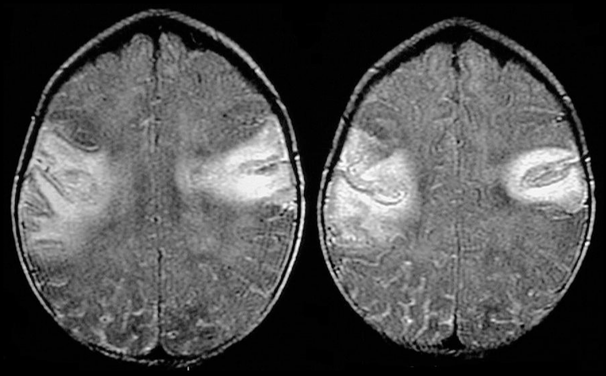

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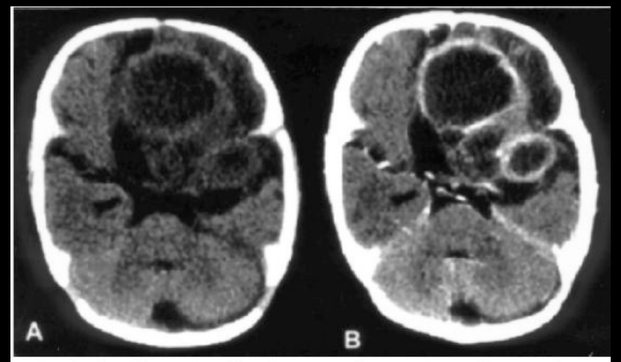

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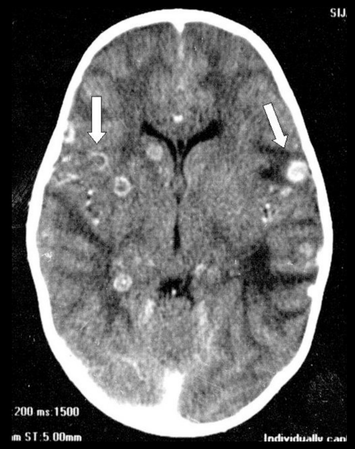
Worms



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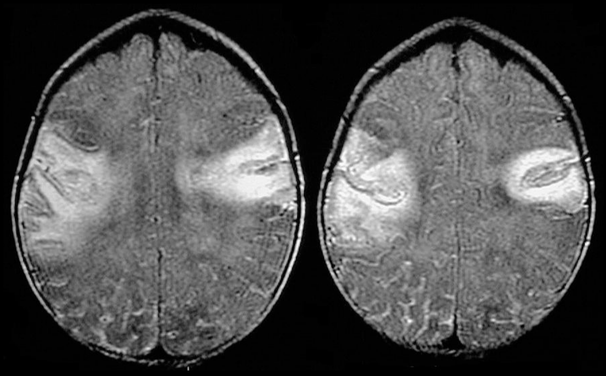

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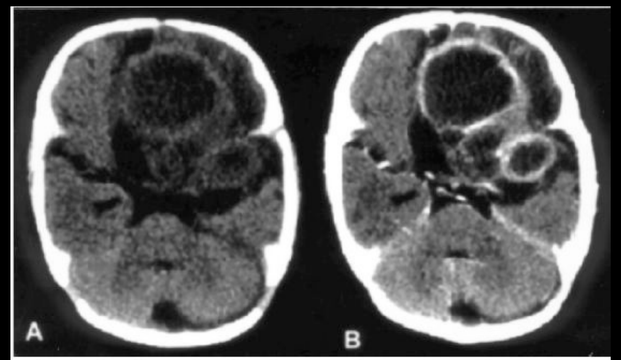

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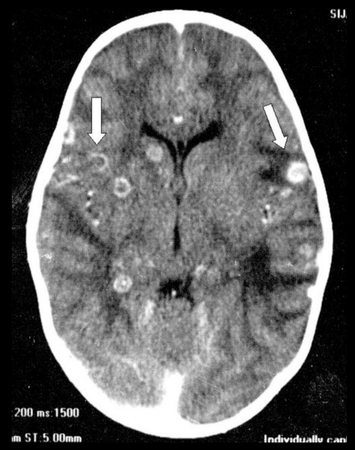
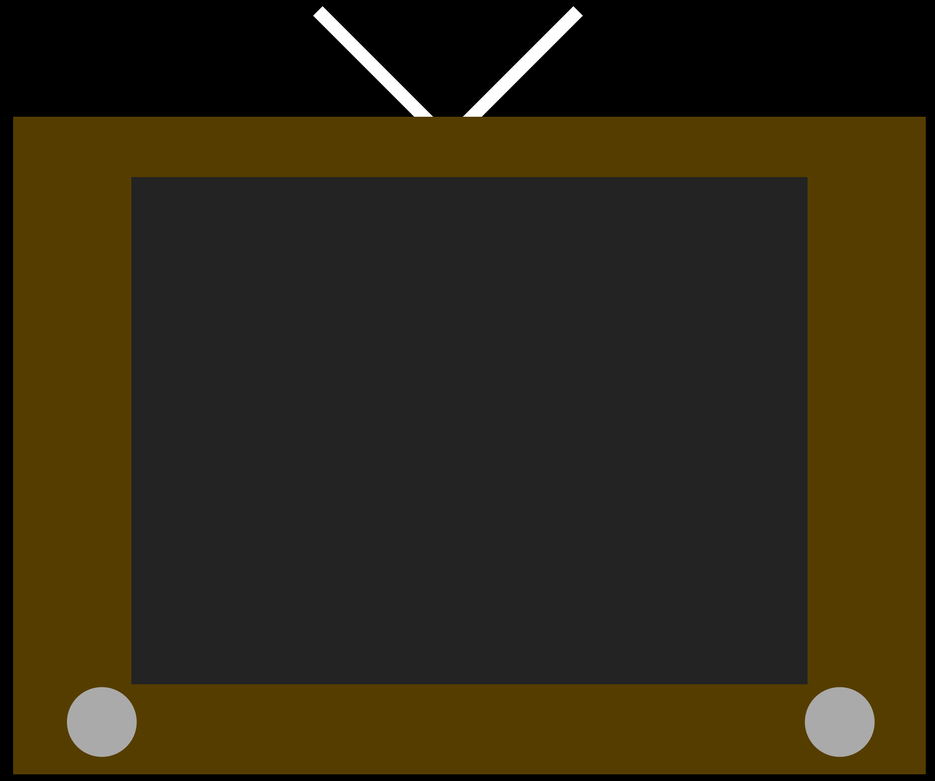
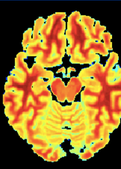




Mind-altering EM transmissions?



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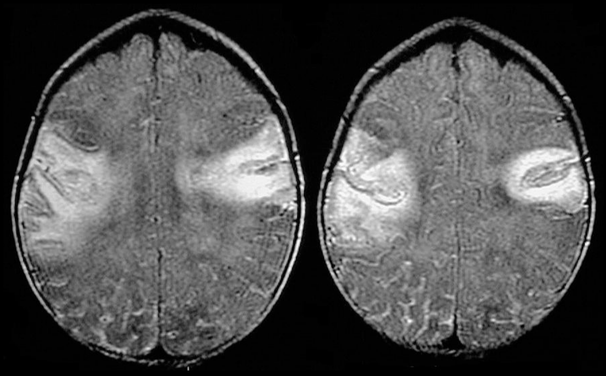

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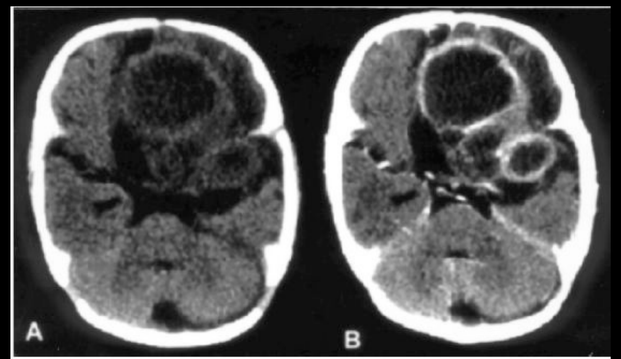

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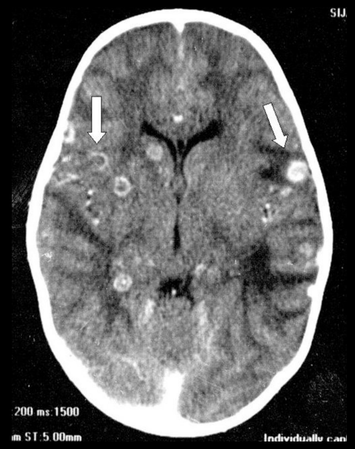

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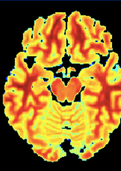

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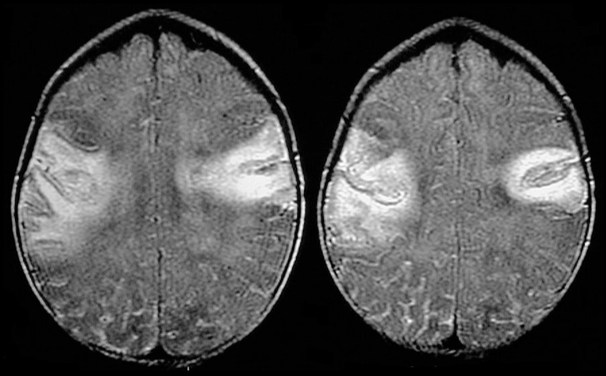

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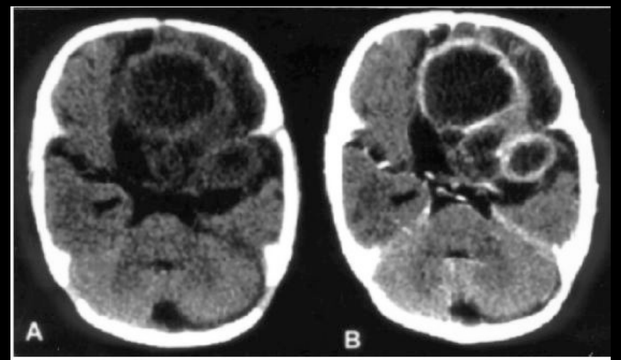

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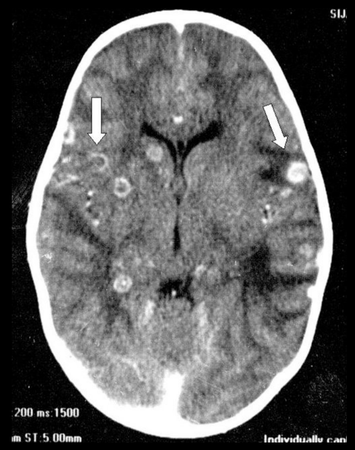
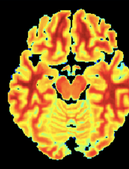
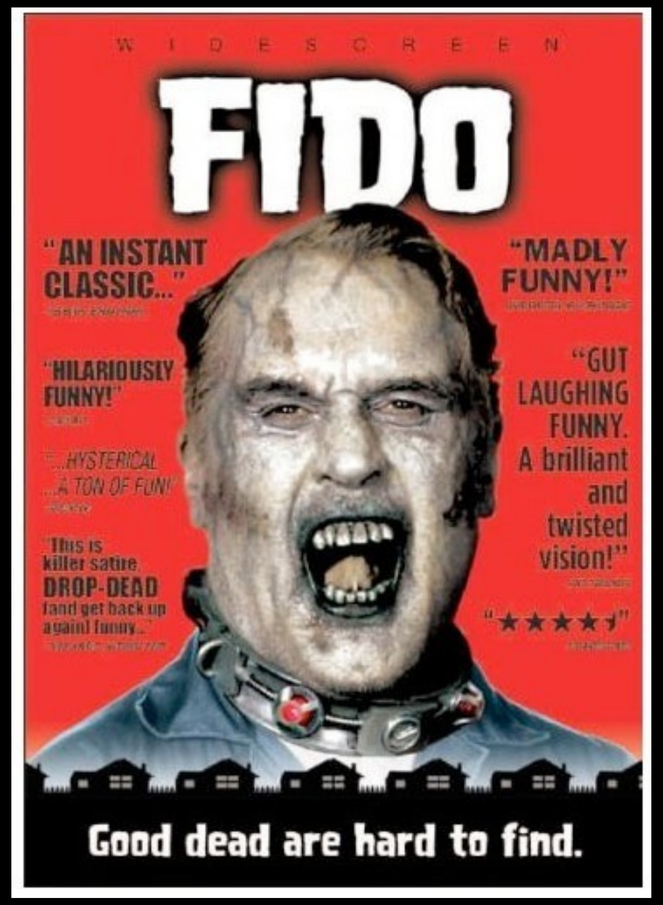


Mind-altering EM transmissions?

I’m going with The Rick Astley Theory!



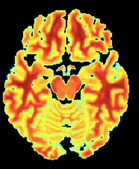
Treatments for the infected?



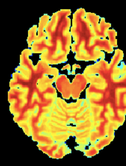
Can we reduce the unwanted CDHD symptoms?

A future hope for neural implants?

José Manuel Rodriguez Delgado



“Remote-controlled Animals”



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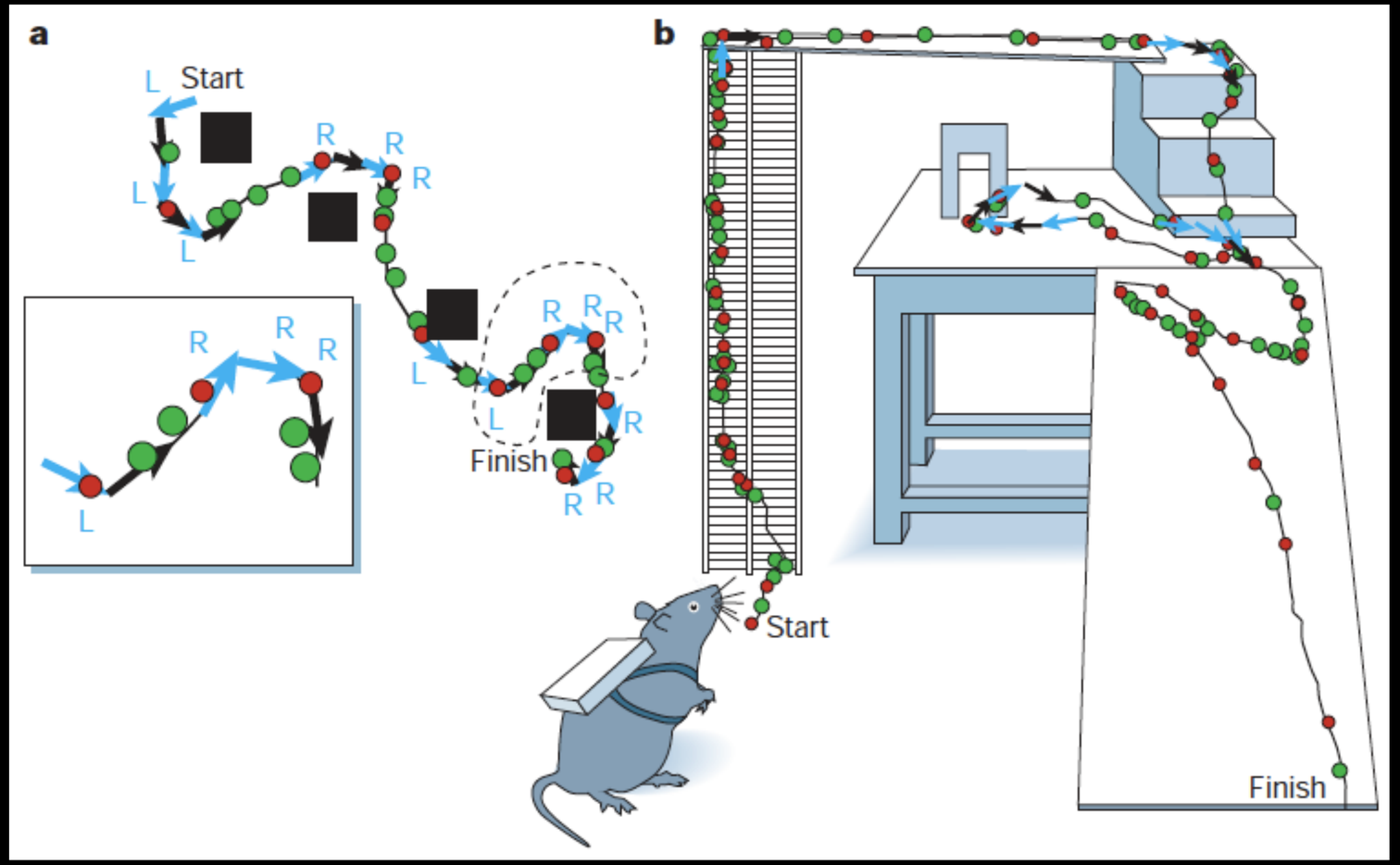
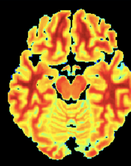
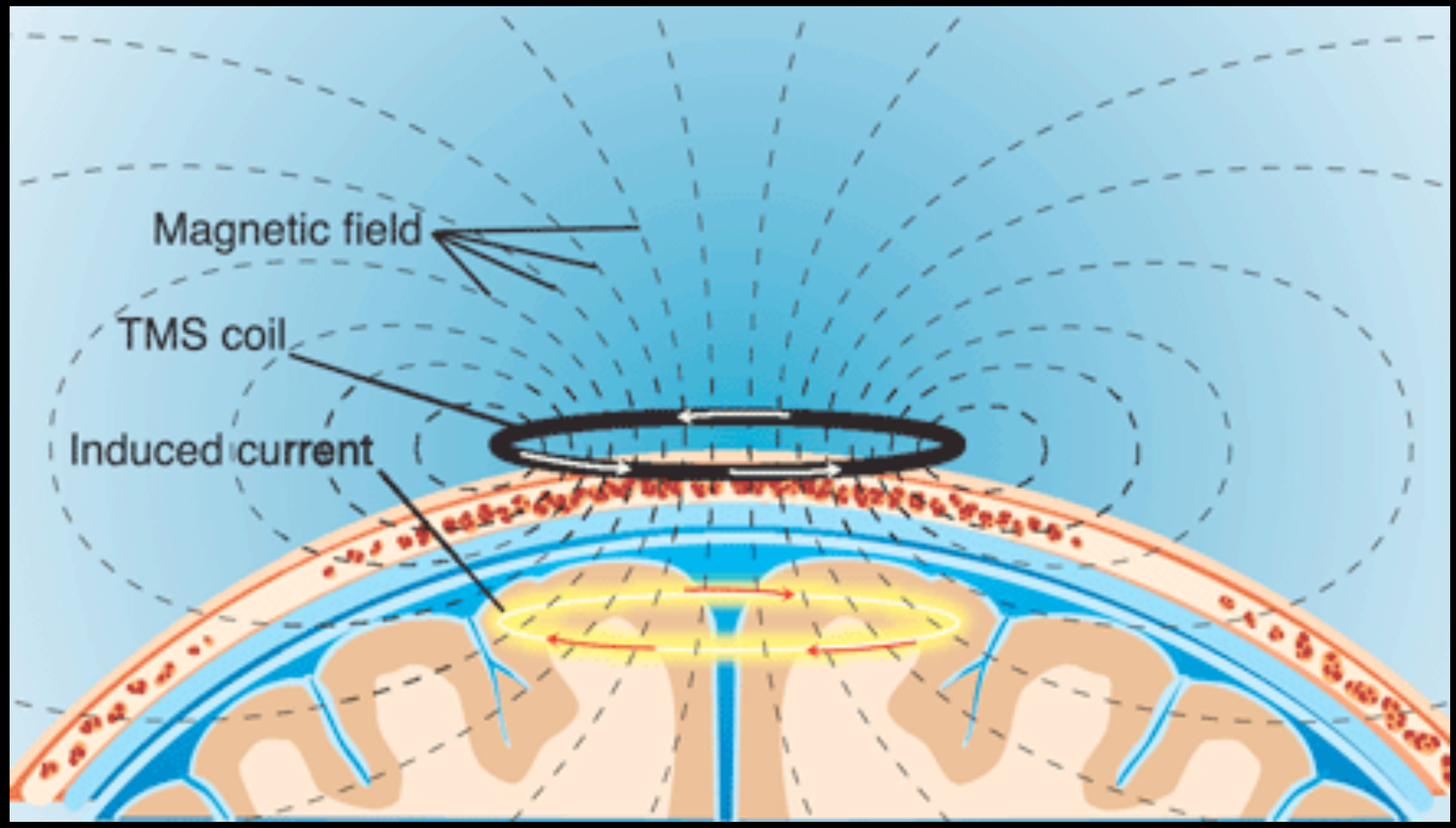


Talwar et al., *Nature* 2002



Attenuating Aggressive Behaviors Magnetically



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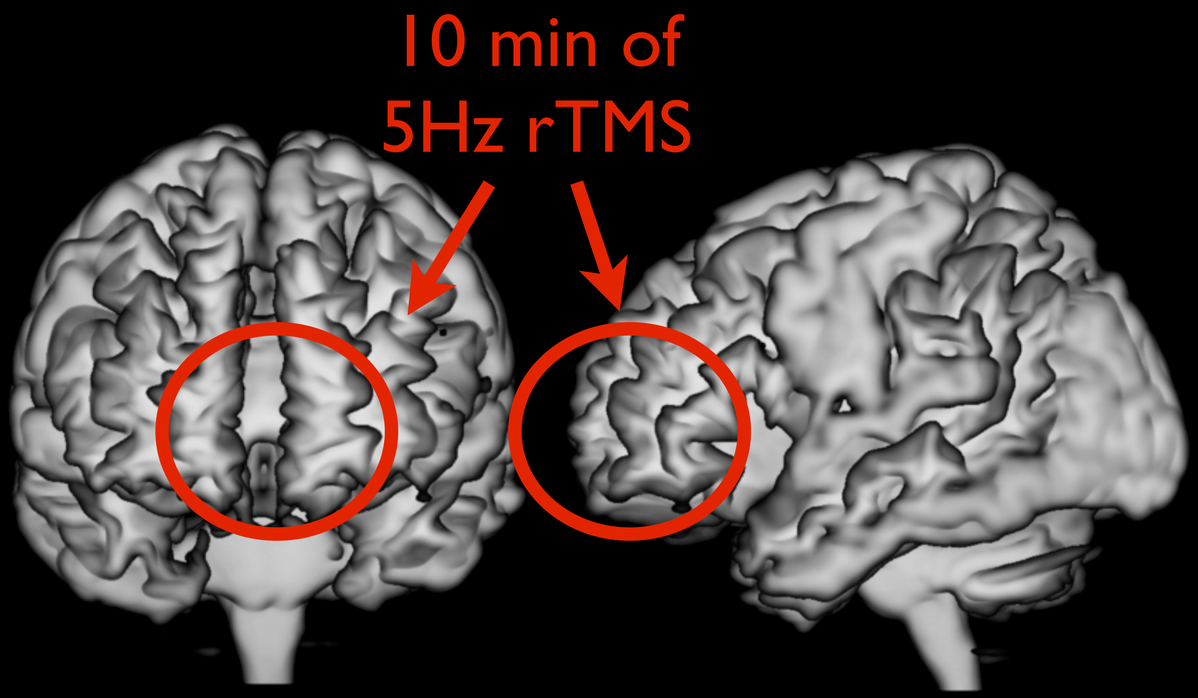

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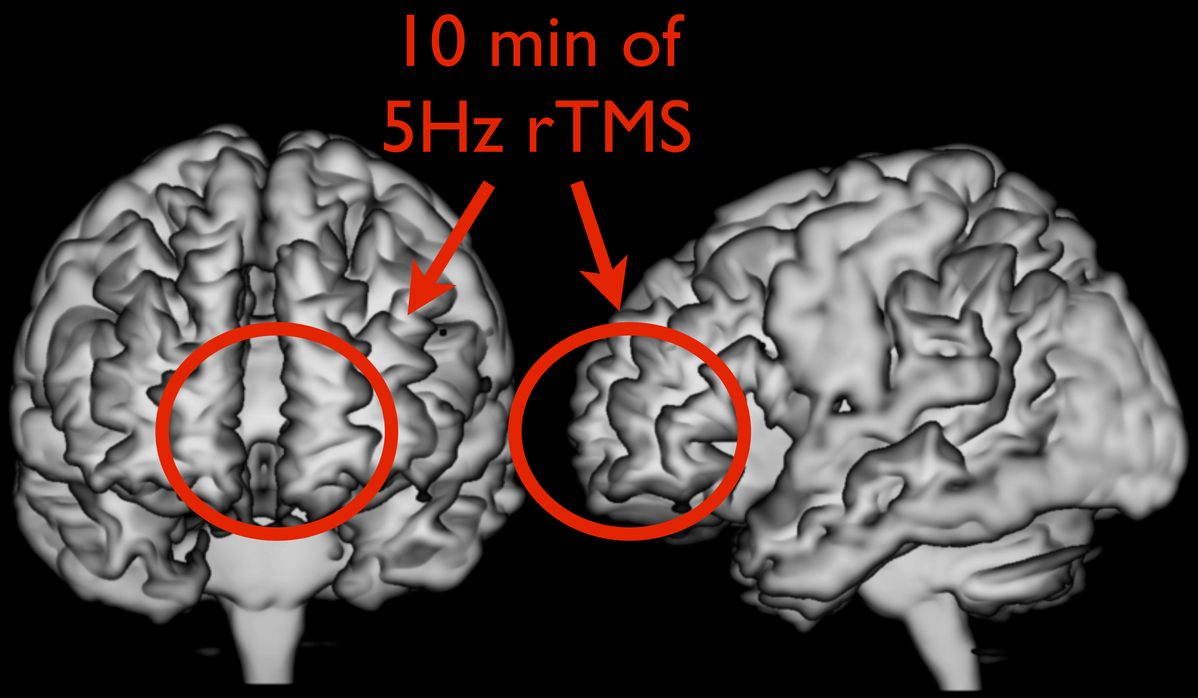

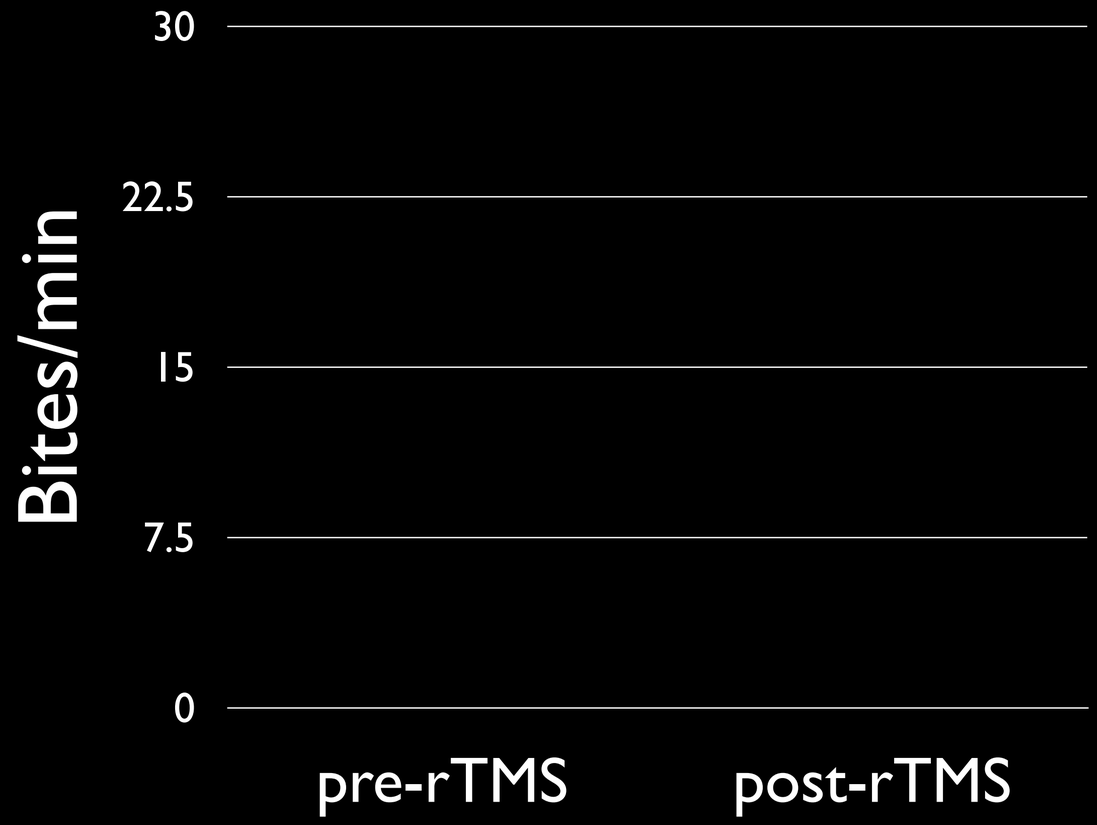

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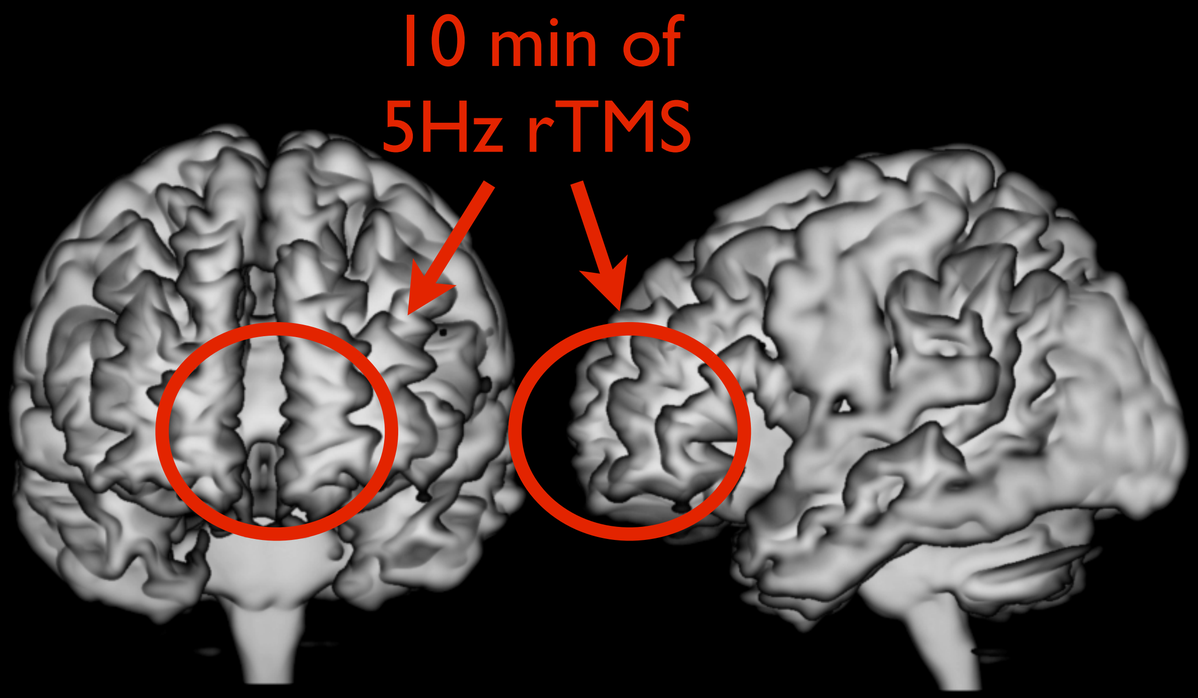
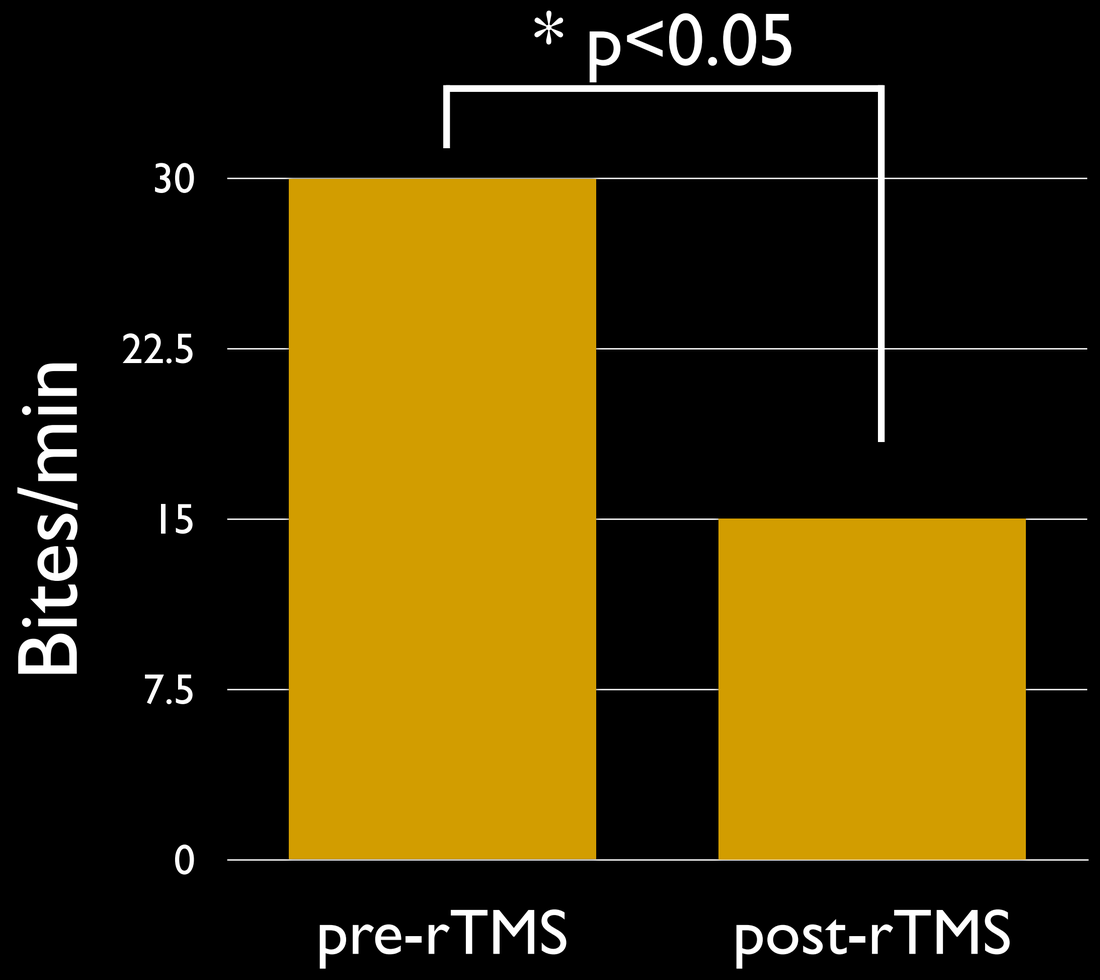
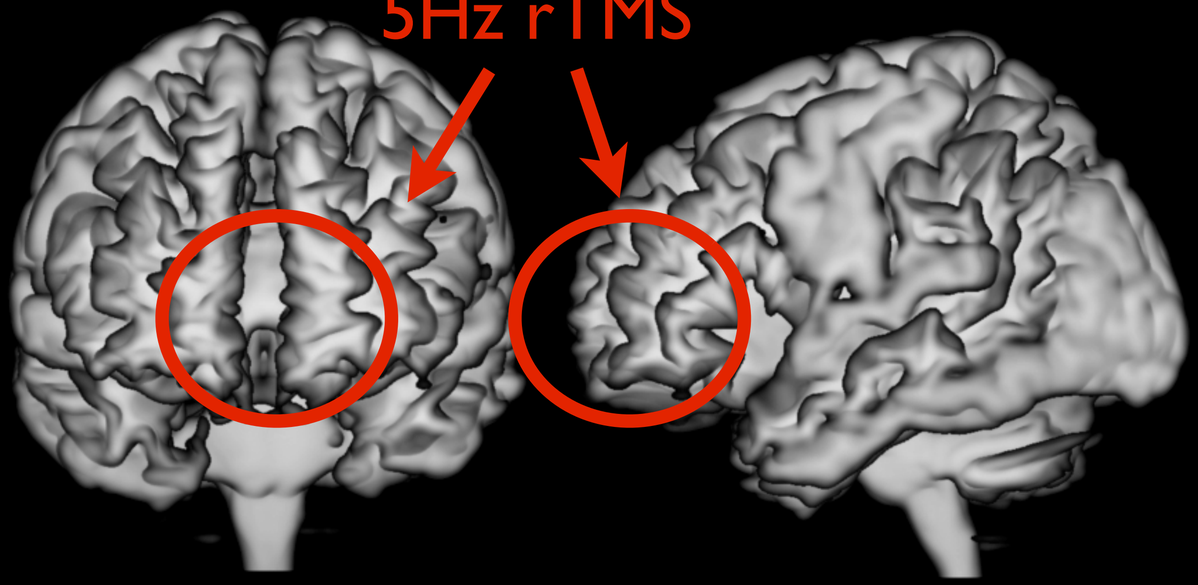
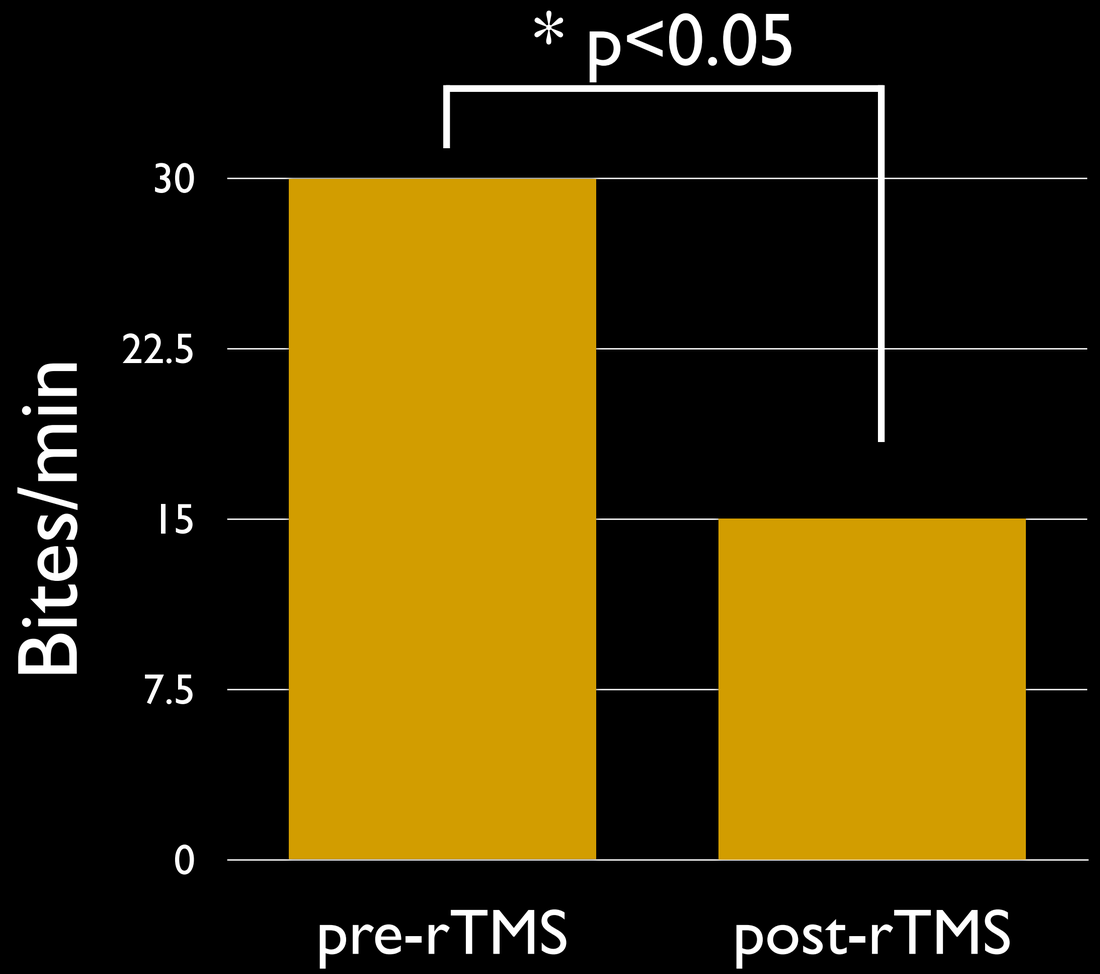




Attenuating Aggressive Behaviors Magnetically





Ramping up orbitofrontal activity reduced aggressive behaviors

The Spectrum of CDHD

This is a zombie …

… explained by science!

Hyper Aggression

Memory Deficits

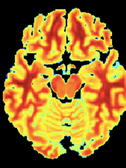
Reduced Impulse Control

Language Disruption

Movement Dysfunction

Visual Recognition Impairments

Attention Problems



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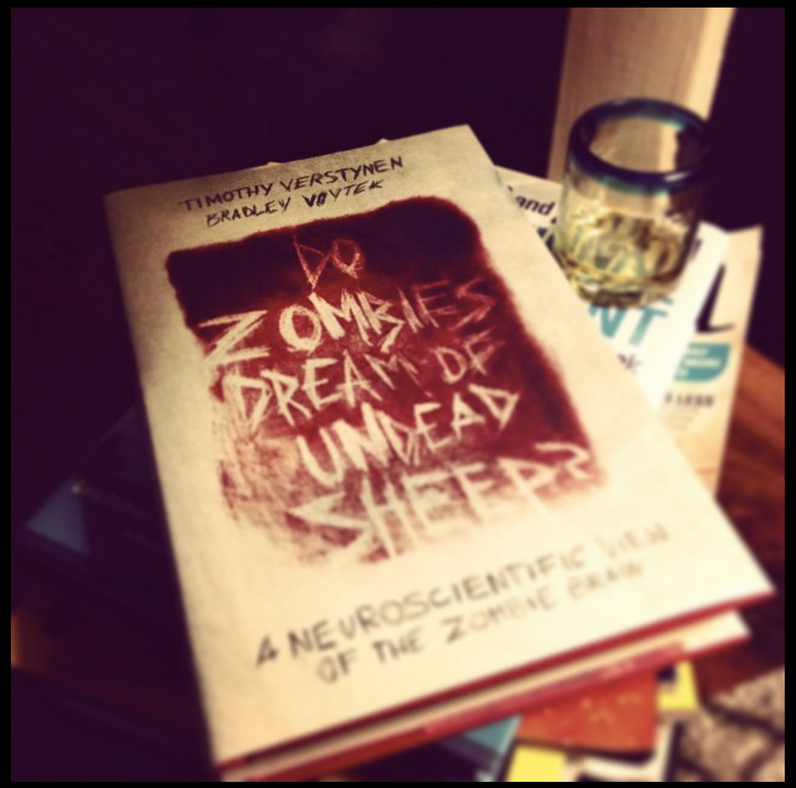

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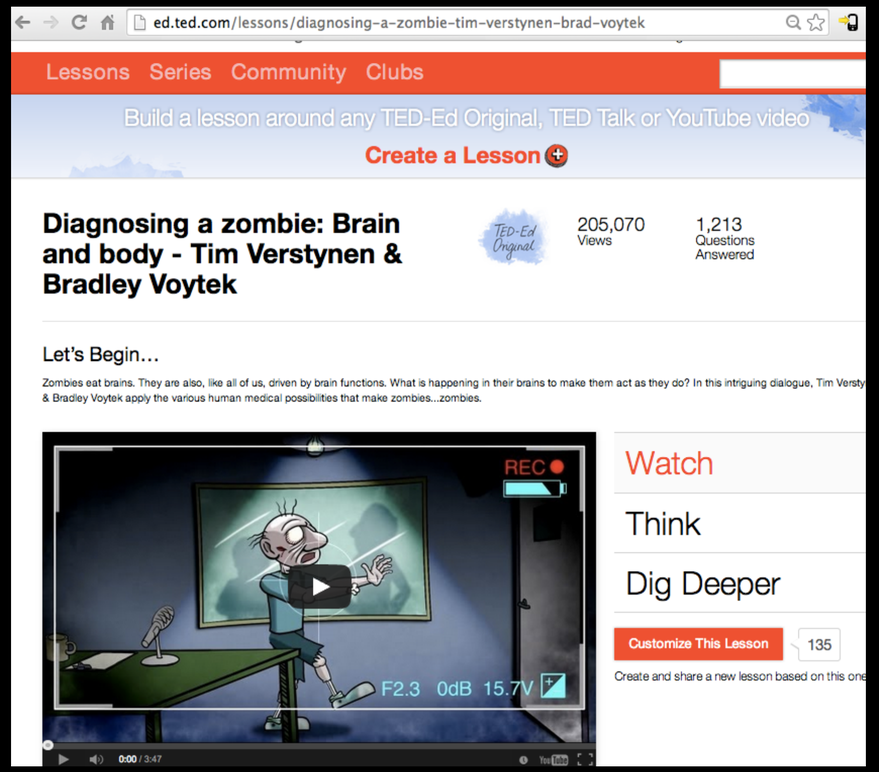

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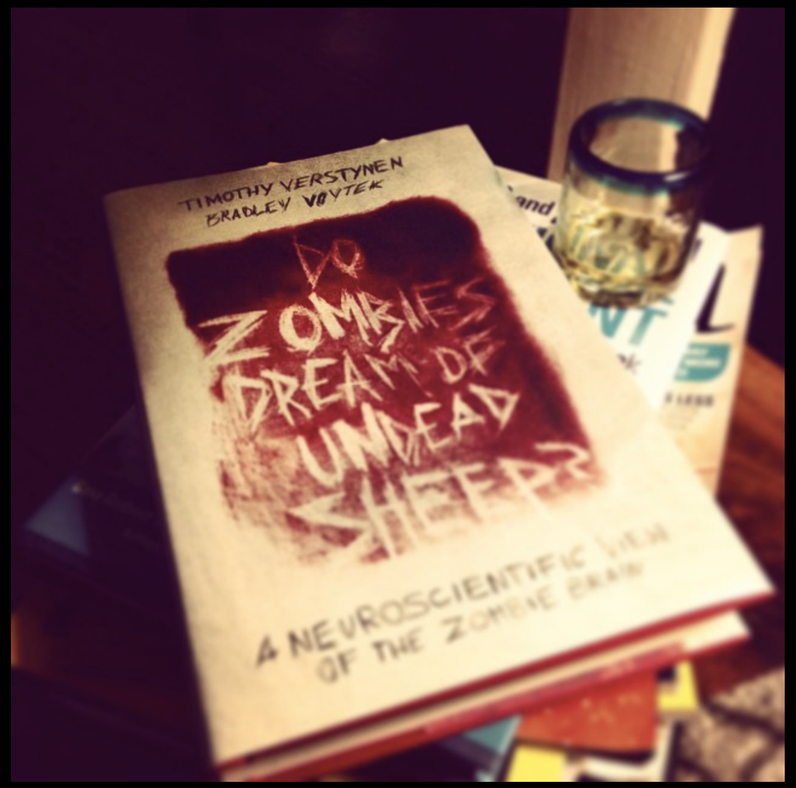

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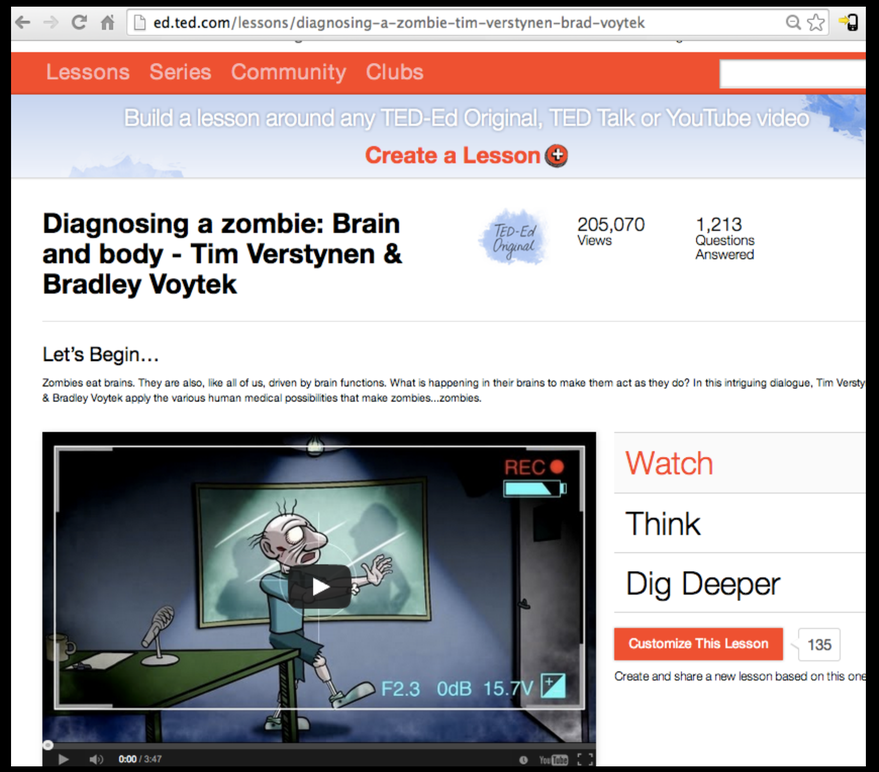

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Thank you!