



Neuroscience of behavioural change: goals and habitual actions

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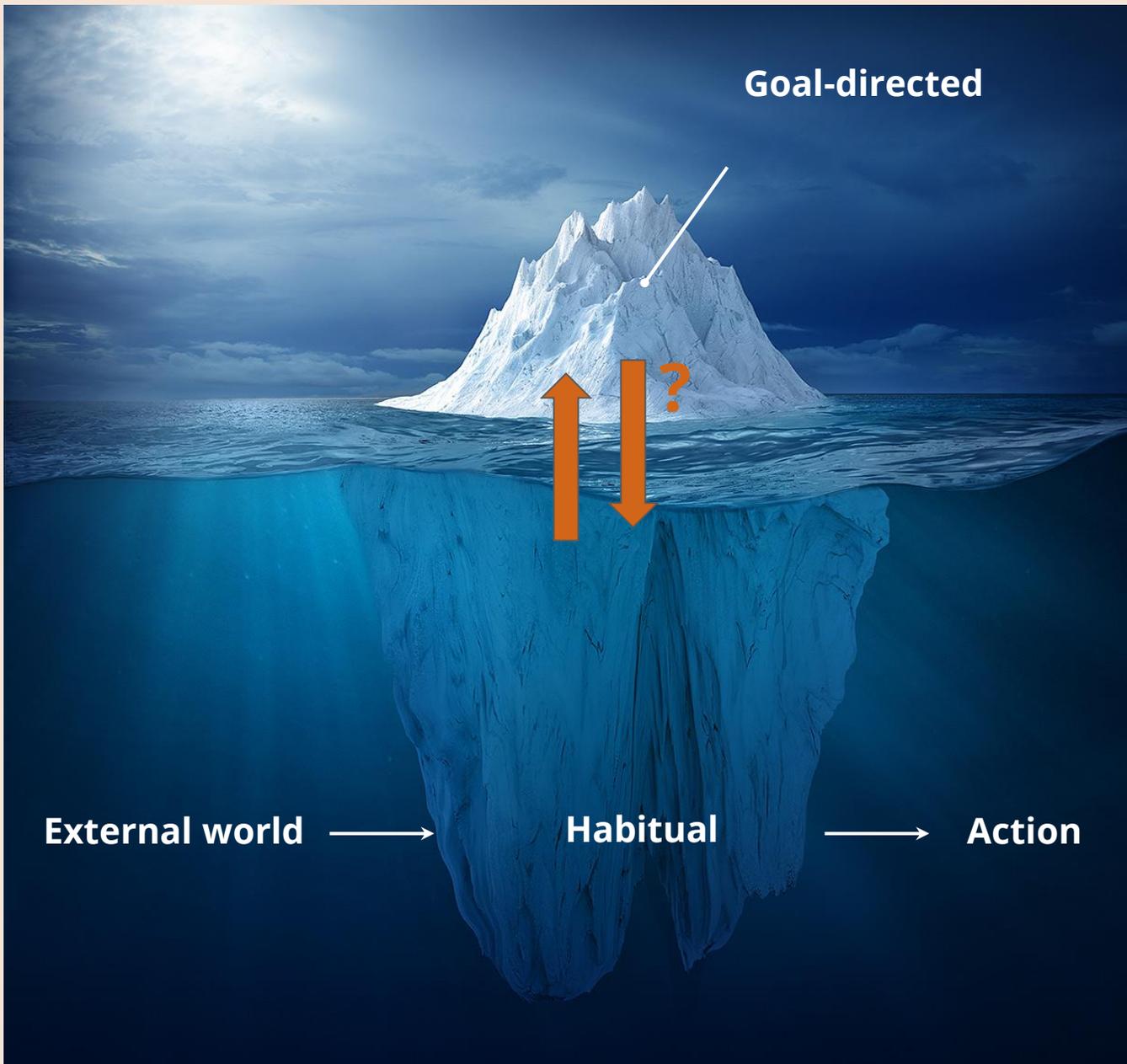
Today

- (1) Mechanisms of goal-directed and habitual actions**
- (2) How stress affects these mechanisms**

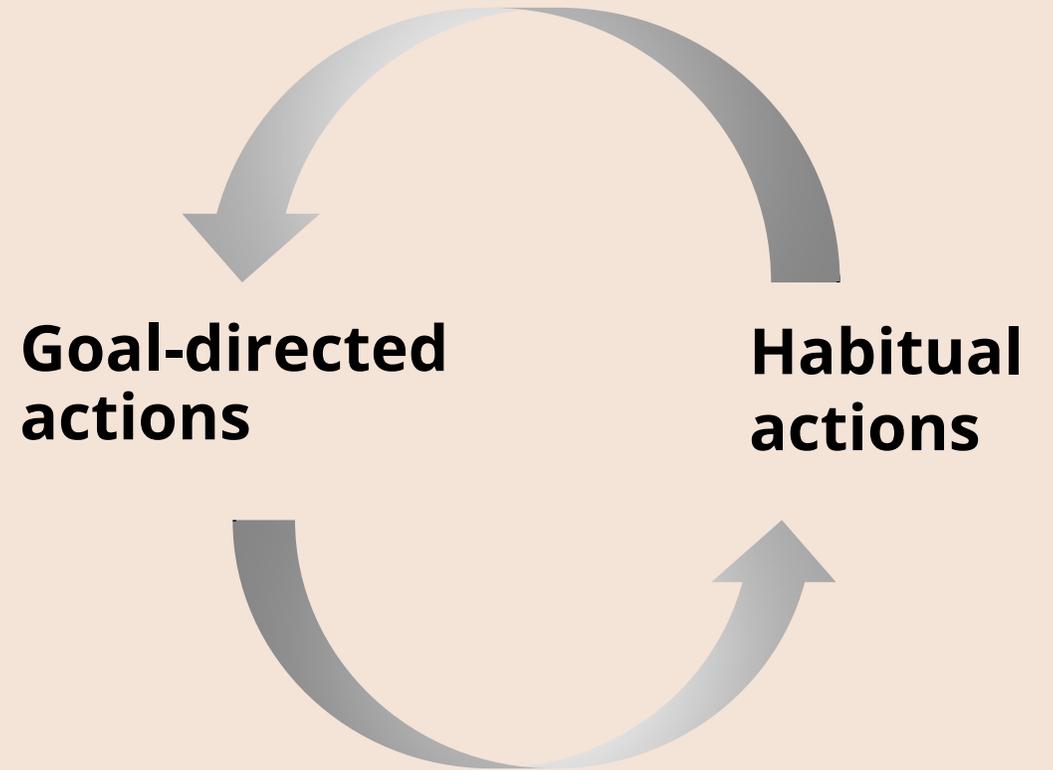
Tomorrow

- (1) Neurobiology of depression in light of psychotherapeutic approach**
- (2) How do antidepressants work?**





Value of the outcome!



Goal-directed actions

- Based on outcome
- sensitive to changes in the expected outcome
- Voluntary control

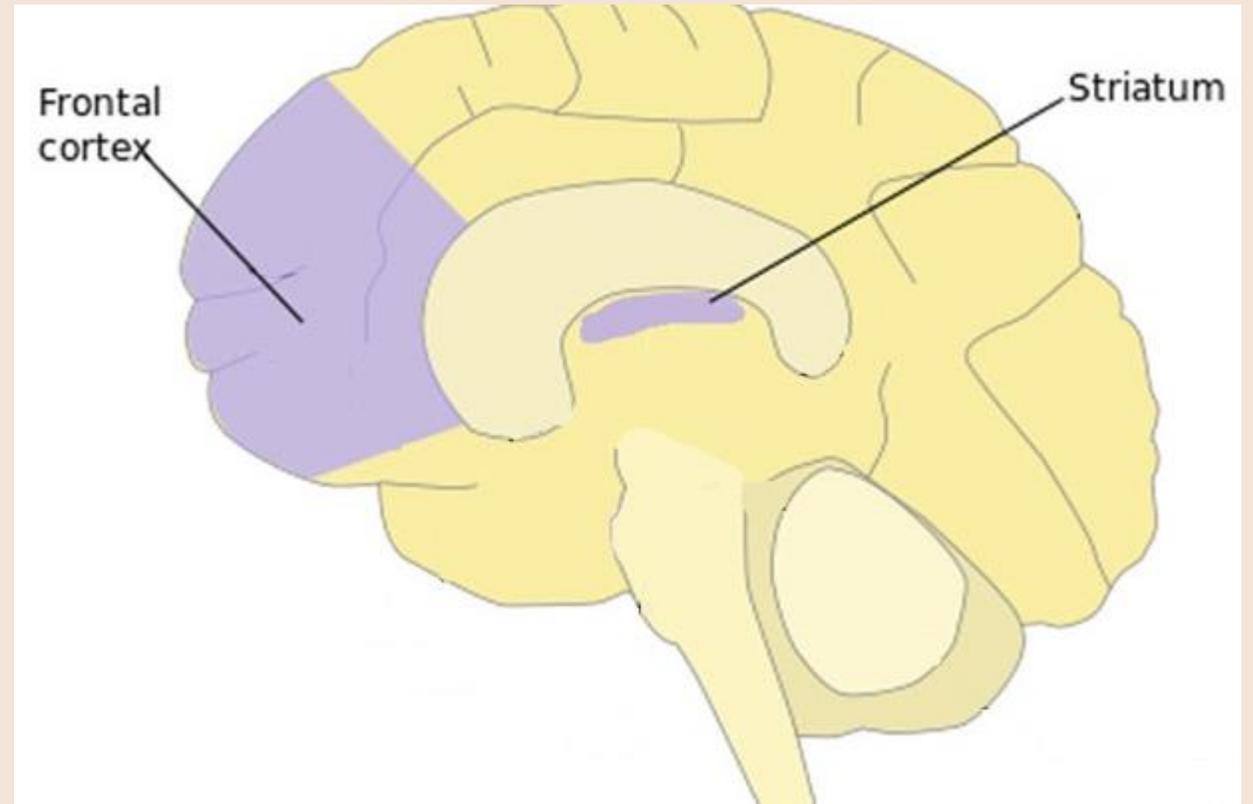
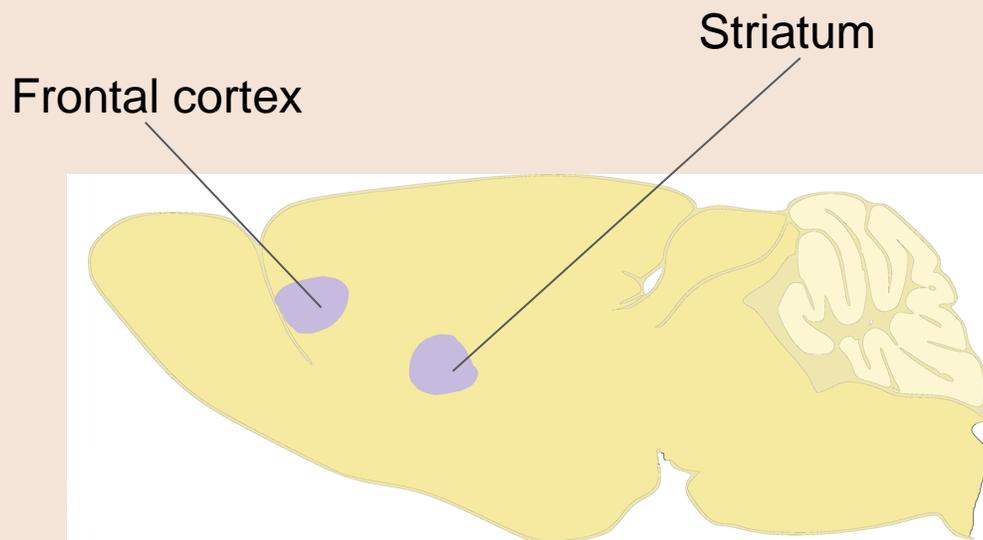
Habits

- To a smaller degree based on outcome
- Less sensitive to changes in the expected value of the outcome
- Towards compulsive behaviour

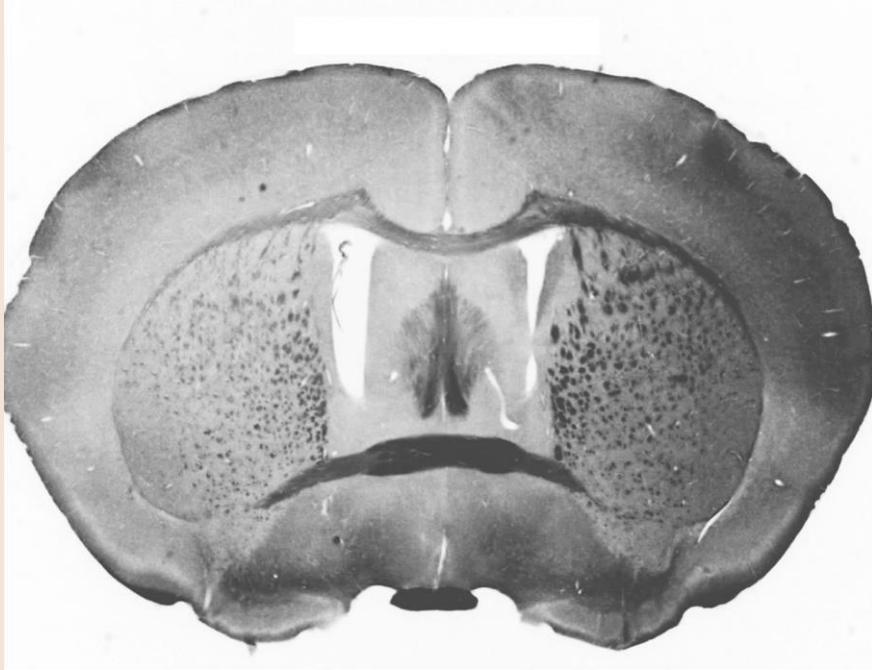
- ★ Extended training,
- ★ different schedules







The brain



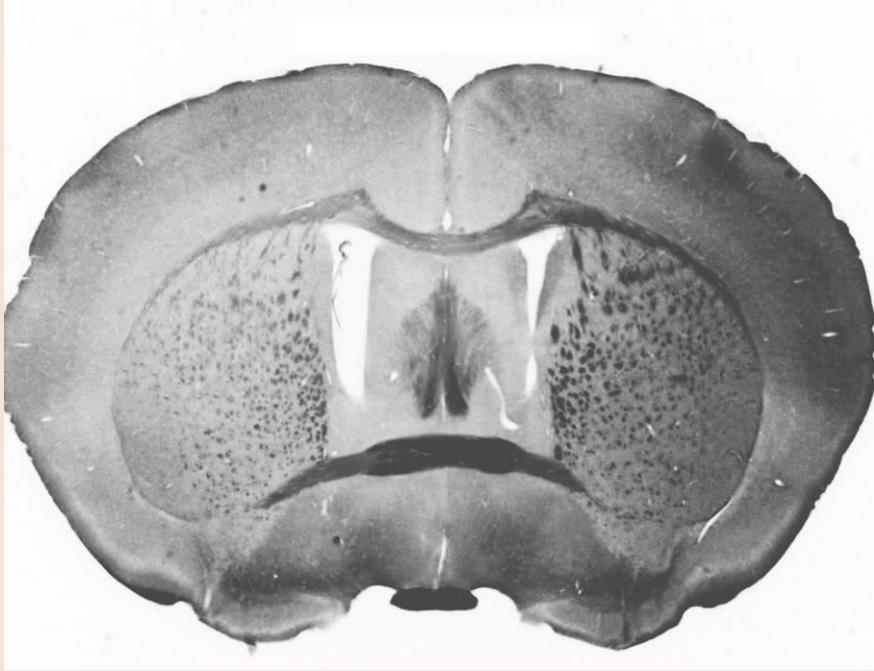
Rat



Human



Striatum

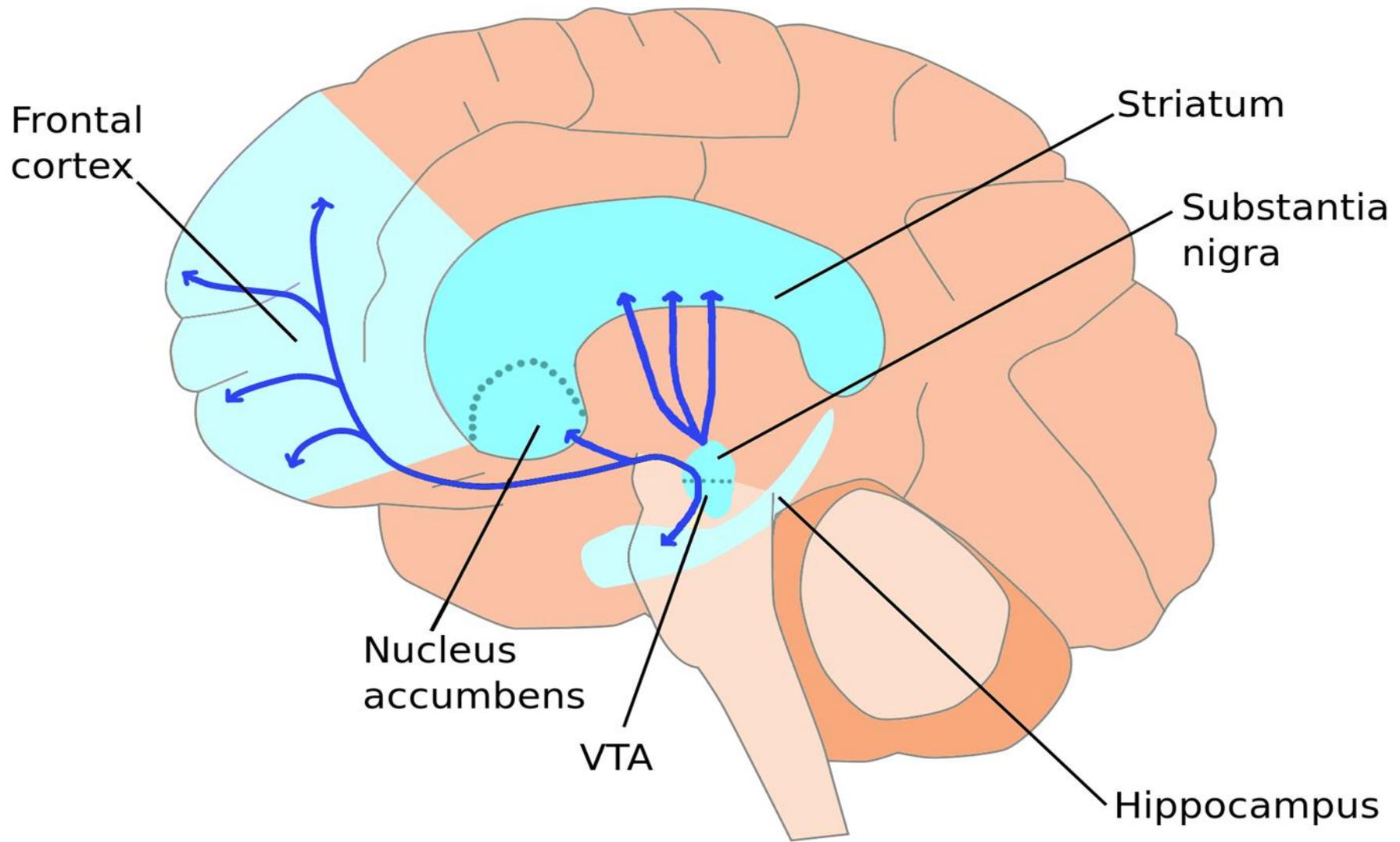


Rat



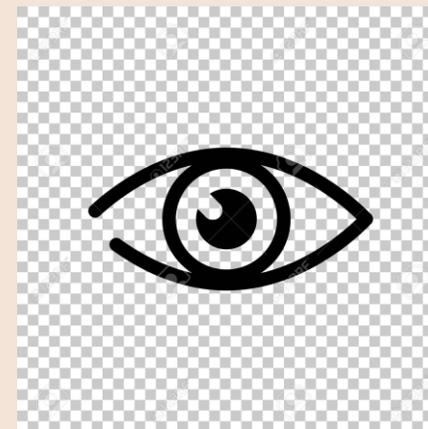
Human





How do scientists study goal-directed behaviour in the lab?





Social stress

**Task with outcome
devaluation**

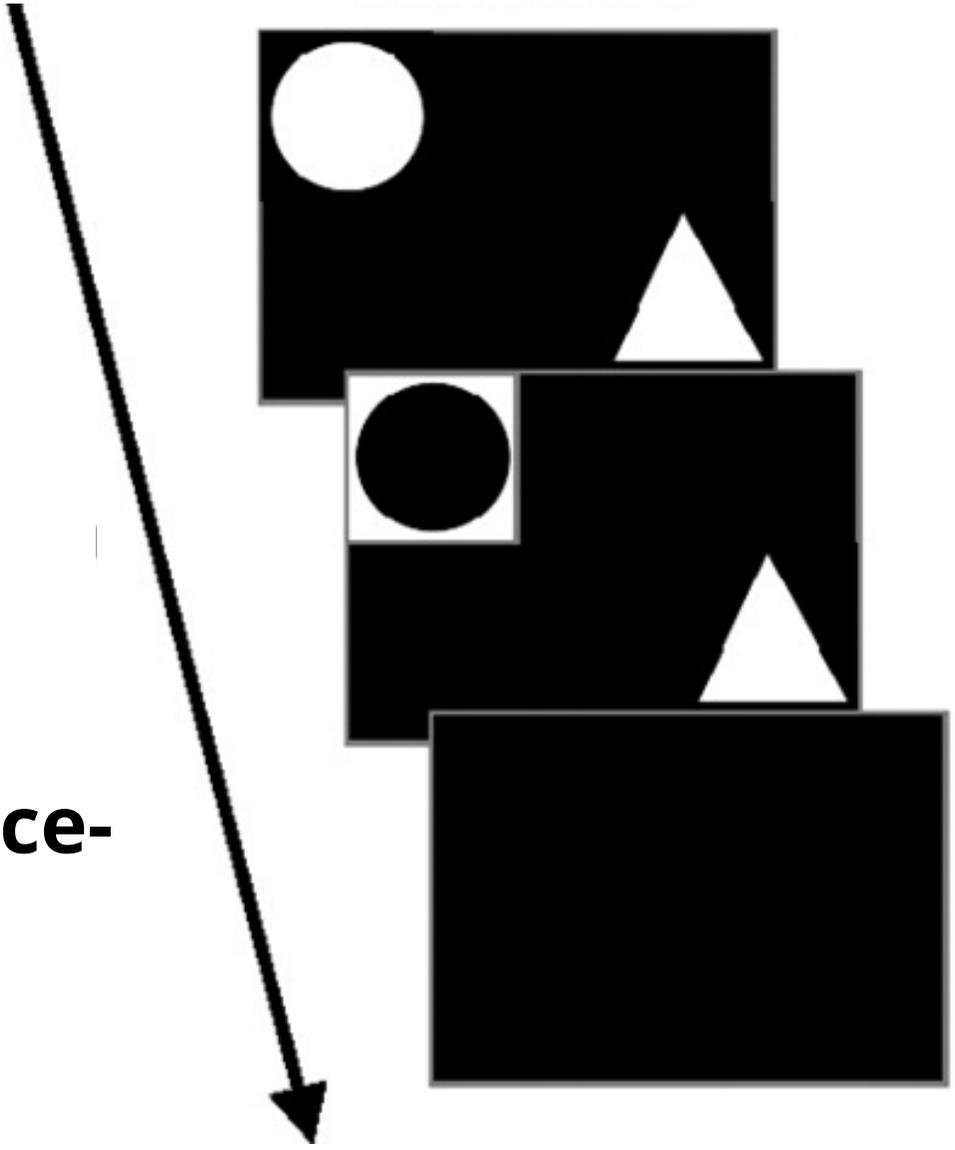
Control group



Options

Choice

Reinforce-
ment



50%

20%

20%



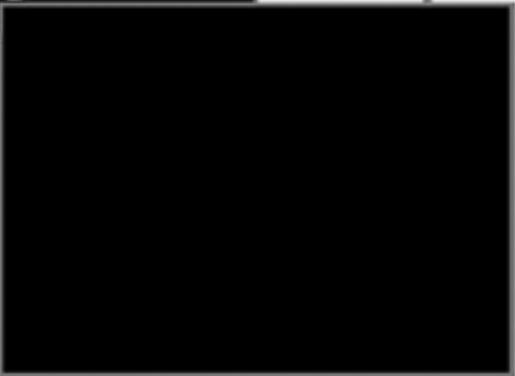
Options



Choice



Reinforce-
ment



50%



20%



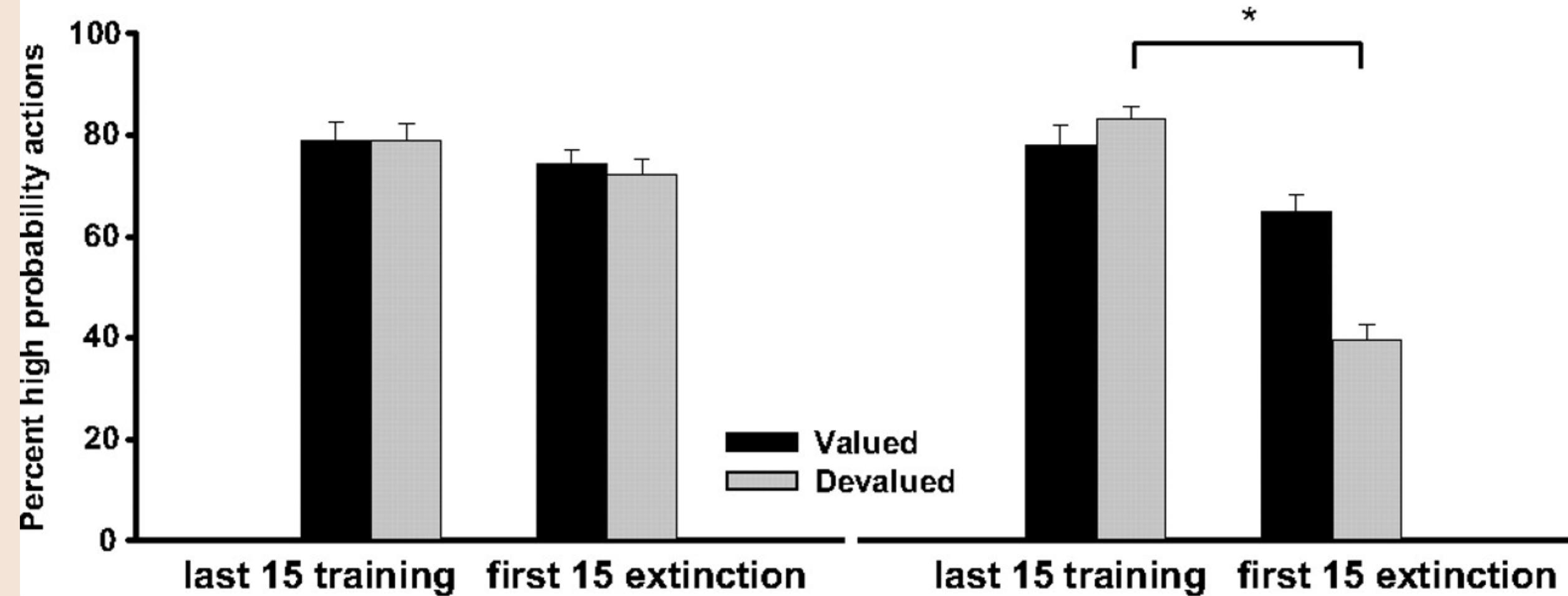
20%





Stress

Control

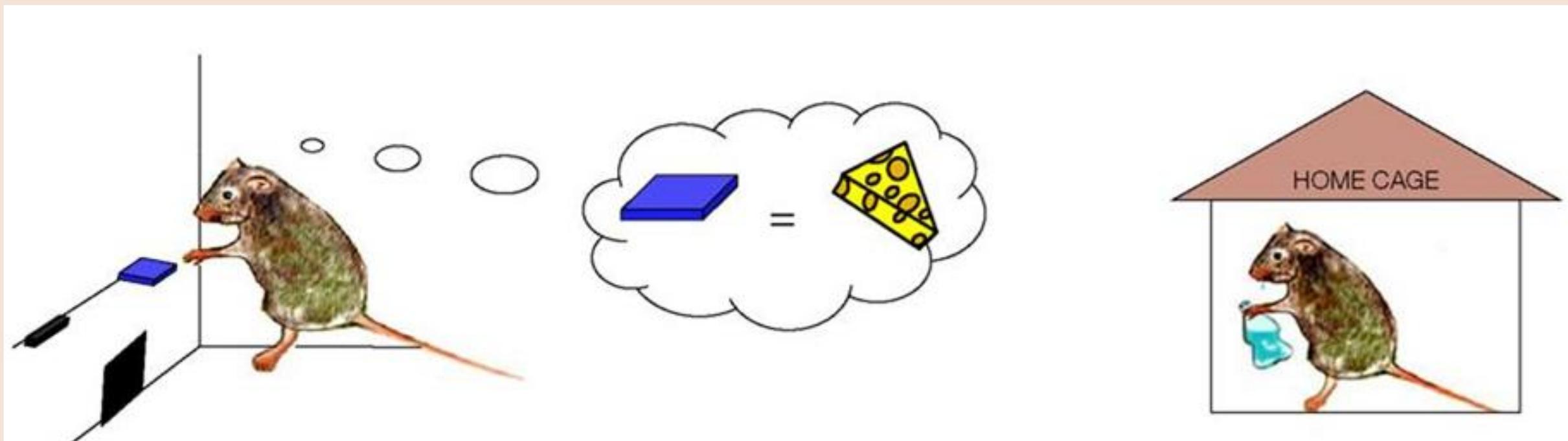


58% vs. 28%

awareness of the action–outcome associations









**How to test
whether the rat's
actions are goal-
directed or
habitual?**





**How to test
whether the rat's
actions are goal-
directed or
habitual?**

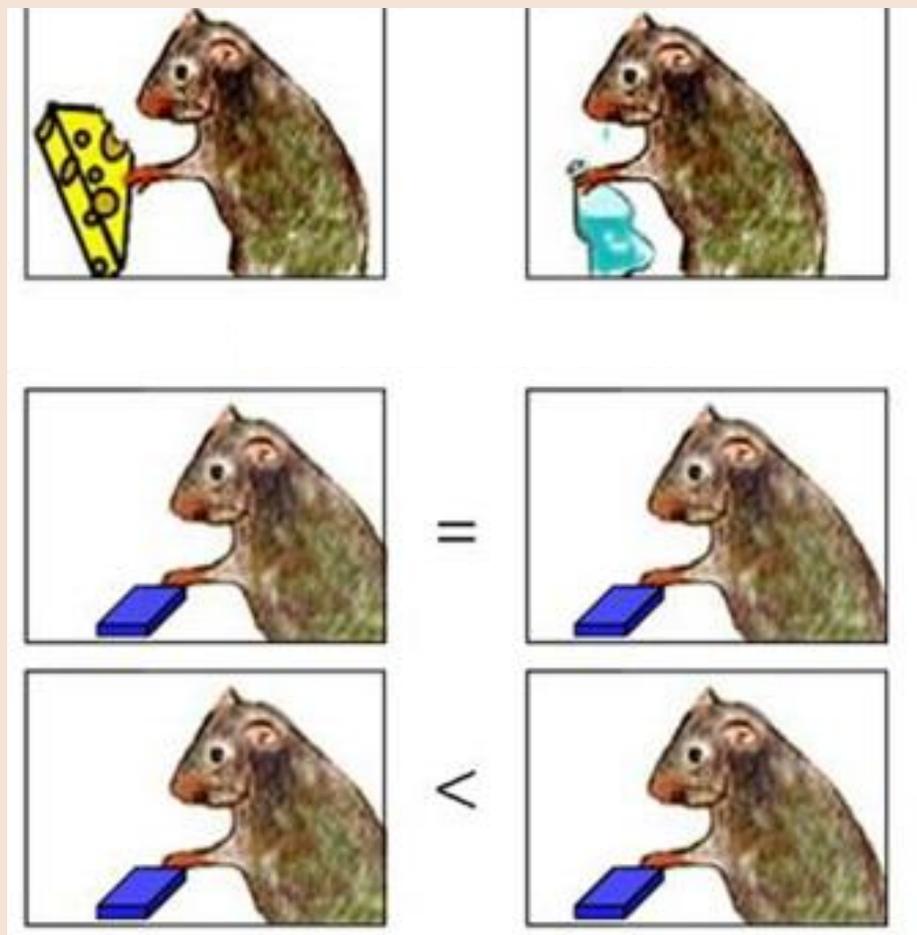
Devaluation!



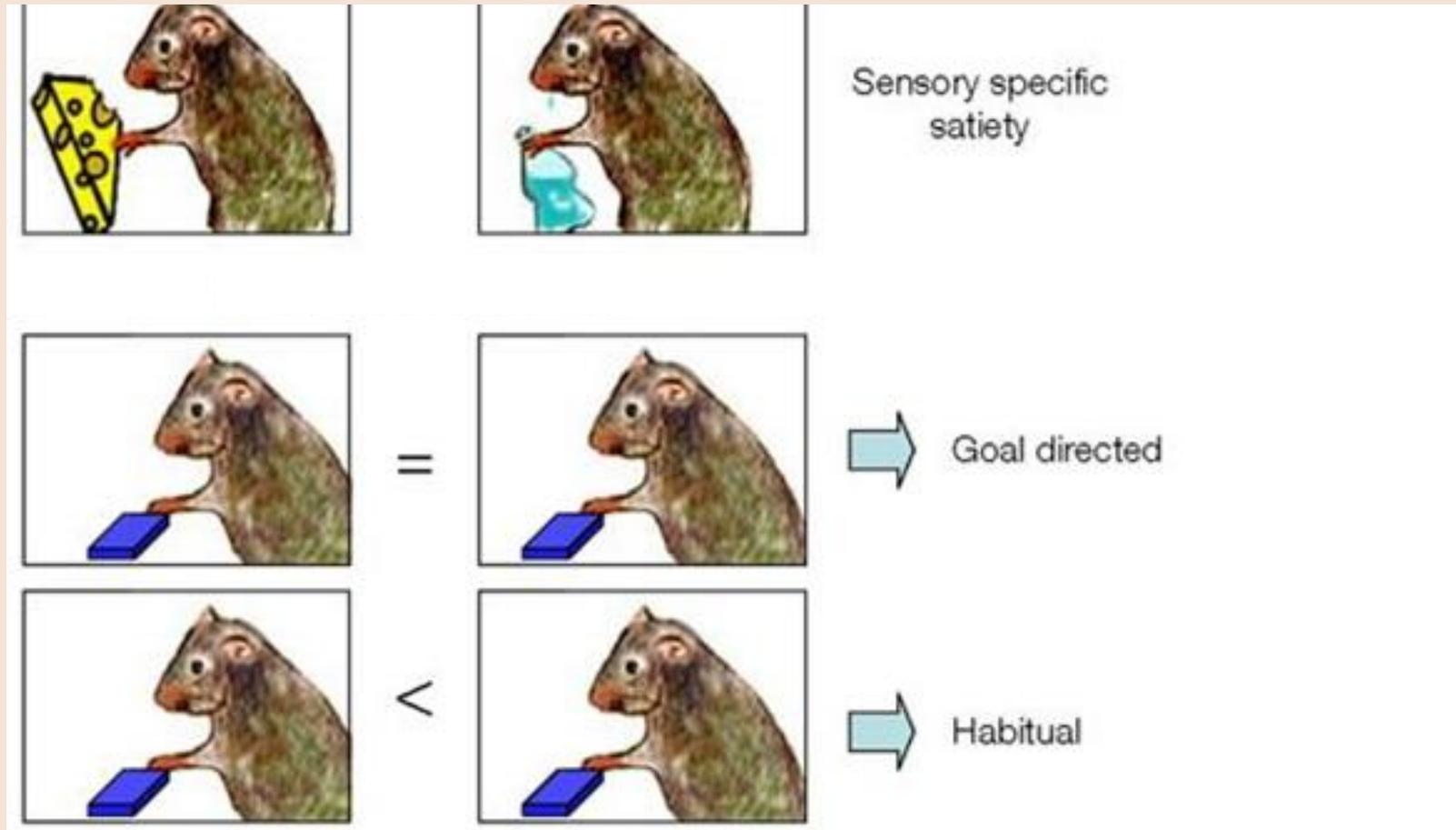
Devaluation test



Devaluation test



Devaluation test



**Behaviour remains more sensitive to devaluation is
reinforcement is random (+- every 20 presses)**



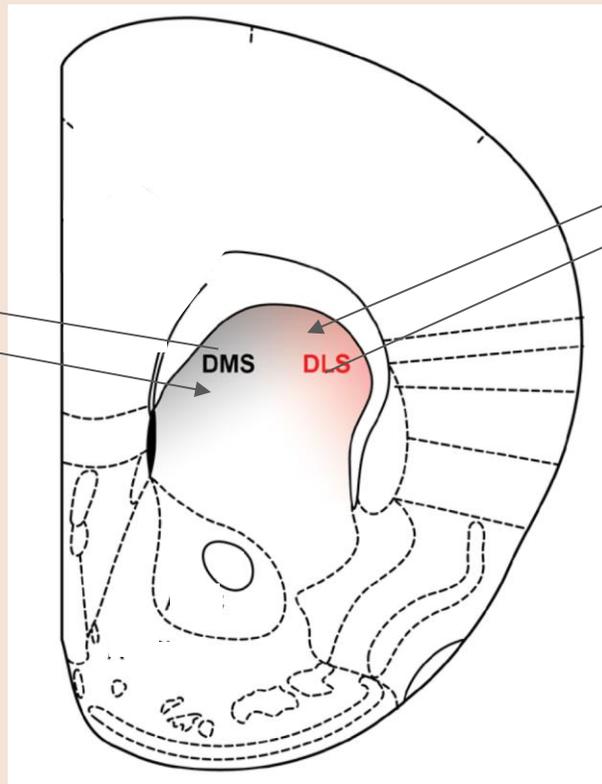
Where we are so far

- Neuroscience uses simple models to study complicated things
- Rats have goal-directed and habitual behaviours
- Sensitivity to the value of the outcome is critical

Next: the brain



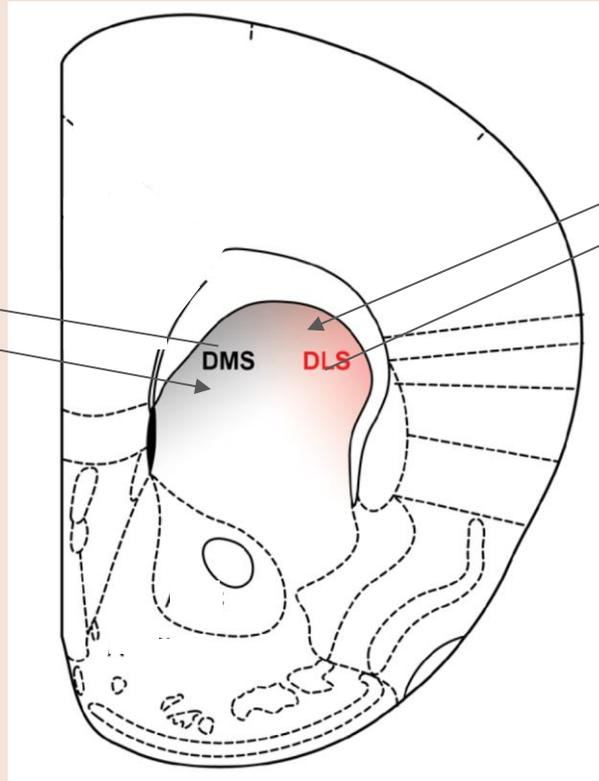
Associative areas



Sensorimotor cortex



Associative areas

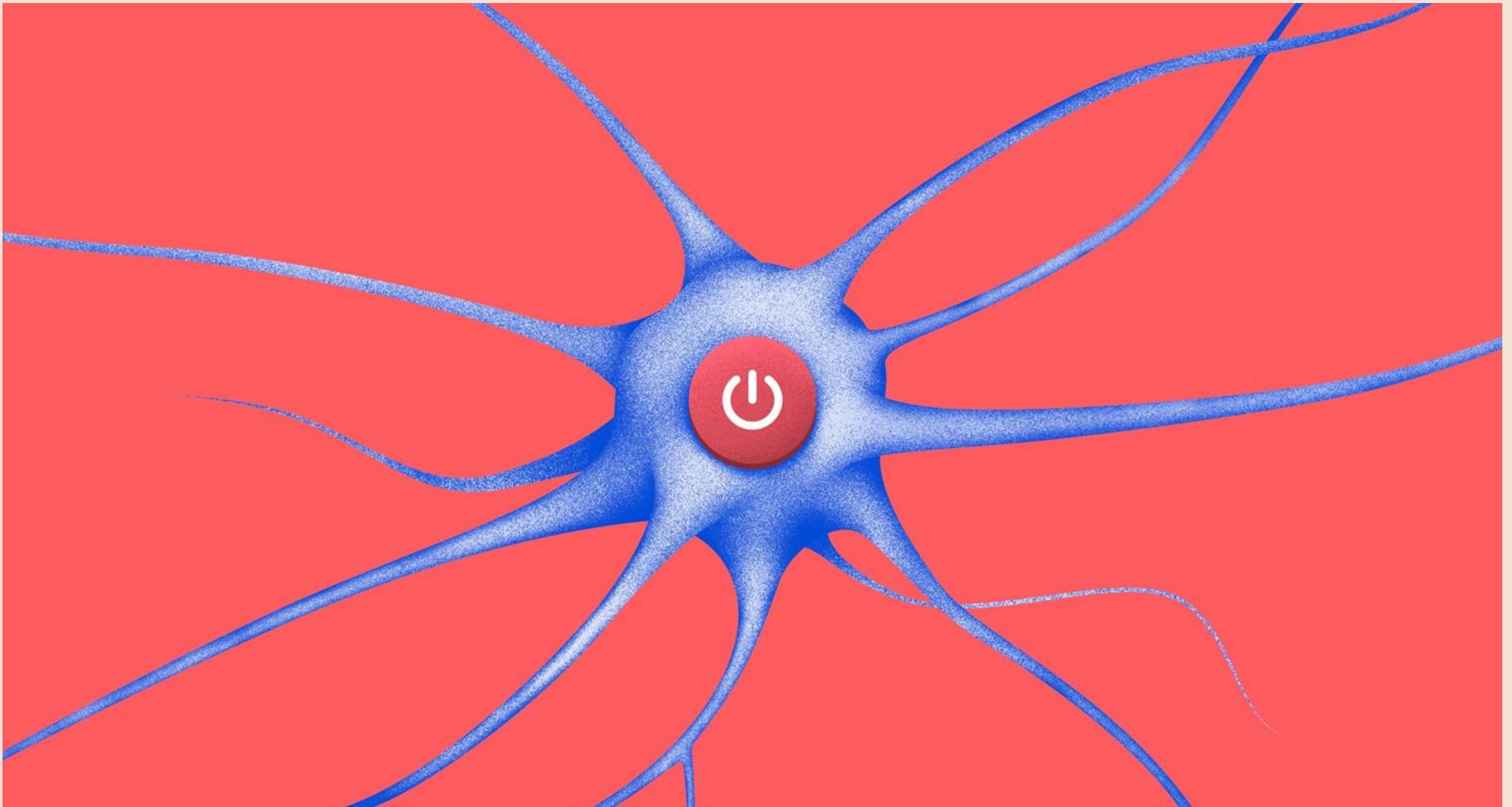


Sensorimotor cortex

Goal directed actions

**“Stimulus-response”
(Habits)**

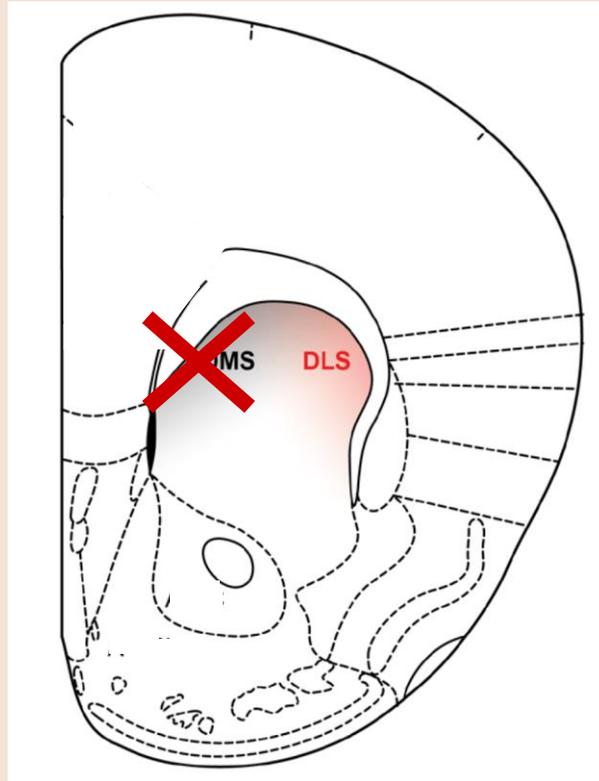




Muscimol- GABA agonist



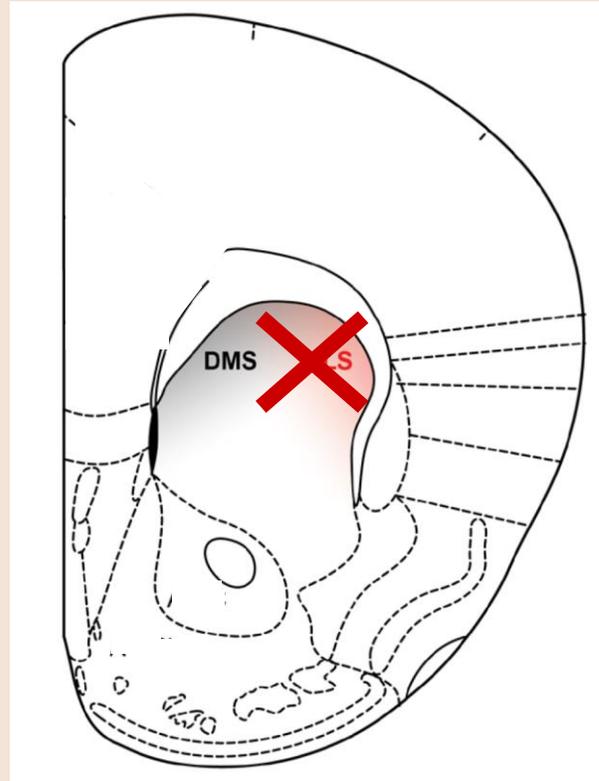
~~Goal directed~~
actions



“Stimulus-response”
(Habits)



Yin et al., 2004, 2005

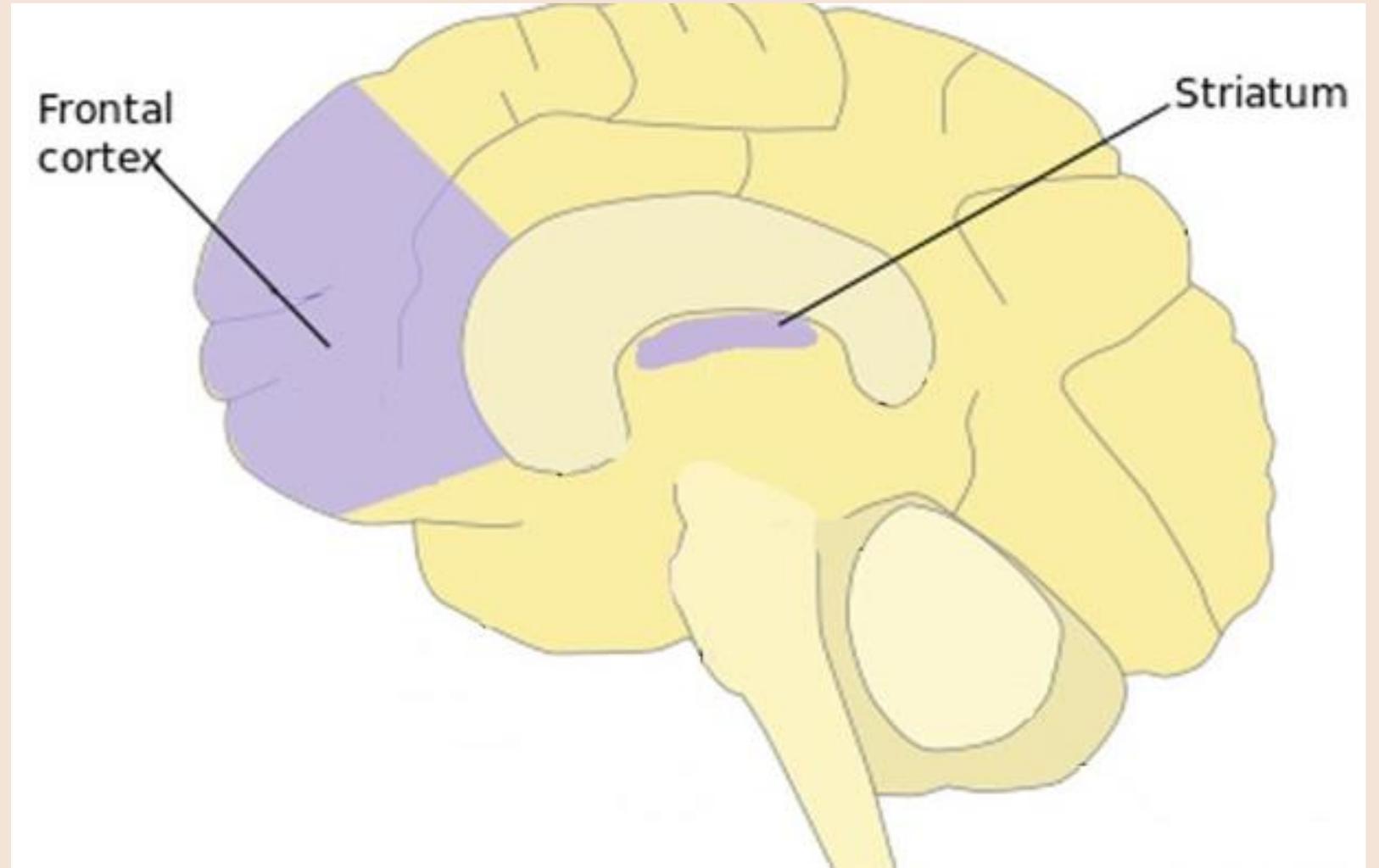


**Goal directed
actions**

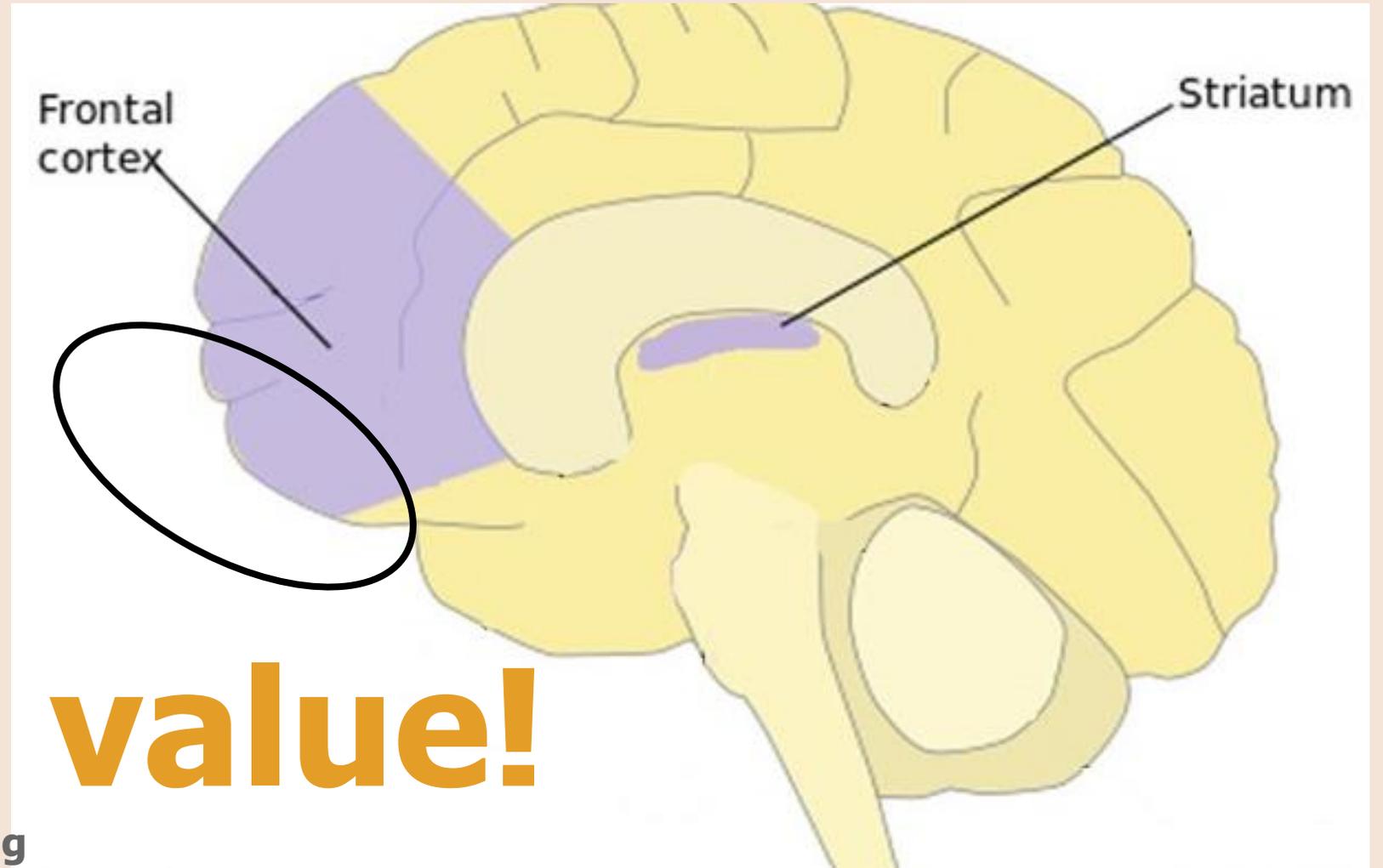
~~**“Stimulus-response”
(Habits)**~~



Frontal cortex

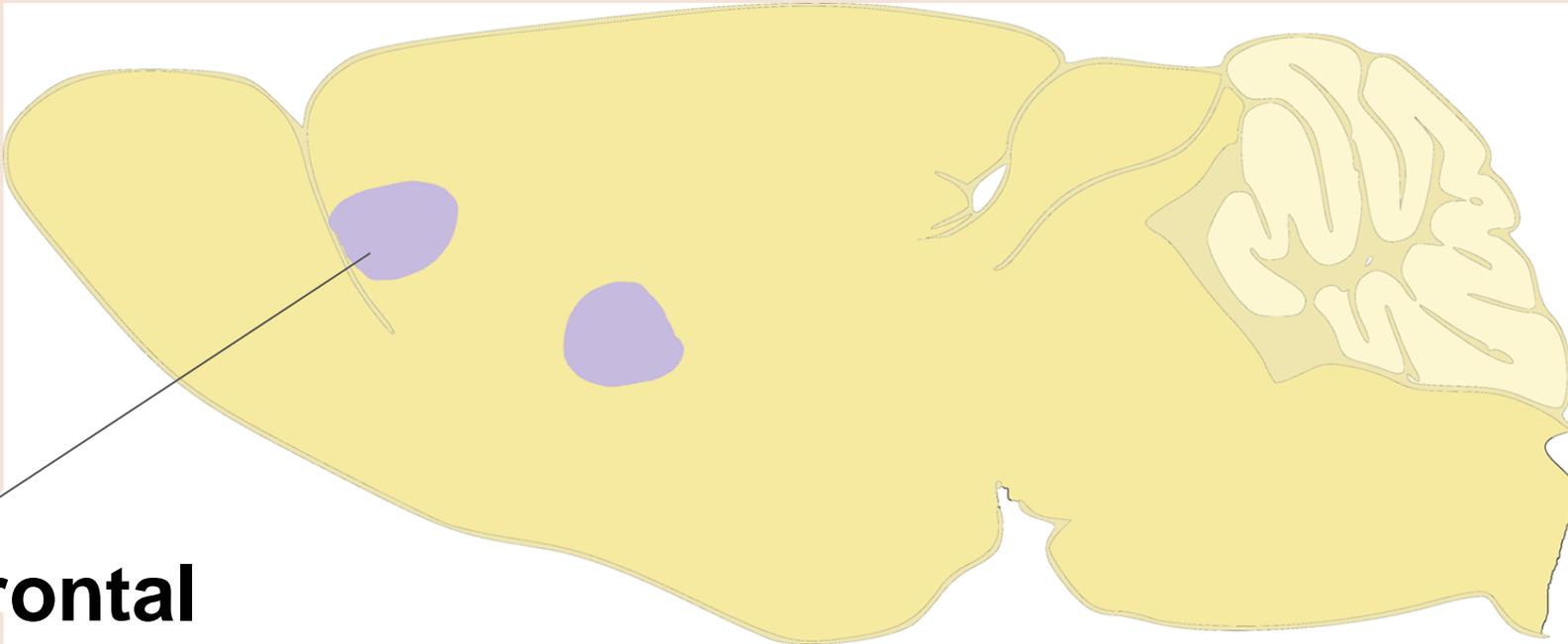


Frontal cortex



- stimulus-outcome learning
- goal-directed decision-making
- dependent on the expected action value





**Orbitofrontal
cortex
(value!)**



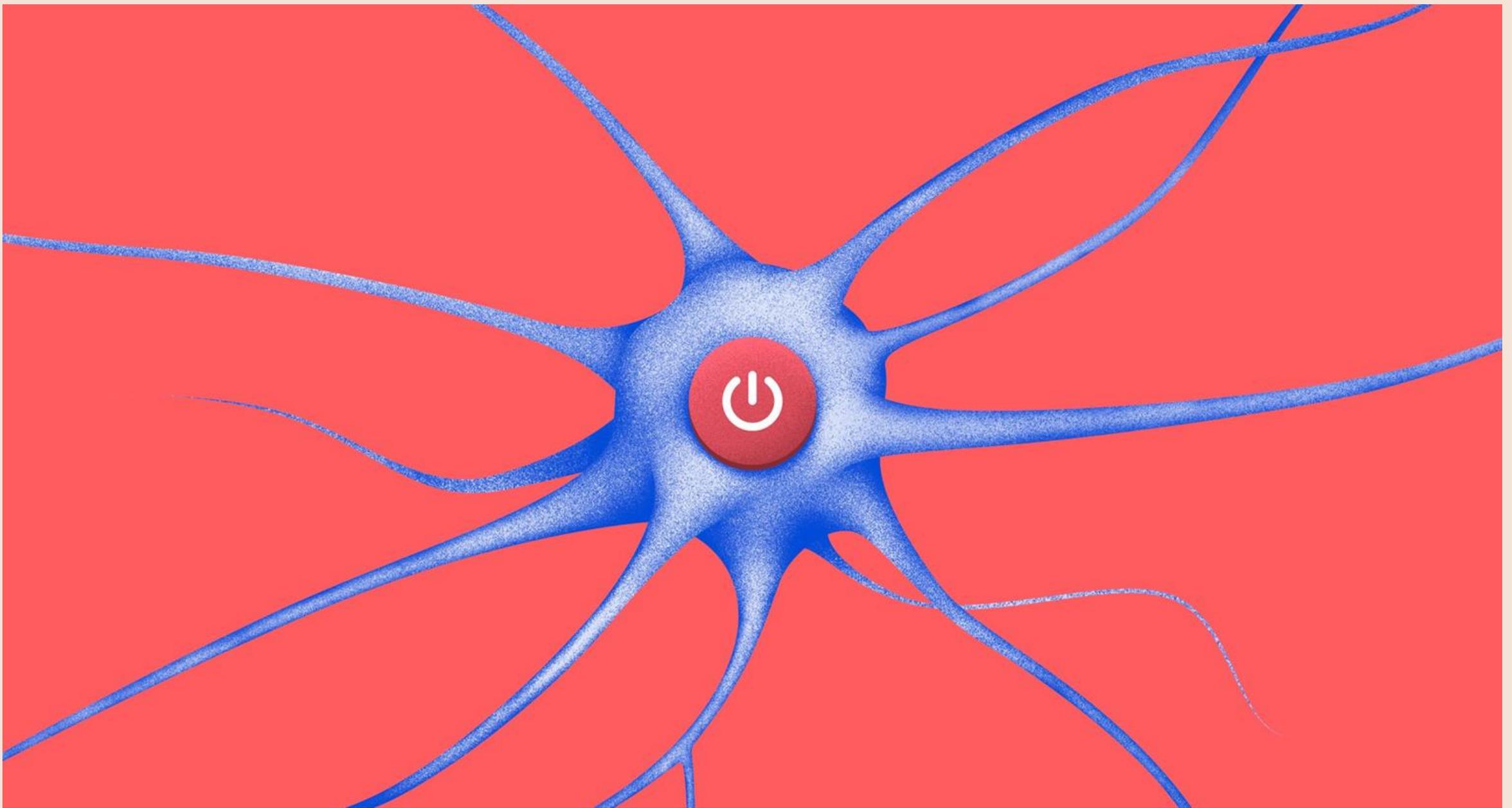
How does orbitofrontal cortex impact habitual behaviour?

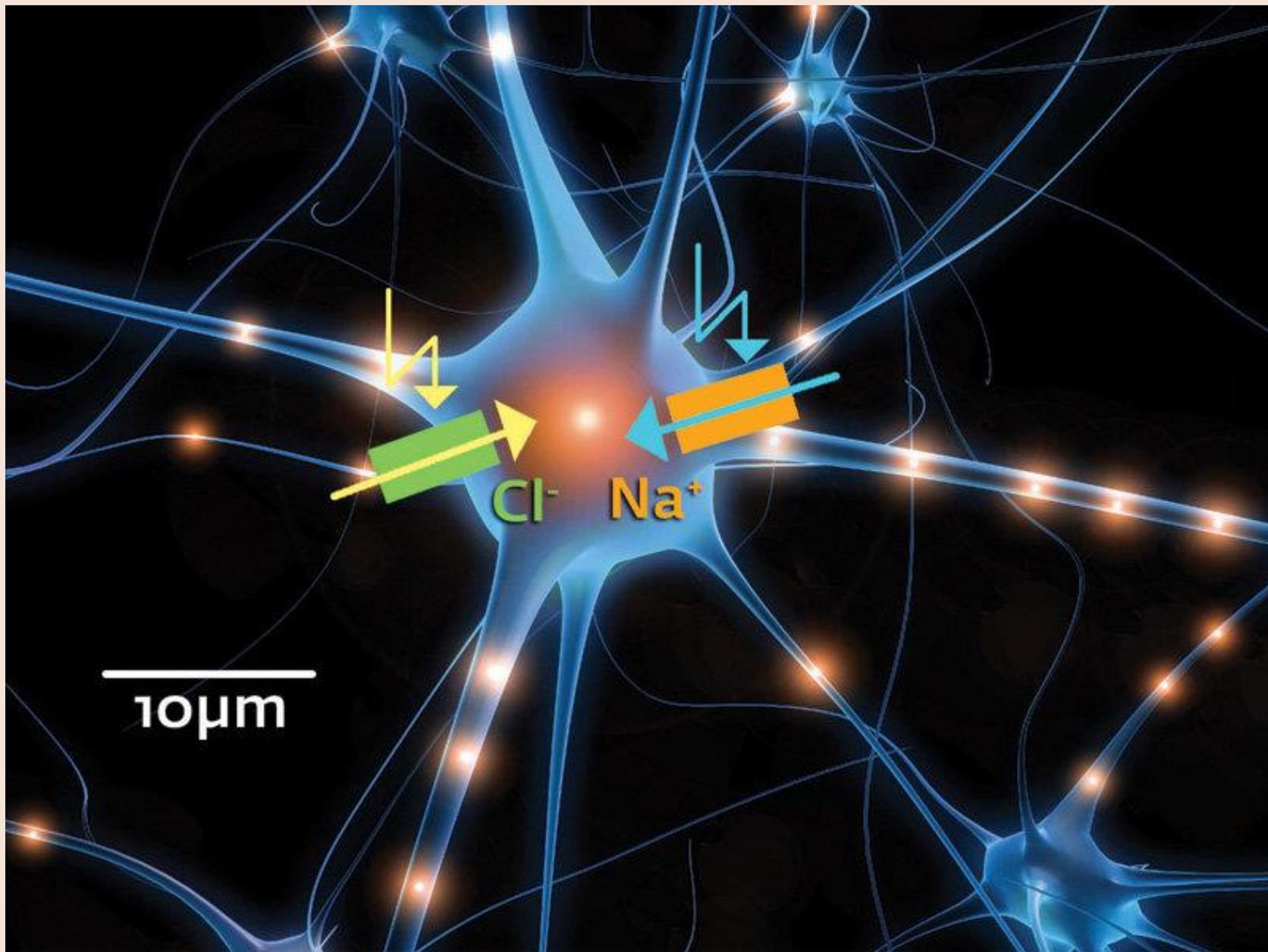


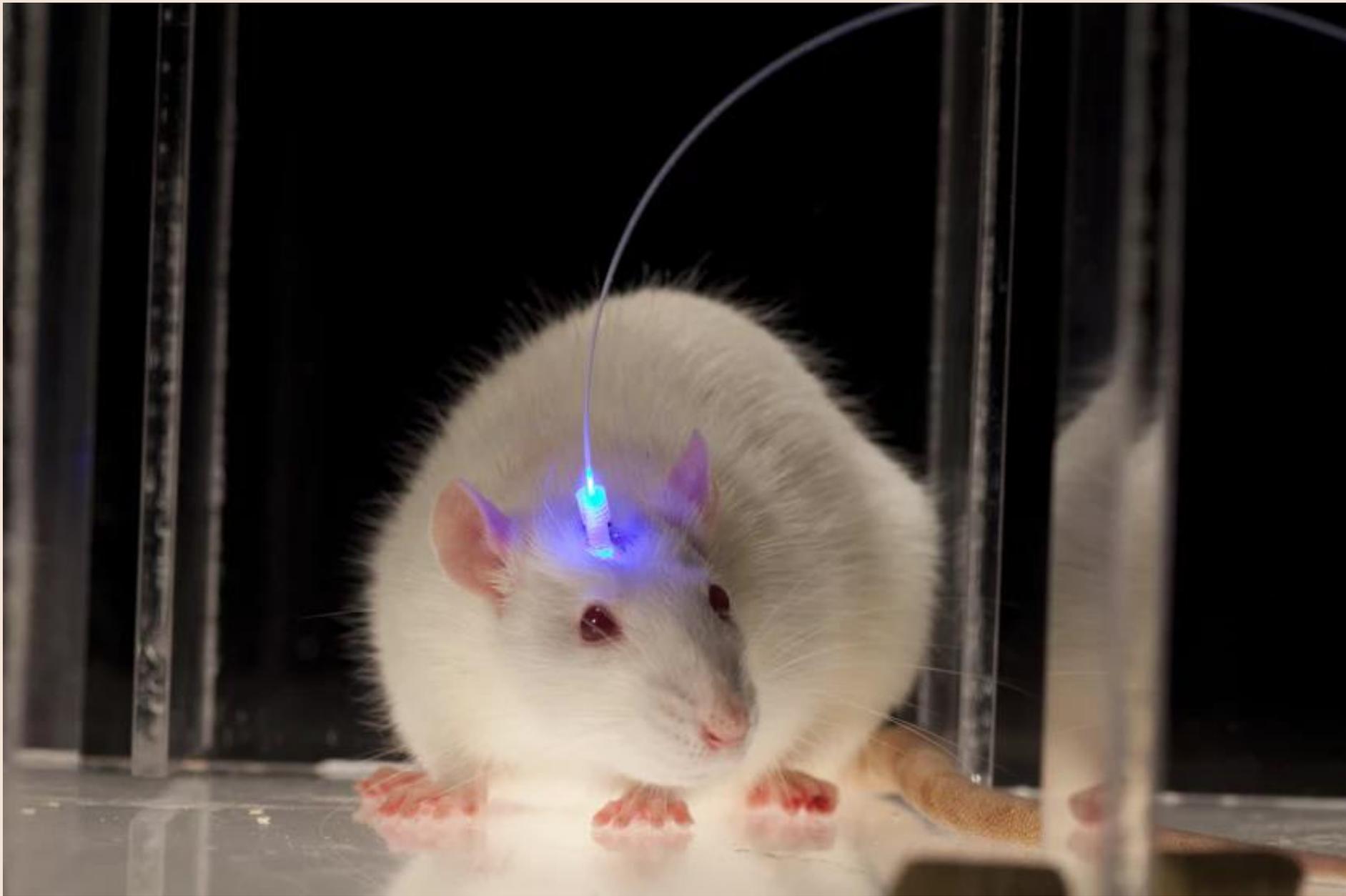
**Orbitofrontal
cortex**

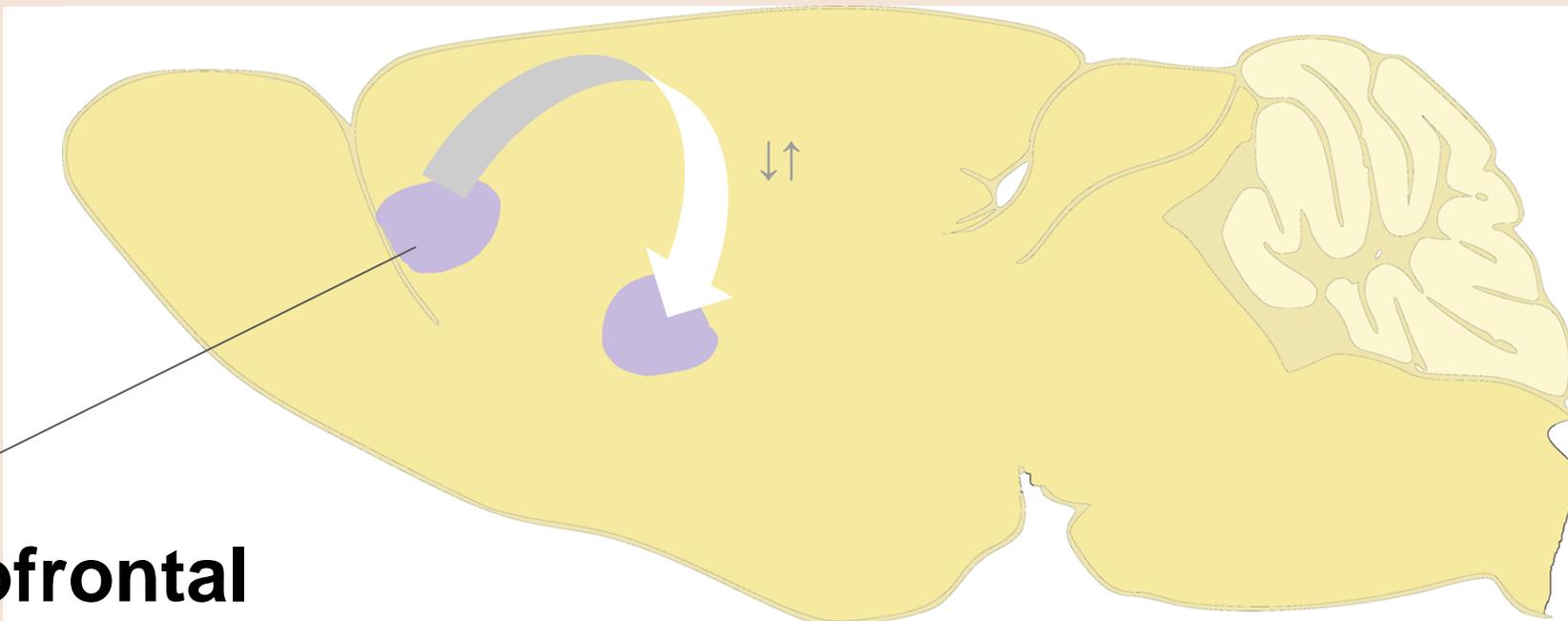
VALUE!











**Orbitofrontal
cortex**

value!



Elaborating on the desired outcome helps clients to switch from habitual to goal-directed mode



S

M

A

R

T



Specific



Measurable



Attainable



Relevant



Time Based



Interim conclusions

- Both cortical and subcortical areas participate in goal directed actions
- Same for habitual actions!
- A frontal area that encodes value shifts behaviour towards goal directed



Why is it more difficult to get rid of habits during stress?





Goal directed

Stress

External world → Habitual actions → Action



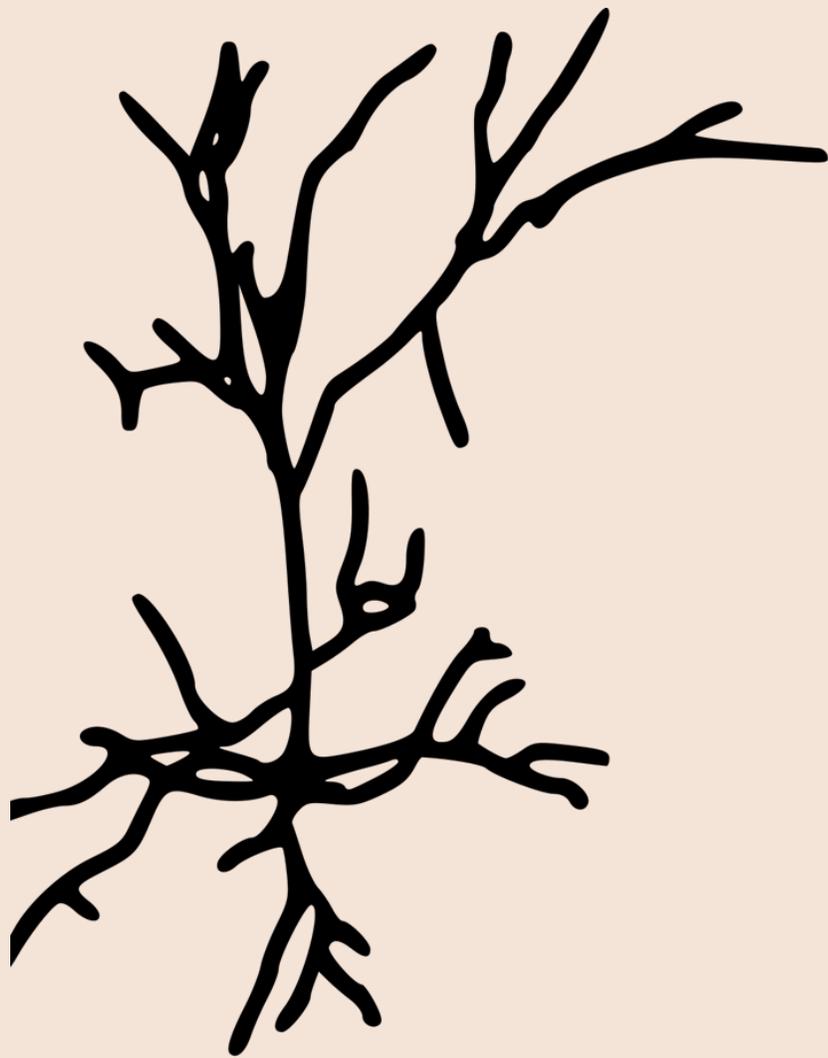
Stress

Valued \approx devalued

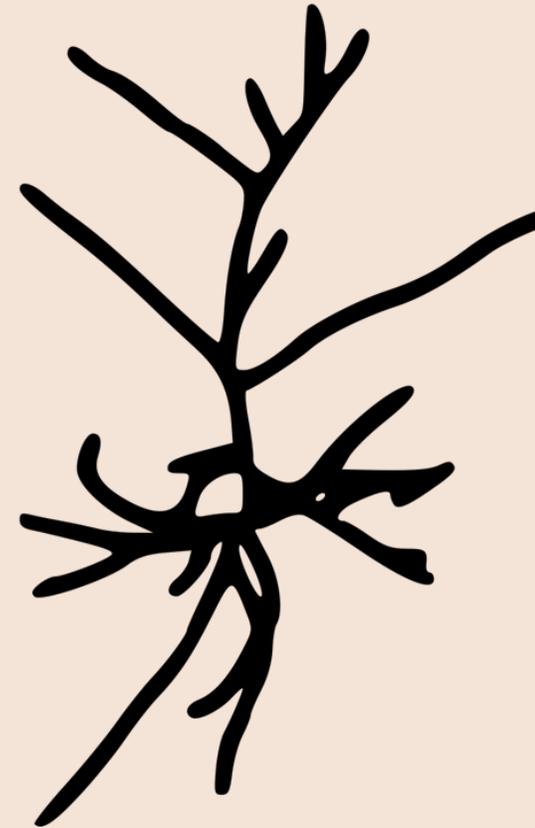


How does stress affect those parts of the brain?



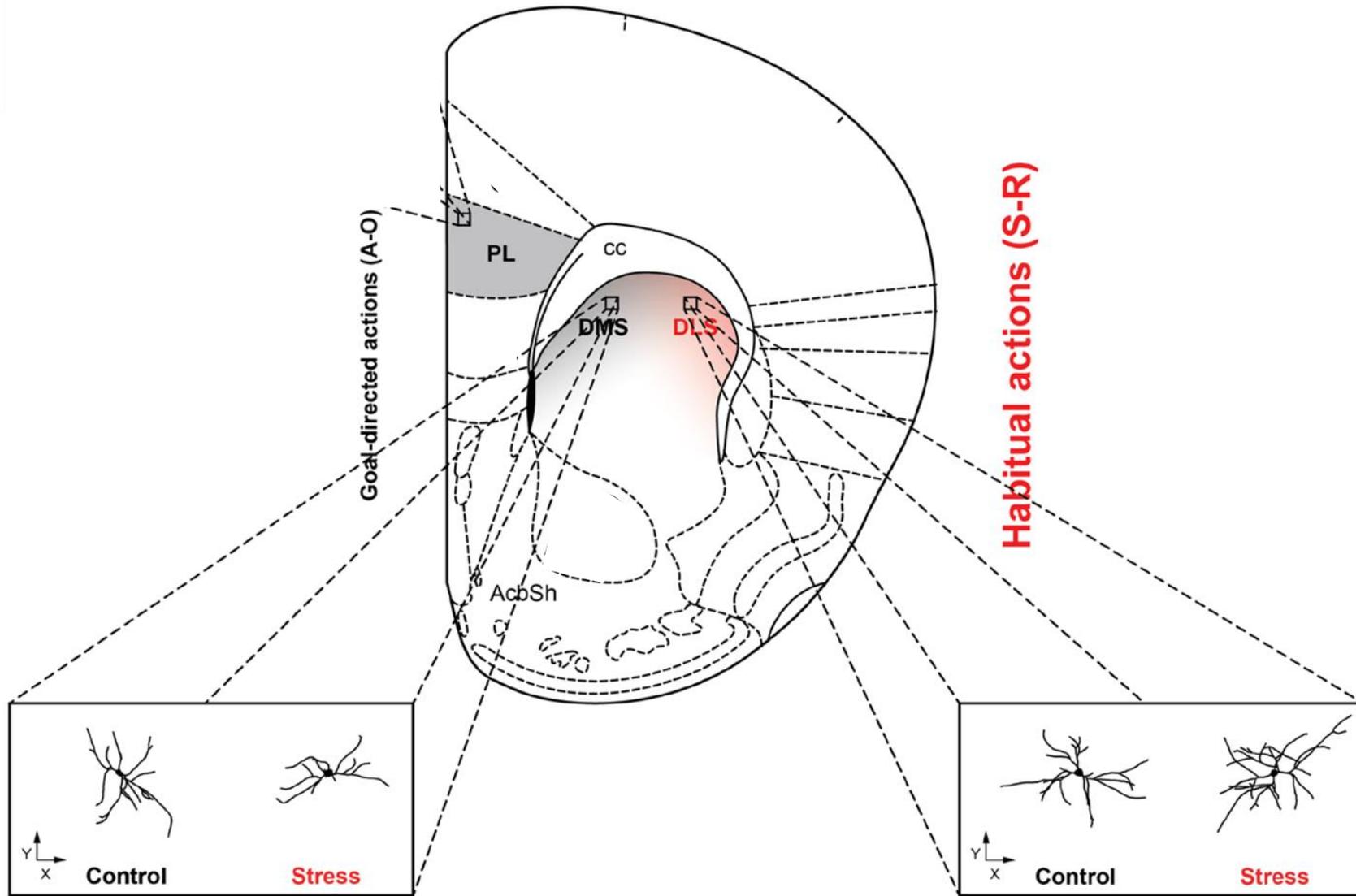


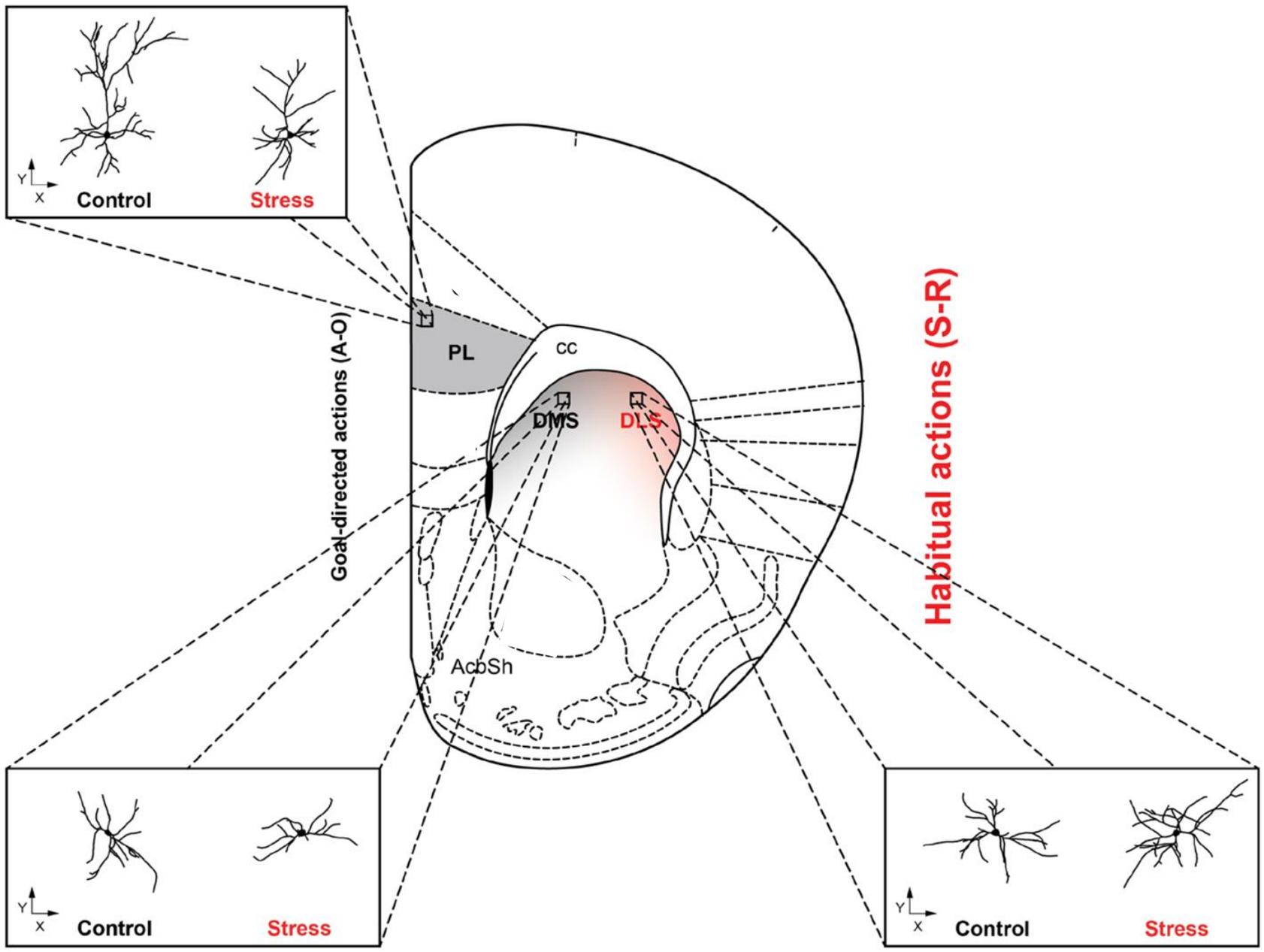
Control



Stress







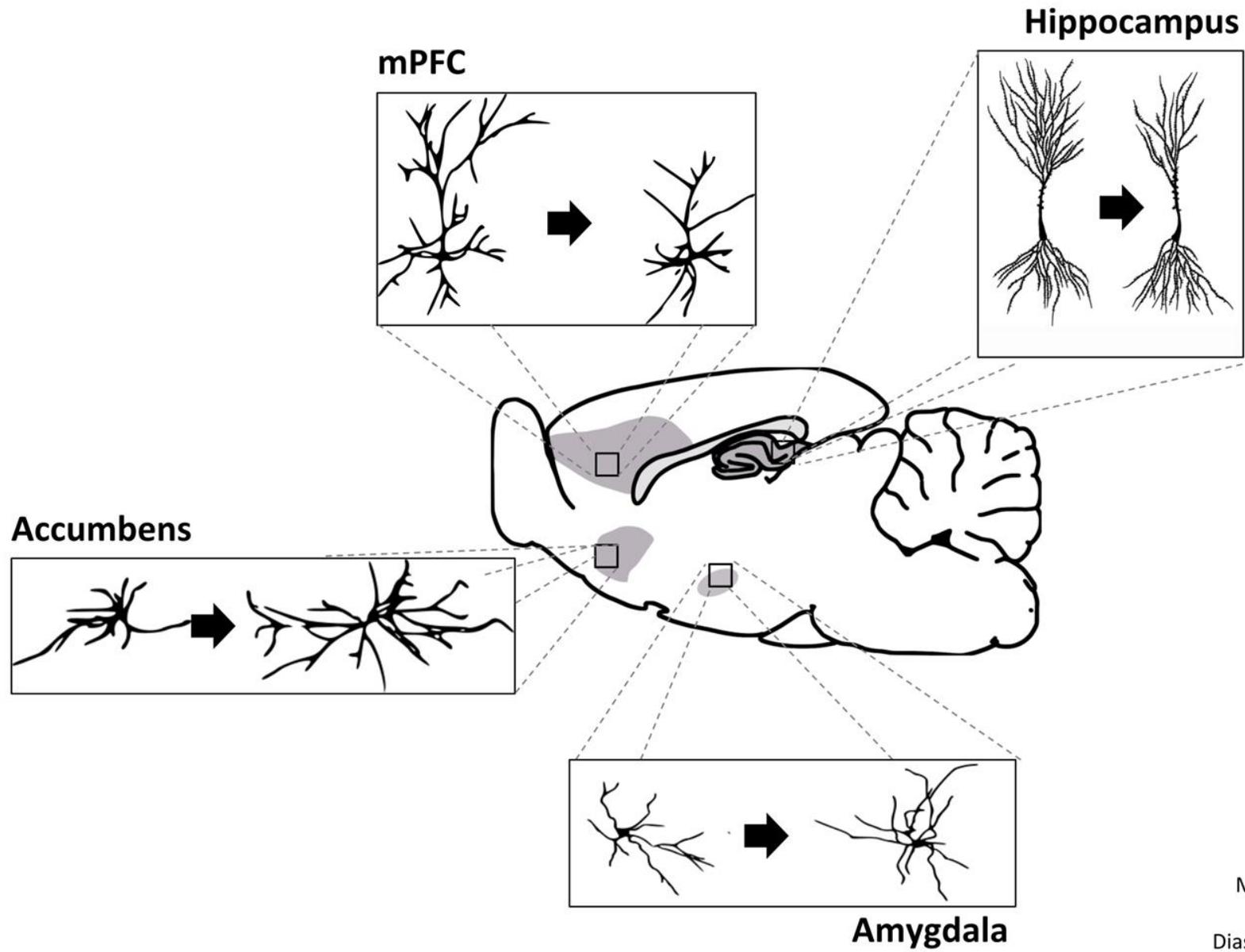


Goal directed

Stress

External world → Habitual actions → Action





Vias et al., 2002
Magarios et al., 1996
Bessa et al., 2013
Dias-Ferreira et al., 2010

Interim conclusions (2)

- Both cortical and subcortical areas participate in goal directed actions
- Same for habitual actions!
- Stress changes neuronal circuits
- Thus alters behaviour: bias towards habitual actions



Stress management as a part of behavioural change efforts

E.g. depression



Predictors of responses to depression treatment

Baseline clinical characteristics most informative in predicting treatment outcome:

- **employment status**
- **income level**

→ a low likelihood of response of 18%

- income < \$10,000, comorbid generalized anxiety disorder,
- < 16 years of education

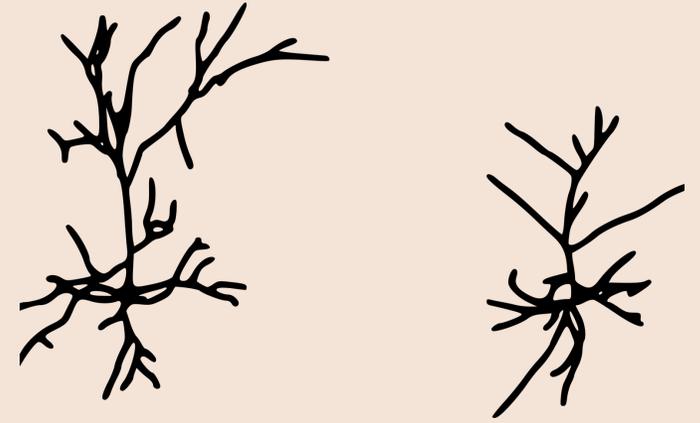
→ high likelihood of response of 68%

- income ≥ \$40,000,
- no comorbid posttraumatic stress disorder



Conclusions

- Habits and Goal-directed actions:
 - Both cortical and subcortical areas participate in goal directed actions and habitual actions
 - Stress alters structure and function of prefrontal-subcortical neuronal circuits, creates bias towards habitual actions
 - SMART goals!



Neurobiology & cognitive technologies



- Myths and truths about the brain
- Decision making: where does confidence come from?
- Resilience: neurobiological mechanisms
- Social intelligence

- Rescripting, EMDR and exposition therapy: brain mechanisms
- Anxiety: what's known about mechanisms of psychotherapy?
- Peculiar brain: mechanisms of OCD



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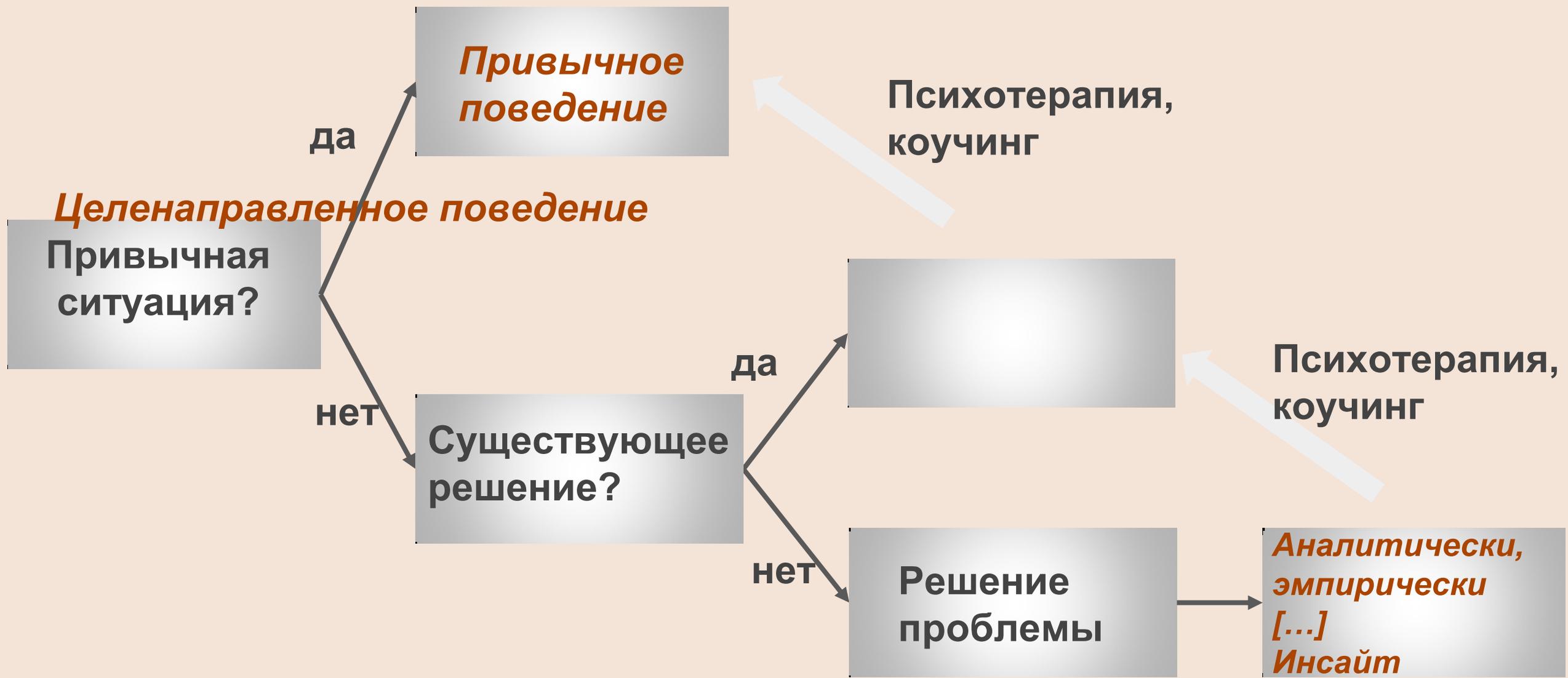


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[ekaterina-vinnik](#)





Целенаправленное поведение

Привычная ситуация?

да

Привычное поведение

Психотерапия, коучинг

нет

Существующее решение?

да

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Психотерапия, коучинг

нет

Решение проблемы

Аналитически, эмпирически [...] Инсайт



Slide title here

INSIGHT

Insight denotes a mental restructuring that leads to a sudden gain of explicit knowledge allowing qualitatively changed behaviour (Köhler, 1947, Sternberg, 1995).

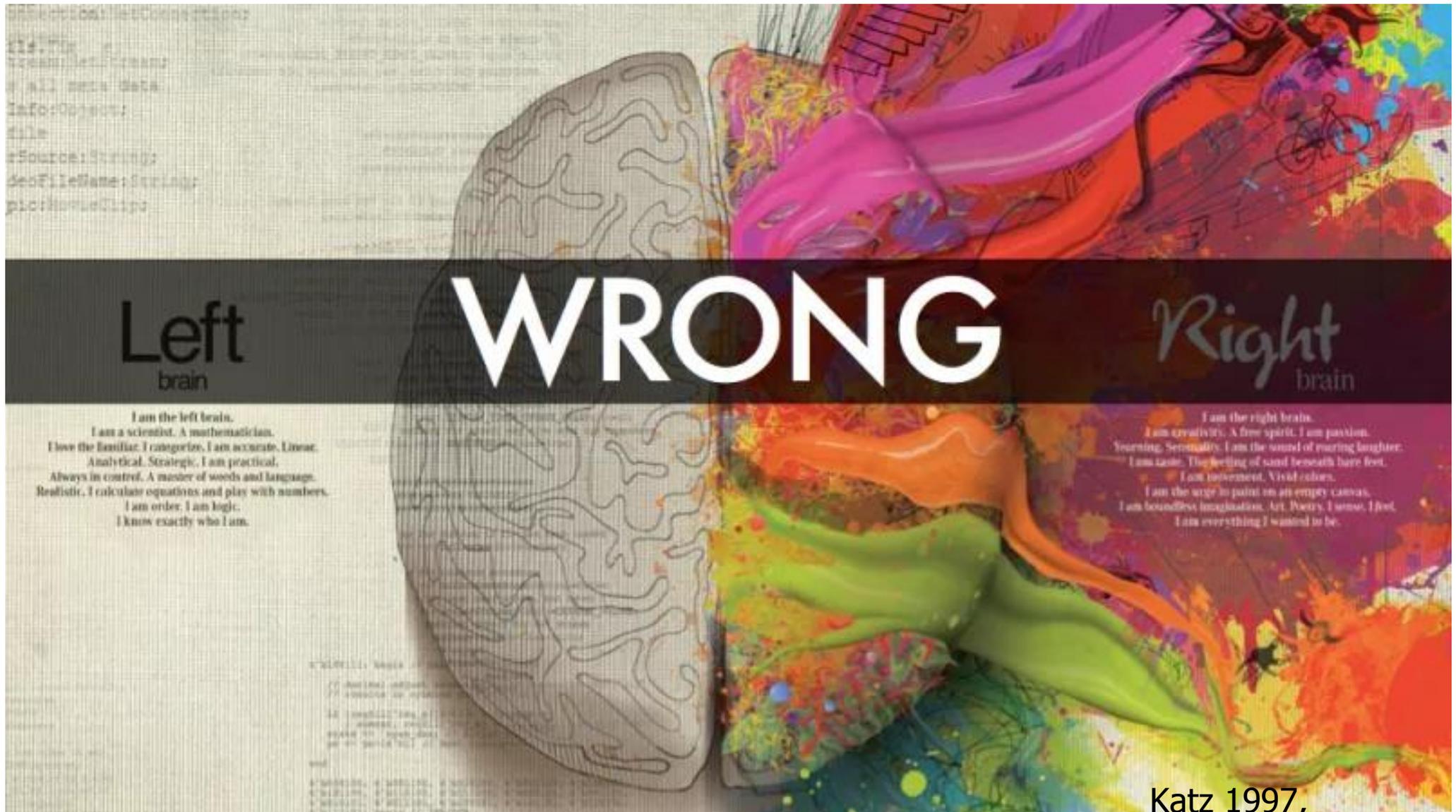


INSIGHT - A TYPE OF CREATIVE THINKING



INSIGHT
Left or right hemisphere?





Left
brain

I am the left brain.
I am a scientist. A mathematician.
I love the familiar. I categorize. I am accurate. Linear.
Analytical. Strategic. I am practical.
Always in control. A master of words and language.
Realistic. I calculate equations and play with numbers.
I am order. I am high.
I know exactly who I am.

WRONG

Right
brain

I am the right brain.
I am creativity. A free spirit. I am passion.
Yearning. Sensuality. I am the sound of roaring laughter.
I am love. The feeling of sand beneath bare feet.
I am torment. Vivid colors.
I am the urge to paint on an empty canvas.
I am boundless imagination. Art. Poetry. I sense. I feel.
I am everything I wanted to be.

Katz 1997,

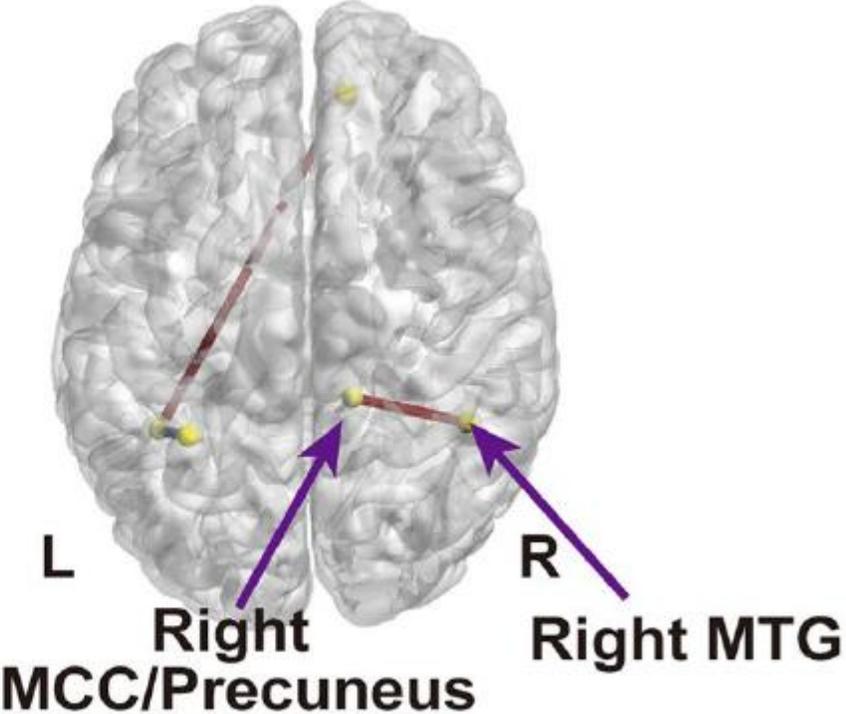
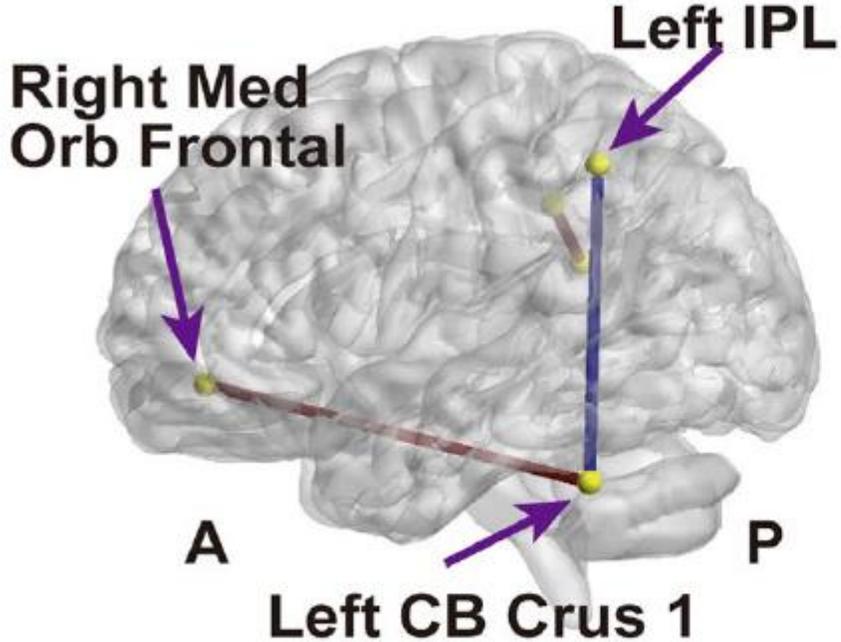
Image source: Gizmondo Dietrich and Kanso, 2010



The left brain is dominant for language and speech.
The right excels at visual-motor tasks.



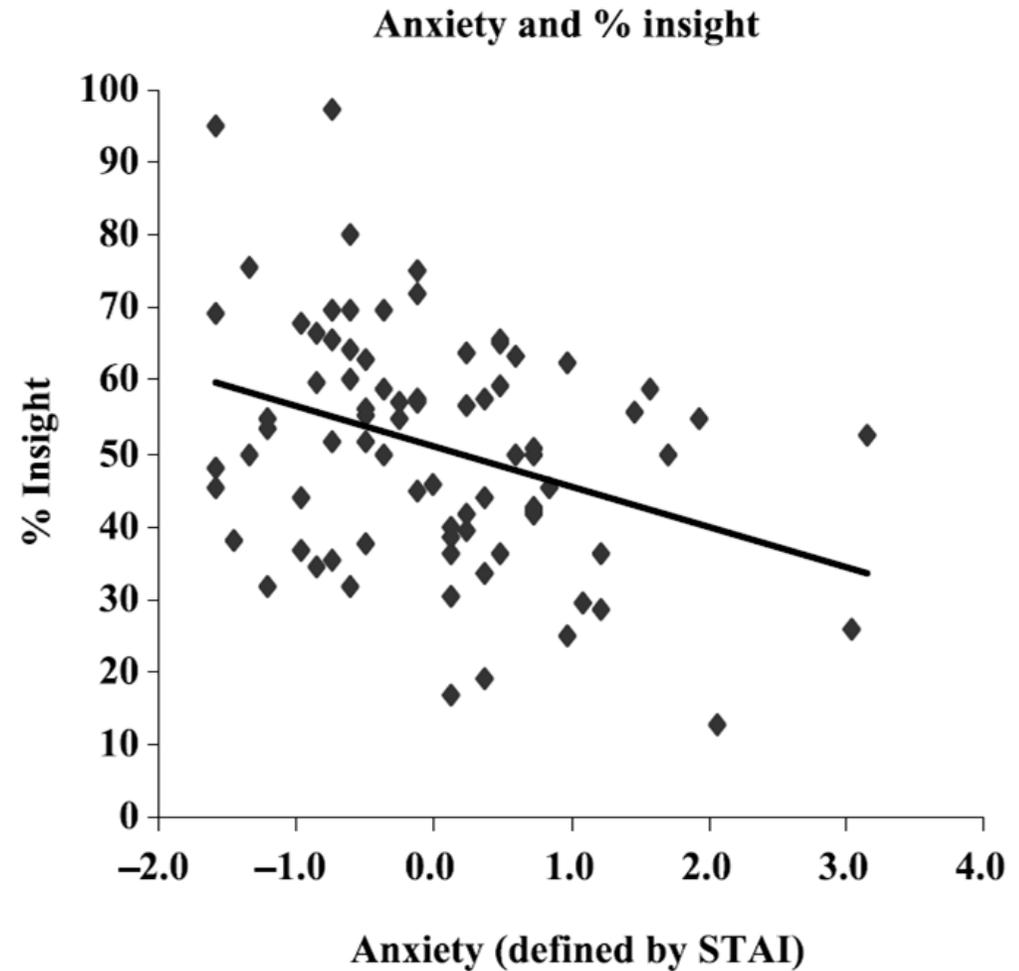
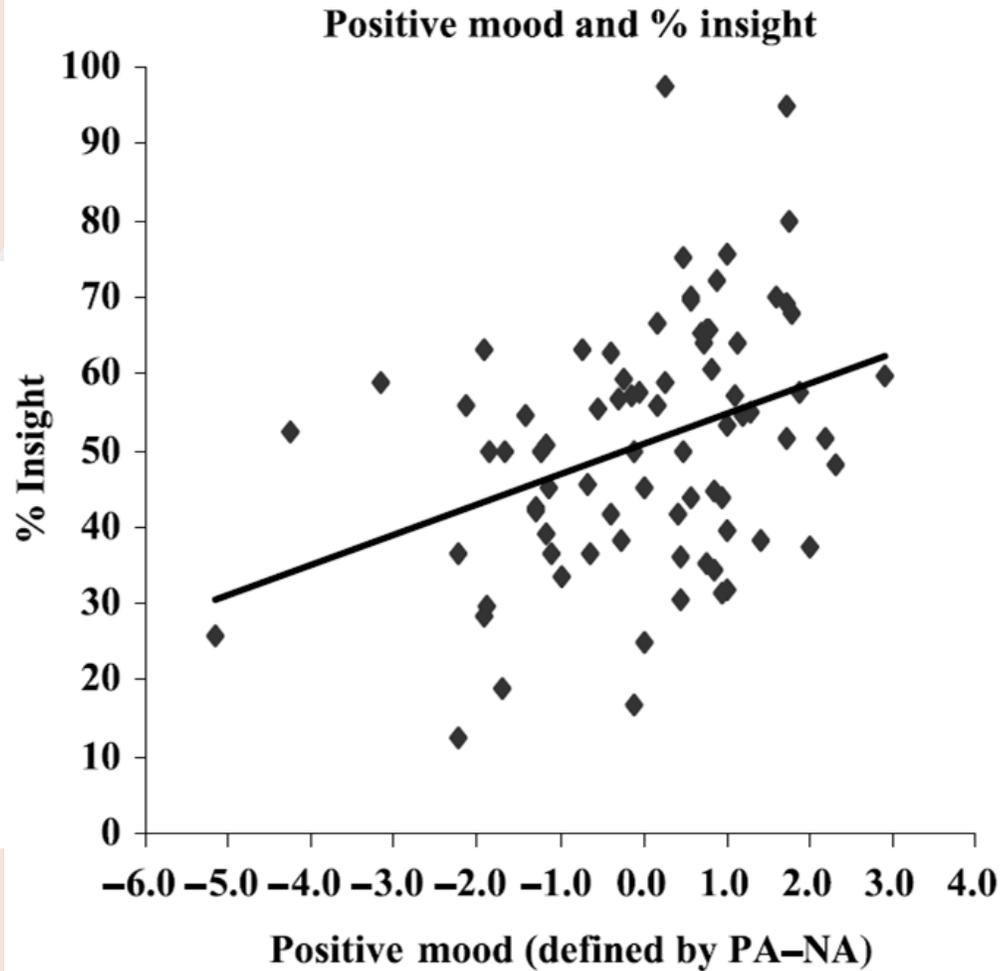
Both left and right!



What do we know?



More insights in good mood



More insights in good mood

Good mood specifically facilitates insight compared to analytical solutions

Positive mood - assessed **or** induced (sic!)

How does it work?

Rowe, Hirsch & Anderson, 2007;
Amabile, Barsade, Mueller, & Staw, 2005; Isen, 1999a, 1999b;
Estrada, Young, & Isen, 1994;
Isen, Daubman, & Nowicki, 1987



ANTERIOR CINGULATE CORTEX

Positive mood is one factors that enhances activity in the dACC, and this mediates the shift toward insight solutions



Conclusions

- Habits and Goal-directed actions:
 - Both cortical and subcortical areas participate in goal directed actions and habitual actions
 - Stress alters structure and function of prefrontal-subcortical neuronal circuits, creates bias towards habitual actions
- Insights:
 - Creative solutions involve right & left hemisphere!
 - Good mood facilitates insight



THANK YOU FOR YOUR ATTENTION!



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Slide title here

A-ha!

a mental restructuring that leads to a sudden gain of explicit knowledge allowing qualitatively changed behaviour



NIGHT
WRIST
WATCH

FIND a solution word
that can form a compound word or phrase with
each problem word. The solution word can precede or
follow each
problem word.

Compound remote associative task





STOP!





Goal-oriented behaviour

**Habitual
behaviour**

COACHING!

**Very familiar
task &
circumstances**

yes

no

**Existing
solution?**

yes

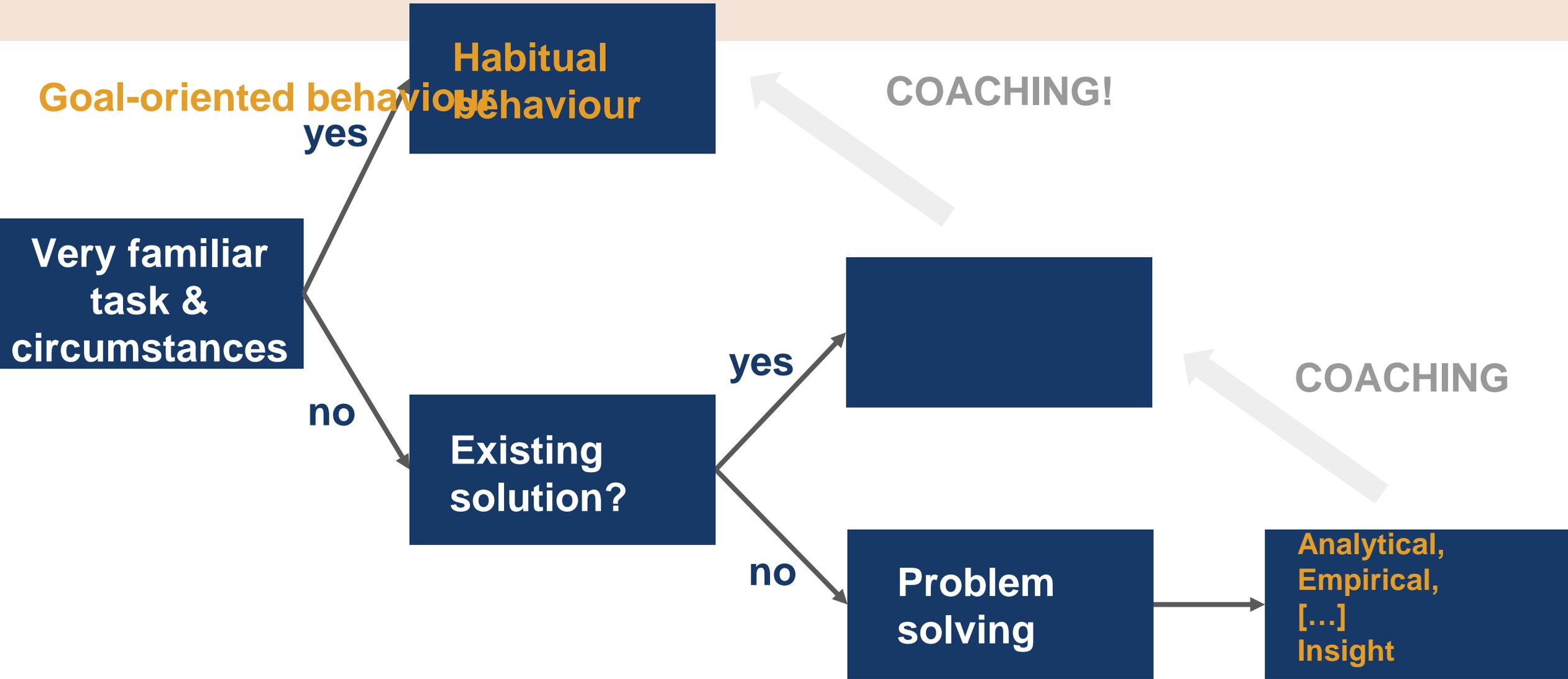
no

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COACHING

**Problem
solving**

**Analytical,
Empirical,
[...]
Insight**



Frontal lobe



ORBITOFRONTAL CORTEX

- stimulus-outcome learning
- goal-directed decision-making
- dependent on the expected action value



Goal-oriented behaviour

**Habitual
behaviour**

**Very familiar
task &
circumstances**

yes

no

**Existing
solution?**

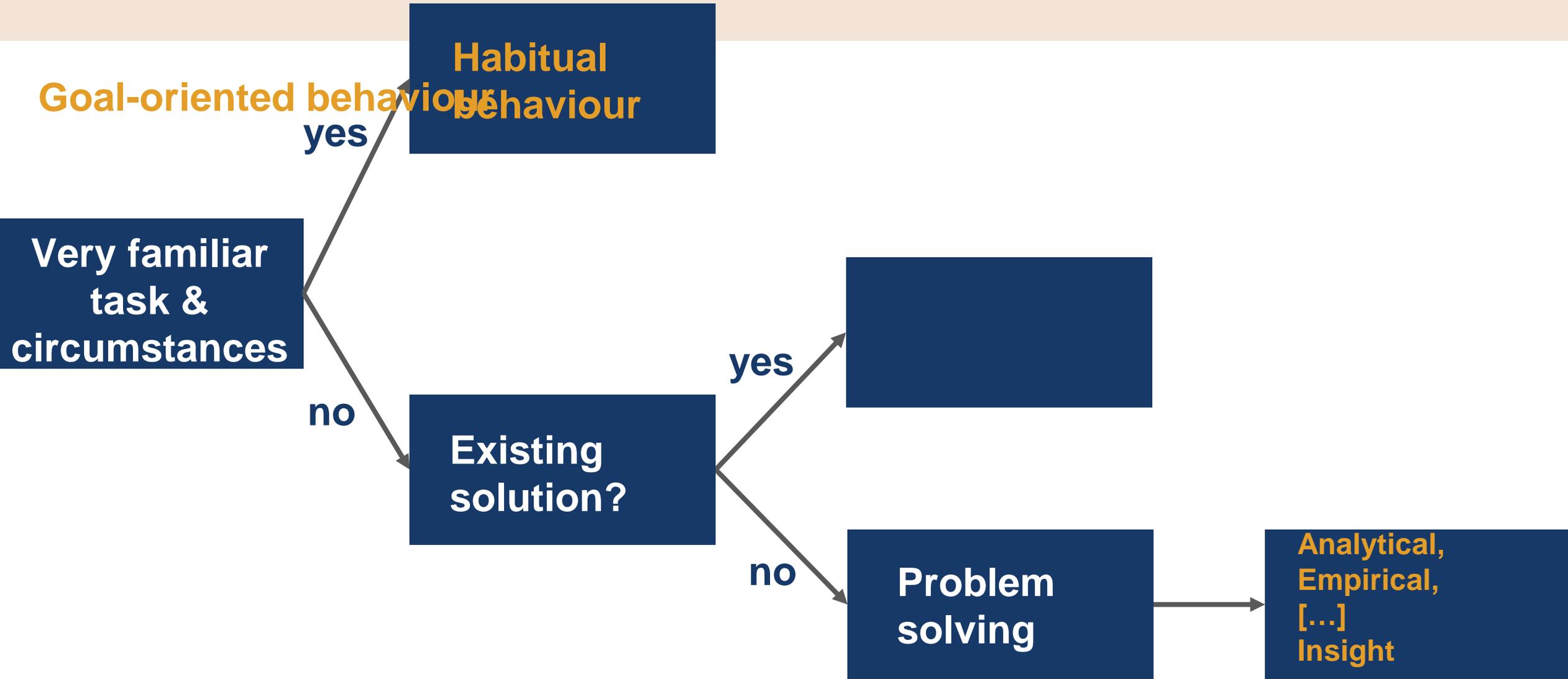
yes

no

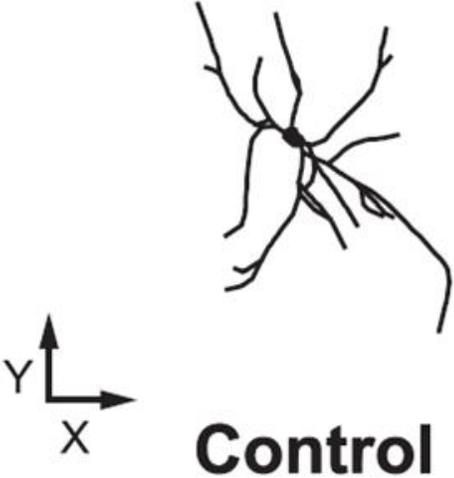
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**Problem
solving**

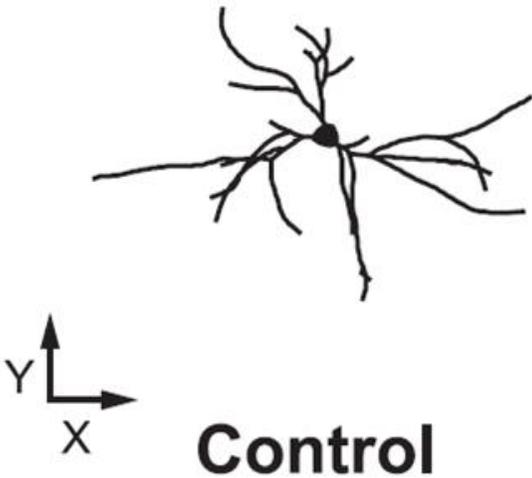
**Analytical,
Empirical,
[...]
Insight**



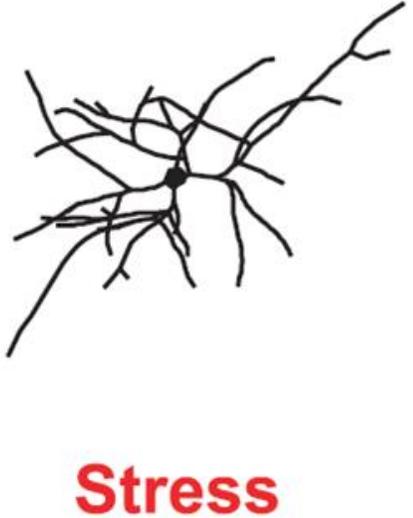
Neurons change!



DMS



DLS

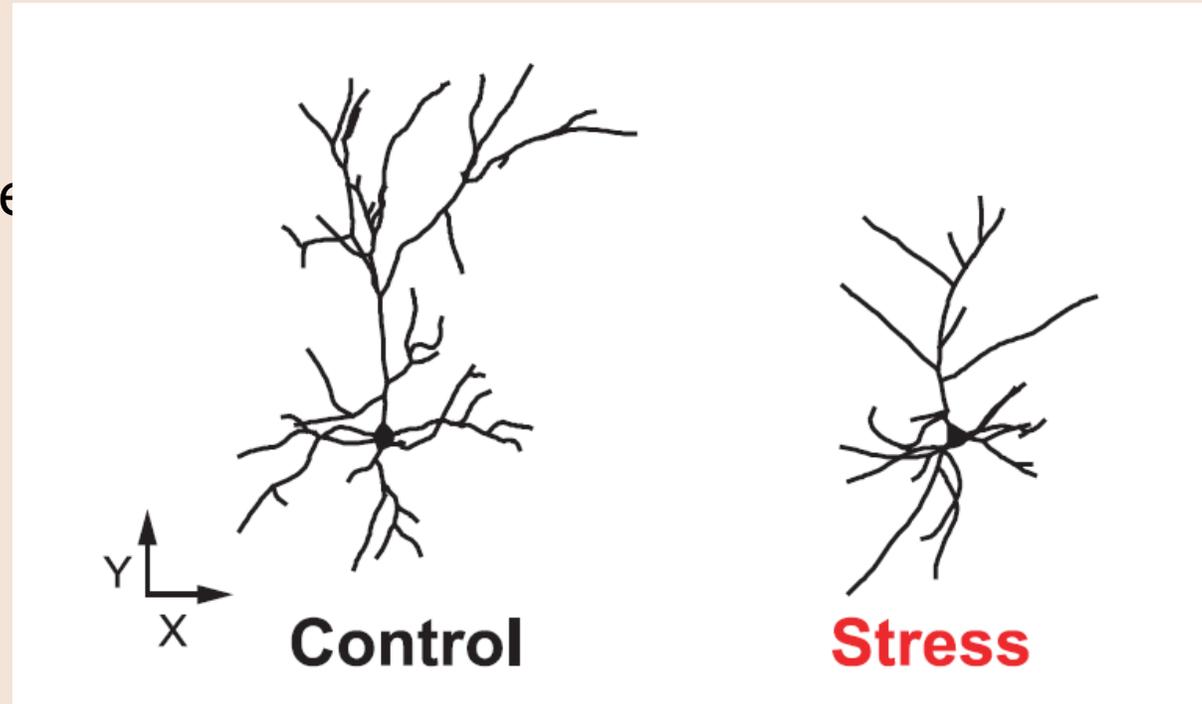


Dias-ferreira et al, 2012



Prefrontal cortex

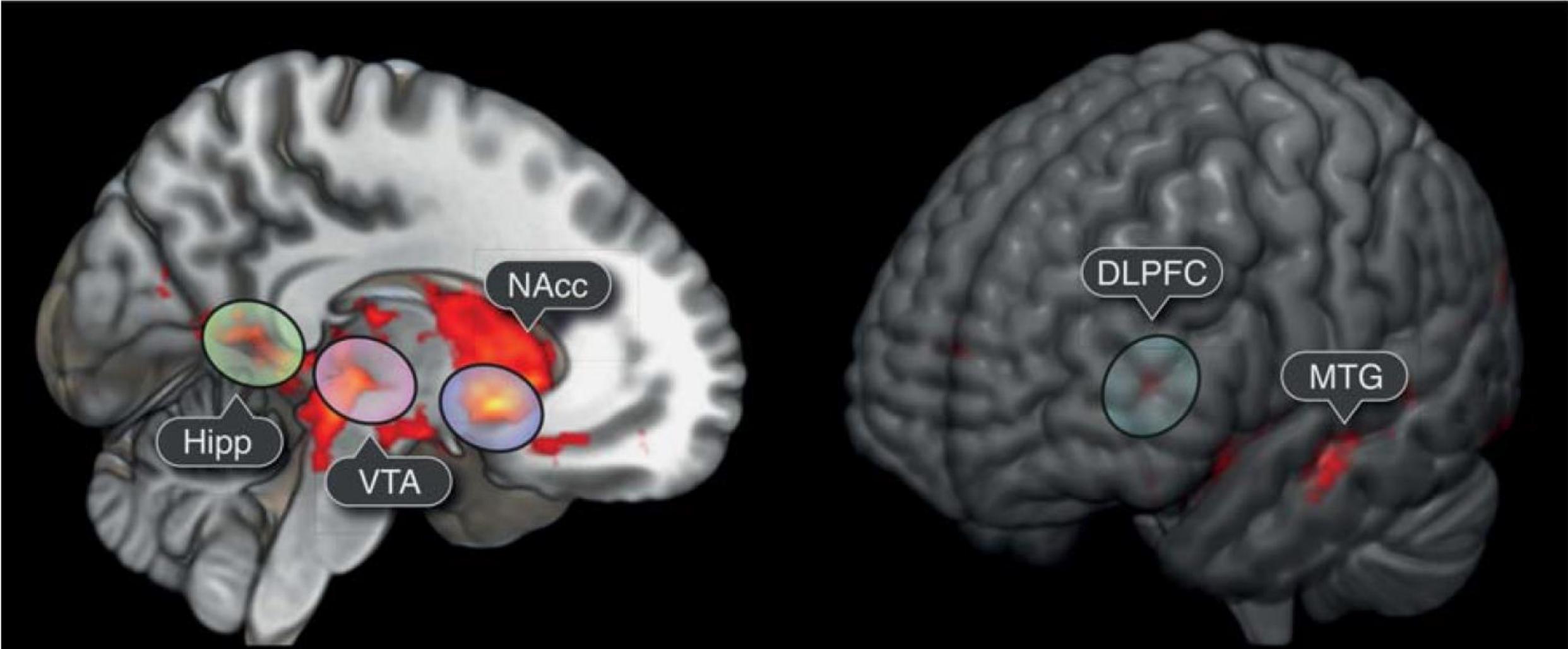
Some areas - shrink, some



Dias-ferreira et al, 2012



Solved > Not Solved Task Blocks



The connection between NAcc, hippocampus, and medial prefrontal cortex (see below), has the potential to explain the effects of positive mood on insight (Isen, Daubman, & Nowicki, 1987; Subramaniam et al., 2009).





Positive affect enhances cognitive flexibility in various settings (Isen, 1984), in negotiation tasks (Carnevale & Isen, 1986), in many problem-solving tasks (Isen, Mitzi, Johnson, Mertz, & Roberti, 1984; Isen & Daubman, 1984).

One possible mechanism by which PA could facilitate insight is through cognitive restructuring processes. PA is likely to facilitate insight by increasing a person's ability to switch and select alternative cognitive perspectives (Baumann & Kuhl, 2005; Dreisbach & Goschke, 2004; Isen, 1999b), reducing perseveration on one particular solution candidate or solving approach, thus increasing the probability of engaging in various cognitive restructuring processes.



HOW?

one hypothesis is that PA promotes a more global scope of attention (Bolte, Goschke, & Kuhl, 2003; Gasper & Clore, 2002), enhancing access to distant or unusual associations (Friedman, Fishbein, Förster, & Werth, 2003; Federmeier, Kirson, Moreno, & Kutas, 2001; Isen et al., 1985), which facilitates creative solutions to classic insight problems such as Duncker's (1945) candle task (Isen et al., 1987) and improves performance (Rowe et al., 2007; Isen et al., 1987) on the Remote Associates Test (Mednick, 1962). Another hypothesis is that PA enhances switching between global and local attentional modes (Baumann & Kuhl, 2005) or between strategies (Dreisbach & Goschke, 2004), or, similarly, that it enhances selection of different perspectives (Ashby et al., 1999).





In contrast, negative affect (NA) states such as anxiety and depression have been associated with deficits in attentional and cognitive control mechanisms (Bishop, Duncan, Brett, & Lawrence, 2004; Mayberg et al., 1999), often inducing a narrow scope of attention (Easterbrook, 1959). Therefore, anxiety in particular should impede cognitive flexibility, problem restructuring, and insight solving.





Compared with solving problems without insight, solving with insight involves stronger activity in right temporal regions integrating distant semantic associations (Jung-Beeman et al., 2004). Additionally, brain regions showed similar but weaker “insight effects” in the earlier study but manifested strong effects in the current study; these include anterior cingulate, posterior cingulate cortex (PCC), parahippocampal cortex (PHC), right superior frontal gyrus (SFG), and right inferior parietal lobe (IPL).



Slide title here

**ANTERIOR CINGULATE
CORTEX**

Stronger ACC activity occurs prior to trials solved with insight than those solved more analytically (Kounios et al., 2006). insights would involve greater cognitive control and restructuring processes, and that the dACC would be involved in the shift and the selection of a new solution path.



ACC

Interaction between cognitive and affective networks





Thus, we have strongly demonstrated that positive mood is reliably associated with preparatory states that increase responsivity in the rostral dACC, and that this modulation is associated with processing that leads to insight solutions. We are not arguing that the activation in ACC represents a neural correlate of positive mood or that positive mood states induce insight. We are concluding that positive mood is one factor that enhances activity in the rostral dACC, and that this mediates the shift toward insight solutions



**TOOTH
HEART
POTATO**

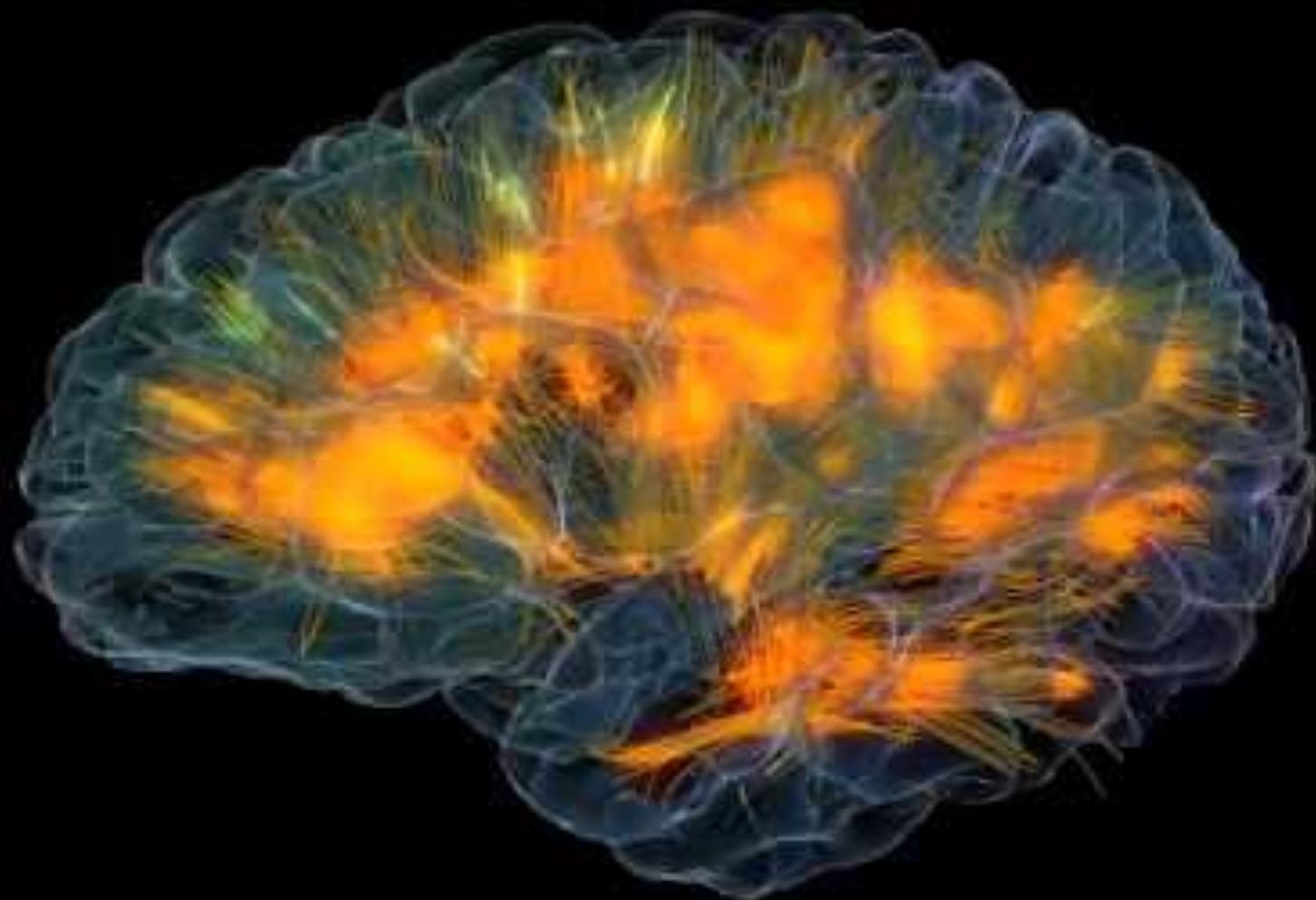
Compound remote assotiative task



**TOOTH
HEART
POTATO**

SWEET





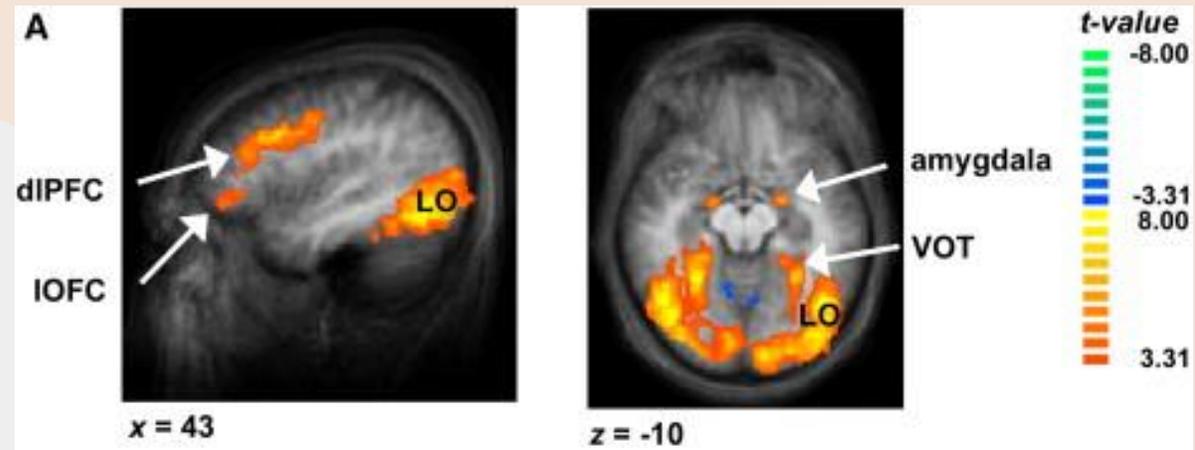
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**Amygdala activation predicts
whether perceptual insight
will be remembered**

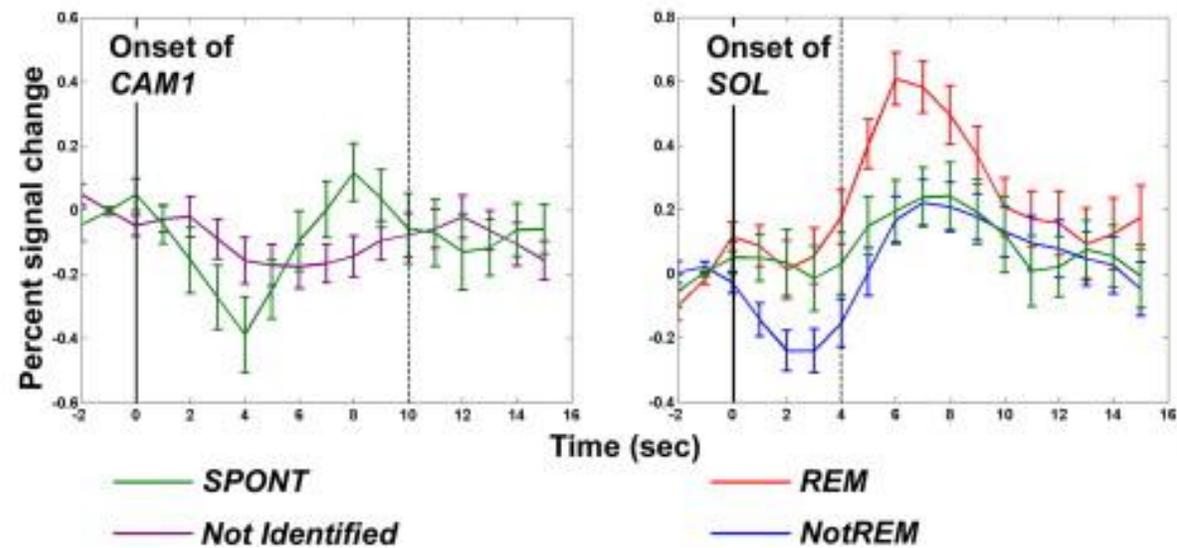






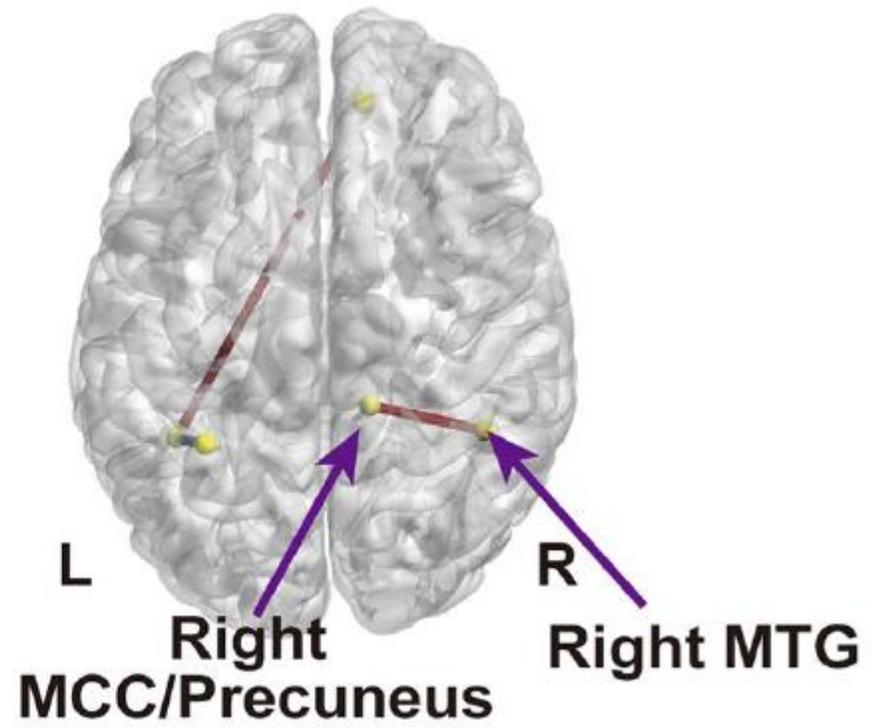
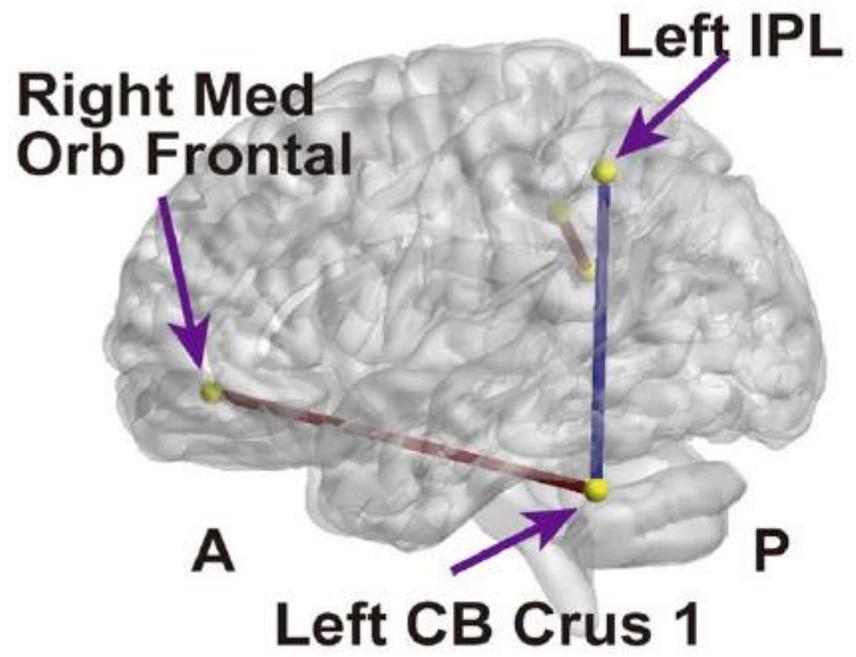


B Left amygdala



**Thank you very much for
your attention!**







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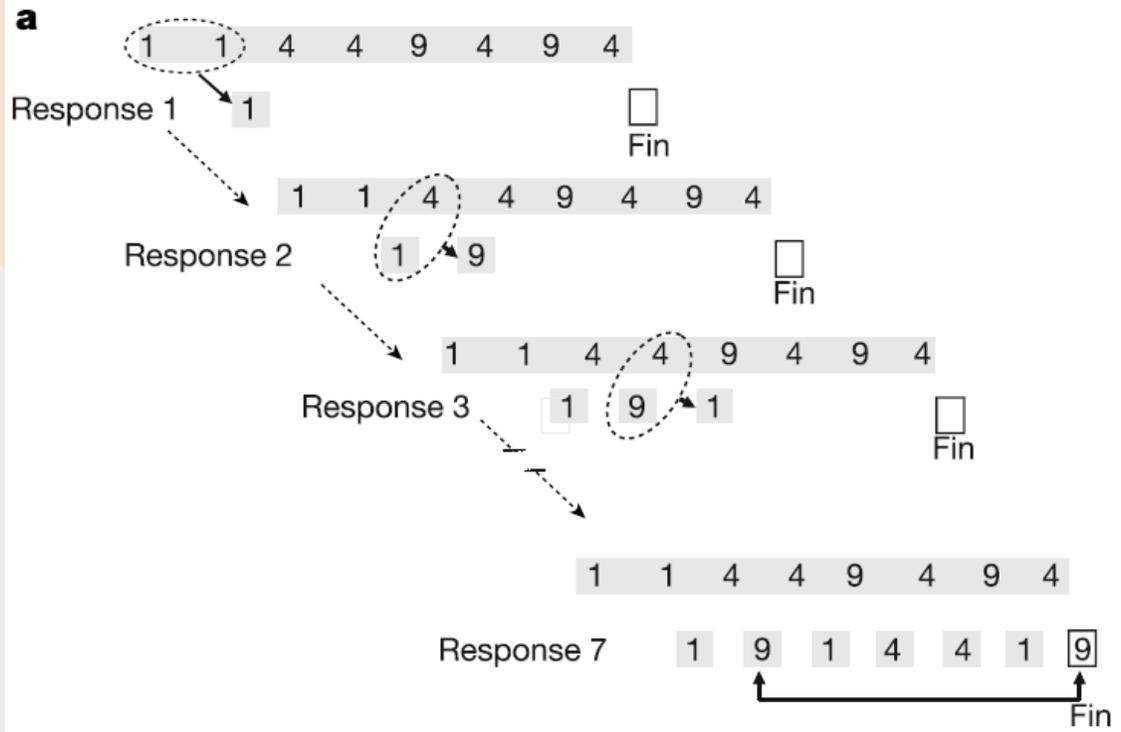
SLEEP ENHANCES INSIGHT

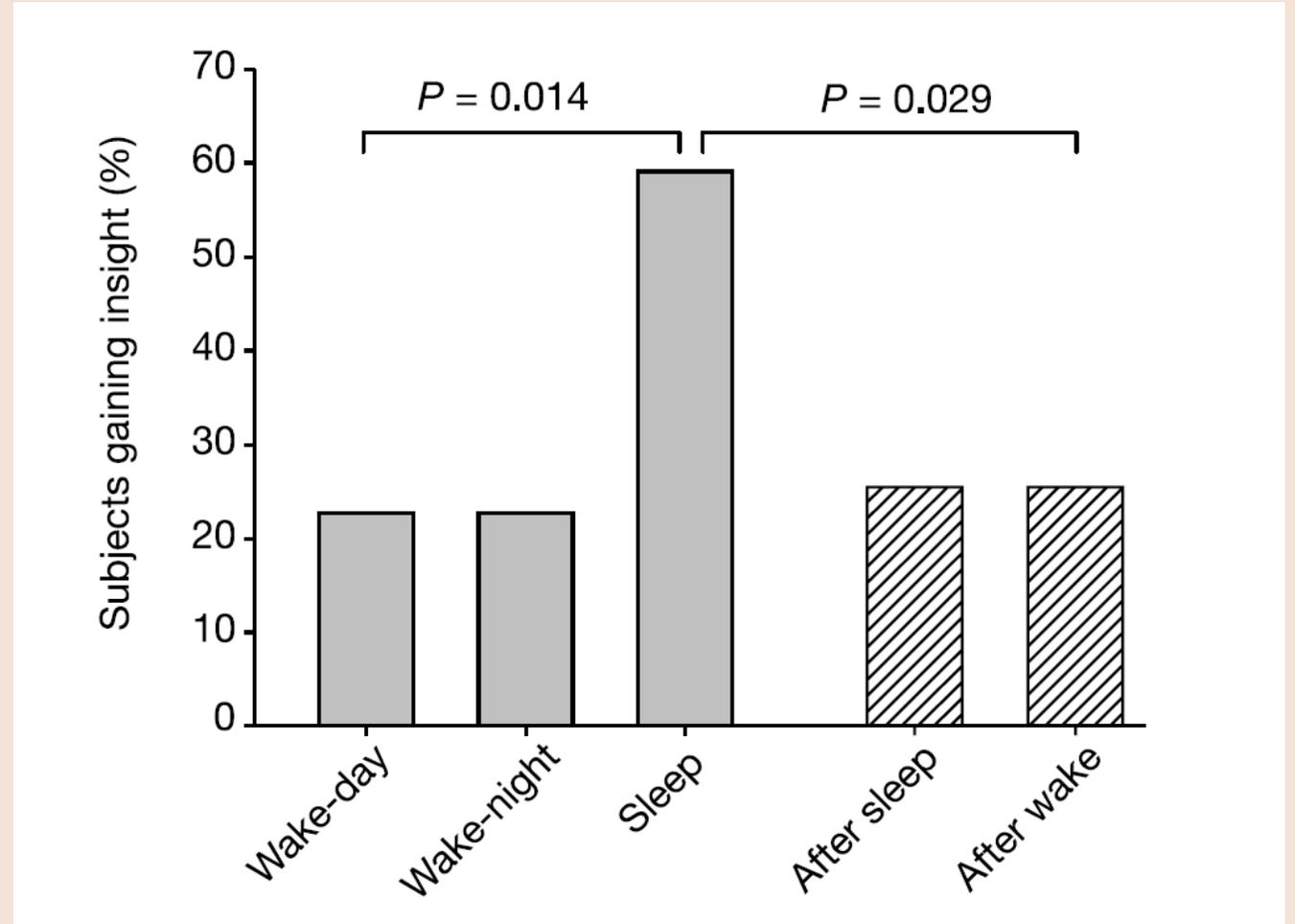




Based on continuous monitoring of subjects' behavioural responses, the task allows the exact determination of the time point when insight occurs, that is, when explicit knowledge of a hidden abstract rule is gained, leading to an abrupt, qualitative shift in responding







Wagner et al., 2004



- 
- Solutions of camouflage images can remain in long-term memory after one-shot viewing
 - Many solutions are lost within a week, but those remembered are retained long after
 - Observers retain different subsets of camouflage solutions in long-term memory
 - Amygdala activity during one-shot viewing predicts which solutions will be remembered



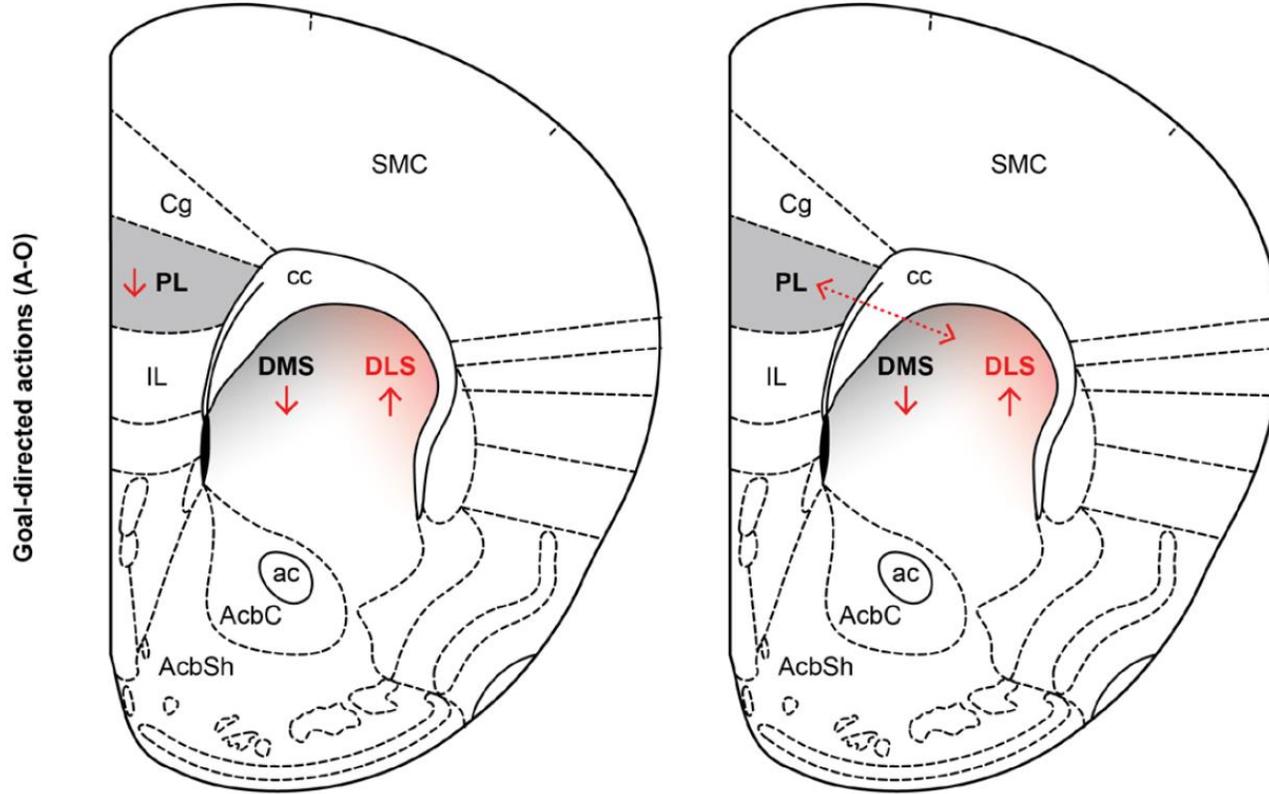
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Frontostriatal reorganization

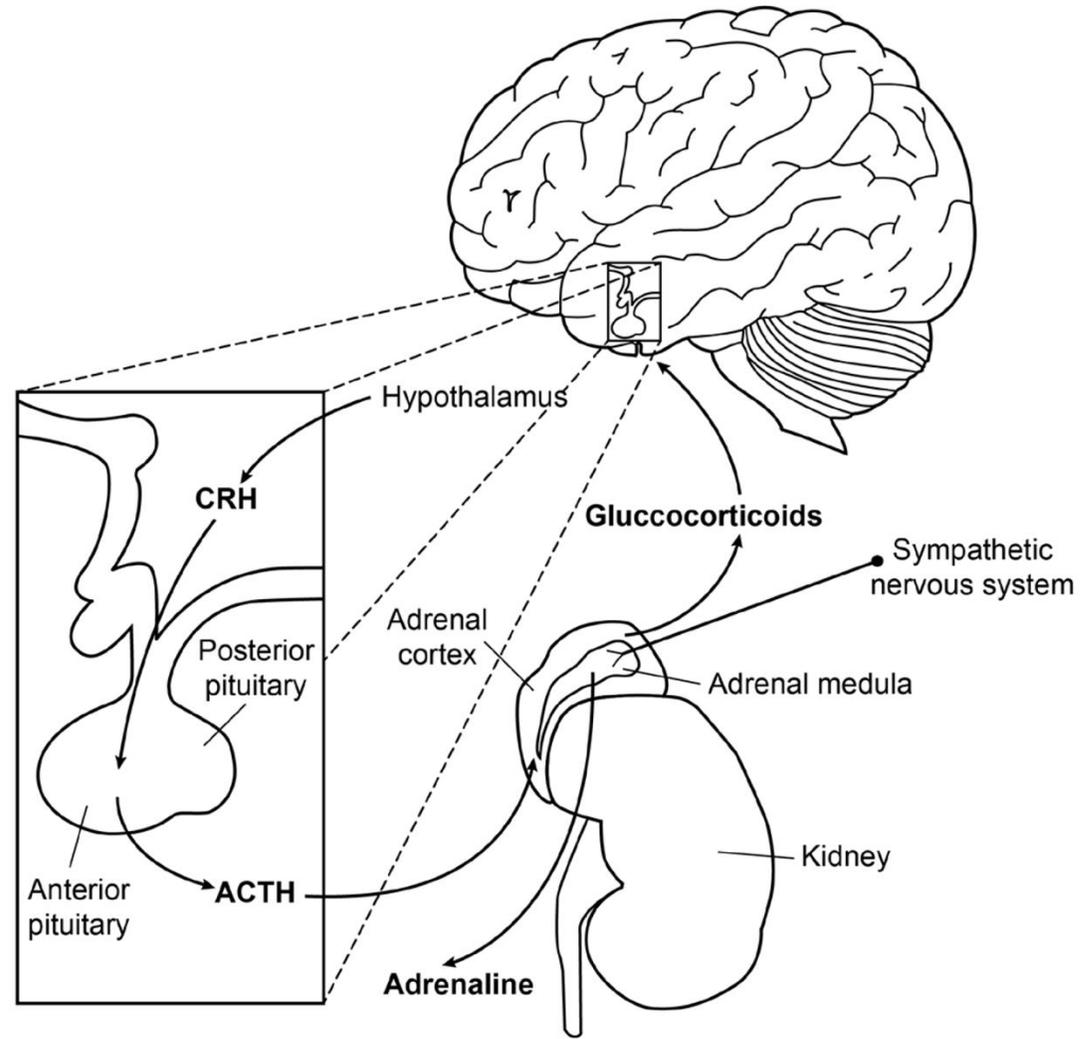
Functional bias



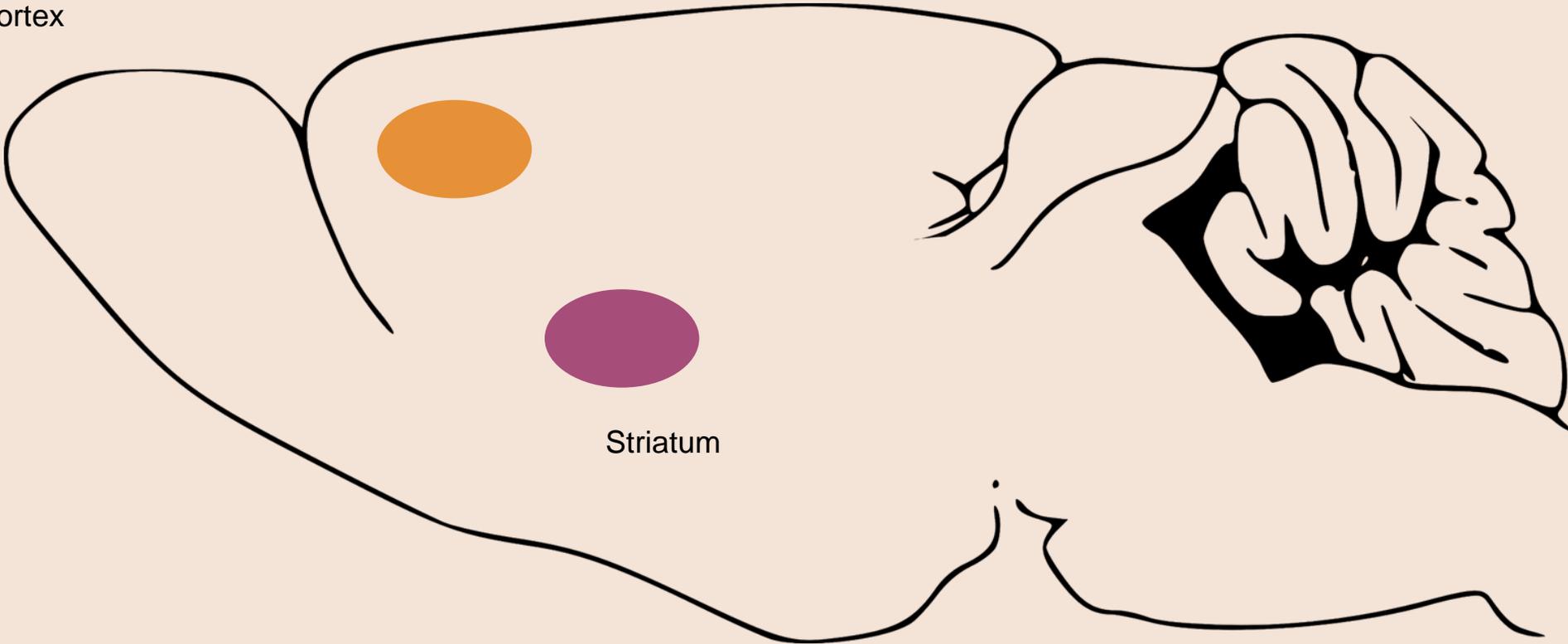
- Amount of training
- Statistics of reinforcement
- Chronic stress



Illustration credit: Dias-ferreira, 2011



Prefrontal cortex



Striatum

