

Goal-directed learning and obsessive – compulsive disorder

Claire M. Gillan^{1,2} and Trevor W. Robbins^{2,3}

¹Department of Psychology, New York University, 6 Washington Place, New York, NY 10003, USA

²Behavioural and Clinical Neuroscience Institute, and ³Department of Psychology, University of Cambridge, Downing Street, Cambridge CB2 3EB, UK

Hyoryang Kim
Bio-imaging & Signal Processing Lab

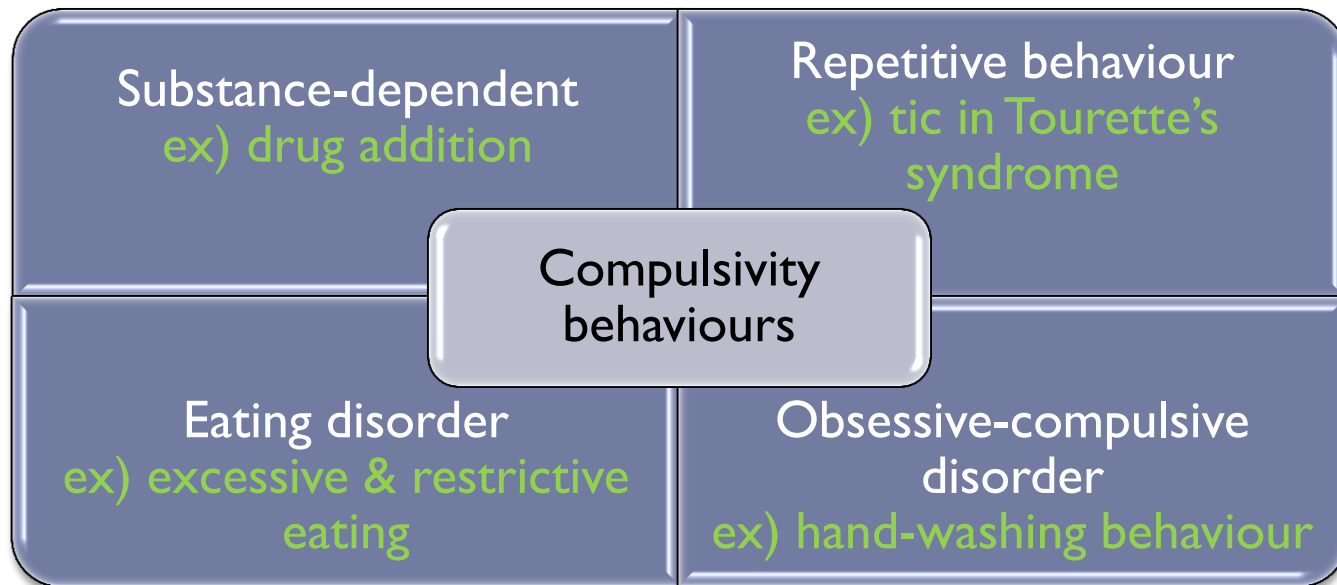
June 9, 2016

INDEX

- ▶ Introduction
 - ▶ Compulsivity and Obsessive-compulsive disorder(OCD)
- ▶ Part I. Habit and OCD
 - ▶ Habit, OCD and Dissociation in neural system
- ▶ Part2. goal-directed dysfunction and OCD
 - ▶ Experimental evidences and Imbalance
 - ▶ Reinforcement learning schema
- ▶ Part3. Habit and compulsive-obsessive disorder(COD)
 - ▶ OCD and COD, Cognitive dissonance, Irrational thought and Anxiety
- ▶ Summary & Conclusion

INTRODUCTION (1 / 2)

- ▶ **Compulsivity : maladapted human behaviour**
 - ▶ A hypothetical trait in which actions are persistently repeated despite adverse consequences



INTRODUCTION (2/2)

▶ Two Underlying mechanisms of compulsivity

1. Value assignment dysfunction

- ▶ View the cost of cessation to be higher than the benefits thereof
- ▶ Compulsions are carried out as purposeful and goal directed attempt to reduce the likelihood of threat
- ▶ “COGNITIVE BIAS”

2. Goal-directed dysfunction

- ▶ Interact with anxiety and irrational belief
- ▶ Patients(OCD) understand the relative value of the available outcomes and the cost of actions, and aim to desist from compulsive behaviour
- ▶ But can't exert the necessary control over actions to realize the goal

INTRODUCTION (2/2)

▶ Two Underlying mechanisms of compulsivity

1. Value assignment dysfunction

- ▶ View the cost of cessation to be higher than the benefits thereof
- ▶ Compulsions are carried out as purposeful and goal directed attempt to reduce the likelihood of threat
- ▶ “COGNITIVE BIAS”

- Belief that thinking about something is equivalent to doing it

- OCD patients motivate to perform avoidance compulsions

2. Goal-directed dysfunction

- ▶ Interact with anxiety and irrational beliefs
- ▶ Patients(OCD) understand the relative value of the available outcomes and the cost of actions, and aim to desist from compulsive behaviour
- ▶ But can't exert the necessary control over actions to realize the goal

INTRODUCTION (2/2)

▶ Two Underlying mechanisms of compulsivity

1. Value assignment dysfunction

- ▶ View the cost of cessation to be higher than the benefits thereof
- ▶ Compulsions are carried out as purposeful and goal directed attempt to reduce the likelihood of threat
- ▶ “COGNITIVE BIAS”

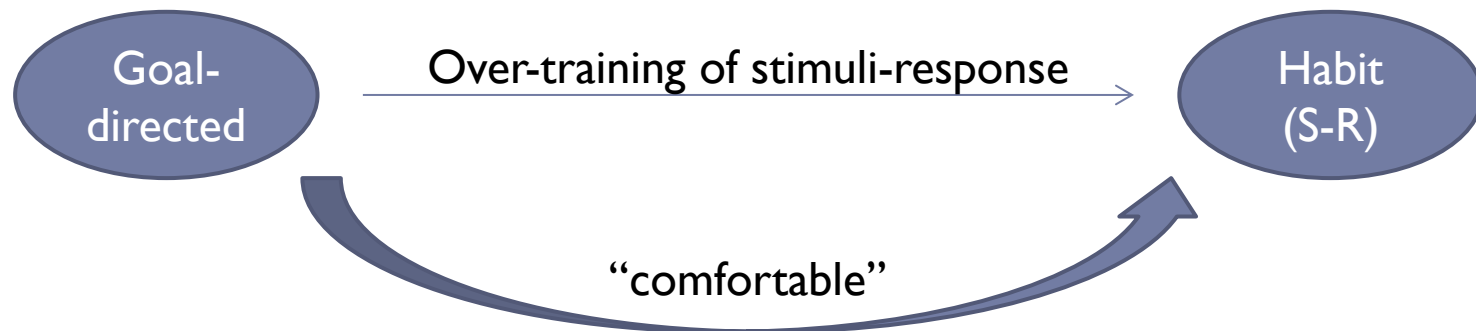
2. Goal-directed dysfunction

- ▶ Interact with anxiety and irrational belief
- ▶ Patients(OCD) understand the relative value of the available outcomes and the cost of actions, and aim to desist from compulsive behaviour
- ▶ But can't exert the necessary control over actions to realize the goal

PART 1. HABIT AND OCD (1 / 4)

▶ HABIT

- ▶ Automatic response like triggered by stimulus
- ▶ The functional reciprocal of goal-directed behaviours
 - intentional, considered, sensitive to the value of goals
- ▶ Goal-directed behaviour is more accurate, but requires effort and attention
- ▶ This control subsides to become comfortable with repetitive action following over-training of the stimulus-response pair



PART1. HABIT AND OCD (2/4)

- ▶ **OCD : disorder of maladaptive habit learning**
 - ▶ ‘fronto-striatal circuits’ : functional loci of repetitive behavioural habits
 - ▶ Shift from associative to this loci mediates the transition from goal-directed to habitual control over behaviour (Graybiel & Rauch, in 2000)

- ▶ **Outcome devaluation test**
 - ▶ Goal-directed : responding to stimuli should decline
 - ▶ Habit : continued responding and become insensitive to the value of the outcomes

OUTCOME-DEVALUATION test

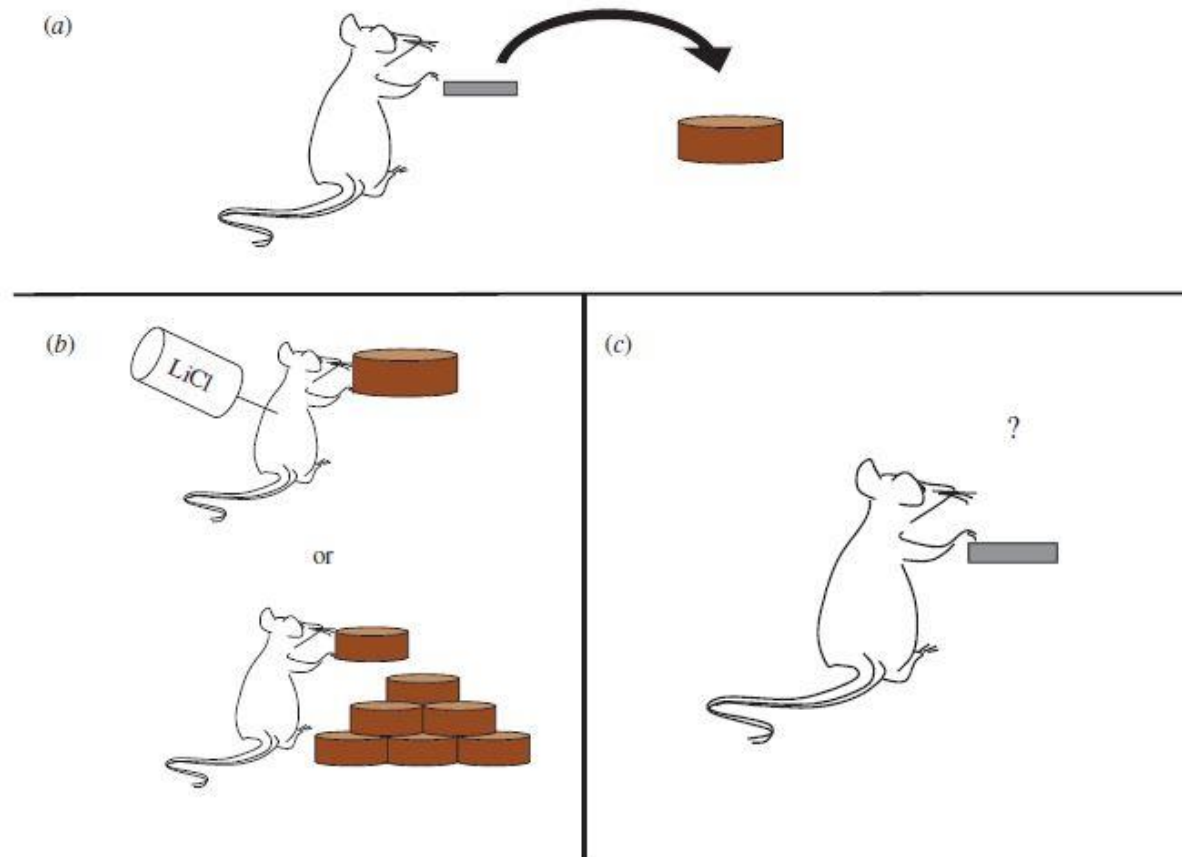


Figure 1. Outcome-devaluation procedure. (a) Animals are trained to press a lever to gain food pellets. (b) Food pellets are typically devalued by, for example, pairing with lithium chloride, which induces nausea, or by feeding to satiety. (c) Animals are tested on extinction. Continued responding reflects insensitivity to outcome devaluation, and thus dominant control of the habit system.

PART1. HABIT AND OCD (3/4)

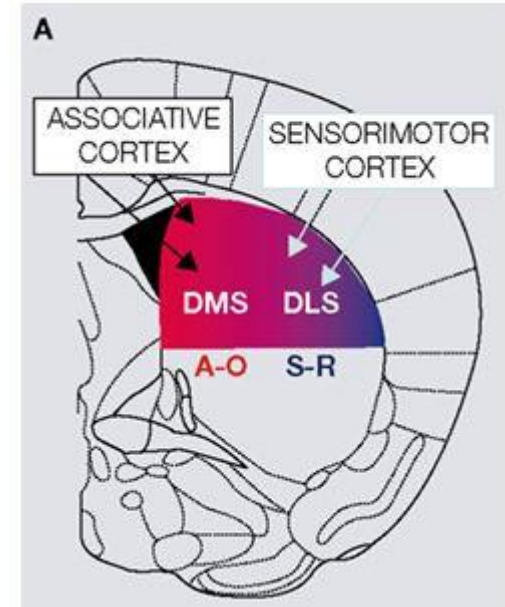
▶ Important dissociations in neural system

1. Striatum

- ▶ DMS(dorsomedial striatum) lesion
: induce habitual responding
→ critical for goal-directed action control
- ▶ DLS(dorsolateral striatum) lesion
: preserves sensitivity to outcome value
→ habitual behaviour control

2. Limbic cortex

- ▶ Prelimbic cortex(PrL) : goal-directed learning
- ▶ Infralimbic cortex(IL) : execution of habits
- ▶ IL may arbitrate between controllers, inhibiting the goal-directed system in favor of performing previously reinforced action



PART 1. HABIT AND OCD (3/4)

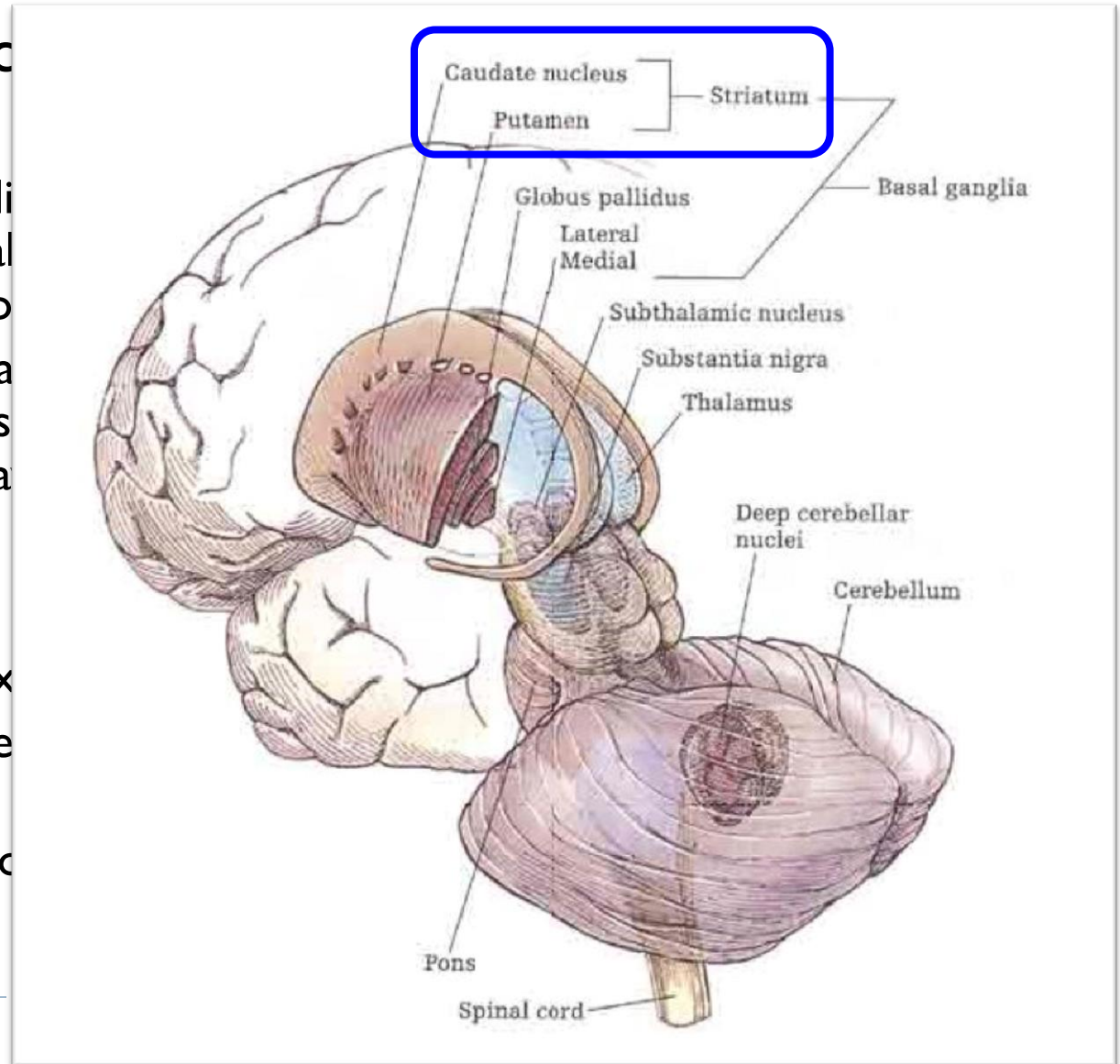
▶ Important dissociation

1. Striatum

- ▶ DMS(dorsomedial striatum): induce habitual behavior → critical for goal-directed behavior
- ▶ DLS(dorsolateral striatum): preserves sensory information → habitual behavior

2. Limbic cortex

- ▶ Prelimbic cortex
- ▶ Infralimbic cortex
- ▶ IL may arbitrate between the two systems in favor of the habit system



PART 1. HABIT AND OCD (3/4)

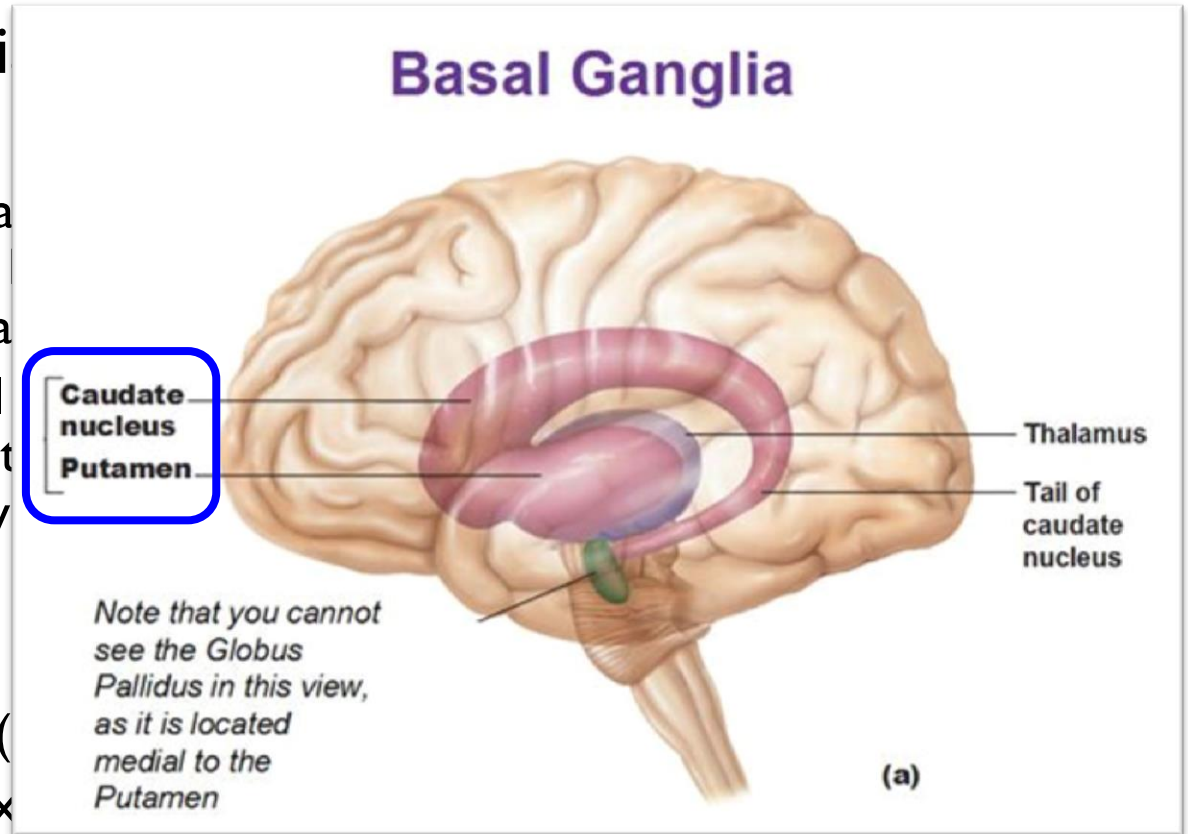
▶ Important dissociation

1. Striatum

- ▶ DMS(dorsomedial striatum)
: induce habitual behavior
→ critical for goal-directed action
- ▶ DLS(dorsolateral striatum)
: preserves sensitivity to action outcomes
→ habitual behavior

2. Limbic cortex

- ▶ Prelimbic cortex (medial prefrontal cortex)
- ▶ Infralimbic cortex (ventromedial prefrontal cortex)
- ▶ IL may arbitrate between controllers, inhibiting the goal-directed system in favor of performing previously reinforced action



PART1. HABIT AND OCD (3/4)

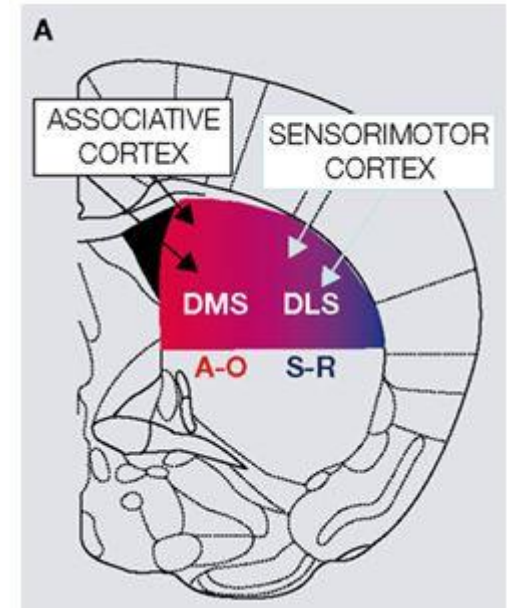
▶ Important dissociations in neural system

1. Striatum

- ▶ DMS(dorsomedial striatum) lesion
: induce habitual responding
→ critical for goal-directed action control
- ▶ DLS(dorsolateral striatum) lesion
: preserves sensitivity to outcome value
→ habitual behaviour control

2. Limbic cortex

- ▶ Prelimbic cortex(PrL) : goal-directed learning
- ▶ Infralimbic cortex(IL) : execution of habits
- ▶ IL may arbitrate between controllers, inhibiting the goal-directed system in favor of performing previously reinforced action



PART 1. HABIT AND OCD (3/4)

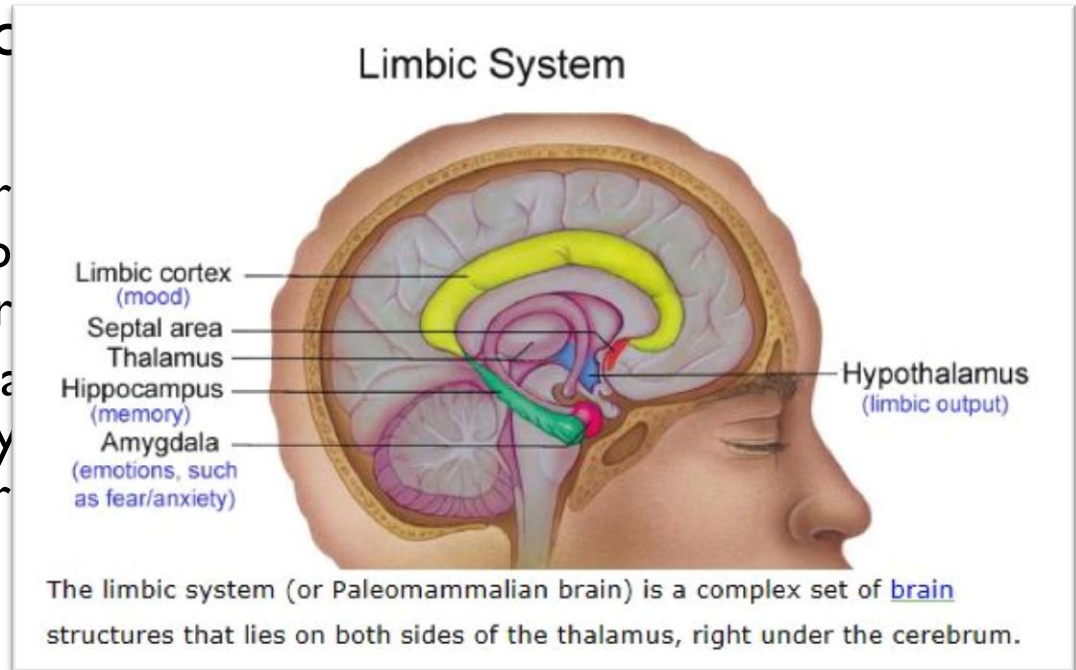
▶ Important dissociations

1. Striatum

- ▶ DMS(dorsomedial striatum) : induce habitual response → critical for goal-directed
- ▶ DLS(dorsolateral striatum) : preserves sensitivity → habitual behaviour

2. Limbic cortex

- ▶ Prelimbic cortex(PrL) : goal-directed learning
- ▶ Infralimbic cortex(IL) : execution of habits
- ▶ IL may arbitrate between controllers, inhibiting the goal-directed system in favor of performing previously reinforced action



PART 1. HABIT AND OCD (4/4)

▶ Studies about neural network

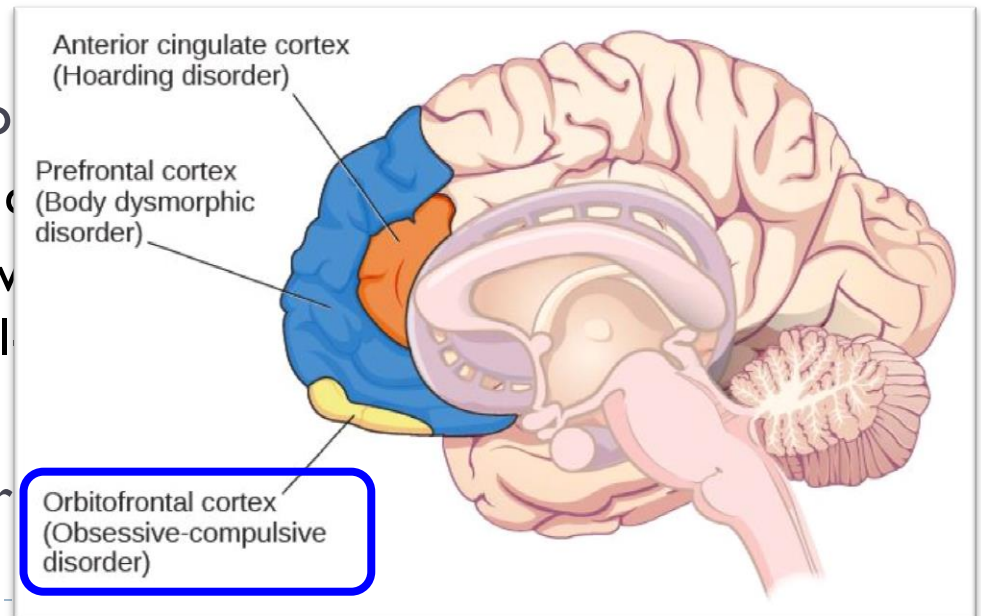
1. Medial orbitofrontal cortex(OFC)

- ▶ Inhibition of activity interferes with goal-directed behavioural control
- ▶ Neuronal firing rates in the DMS, DLS and OFC dynamically change in concert with a shift between goal-directed and habitual actions
→ A key role of goal-directed action selection

2. Ventromedial prefrontal cortex

- ▶ A key role of goal-directed control
- ▶ More posterior portion of vmPFC : more active, carry out goal-directed actions

3. The putamen for habit learning

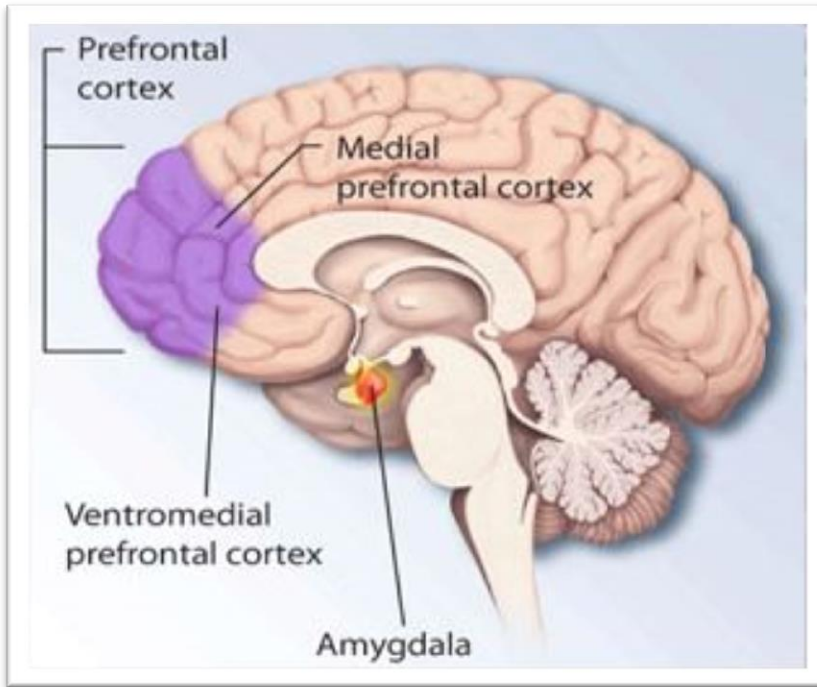


OCD (4/4)

ork

(OFC)

es with goal-directed behavioural control
DMS, DLS and OFC dynamically change in
goal-directed and habitual actions
d action selection



2. Ventromedial prefrontal cortex (vmPFC)

- ▶ A key role of goal-directed control over action
- ▶ More posterior portion of vmPFC (co. perigenual anterior cingulate) : more active, carry out goal-directed as opposed to habitual actions

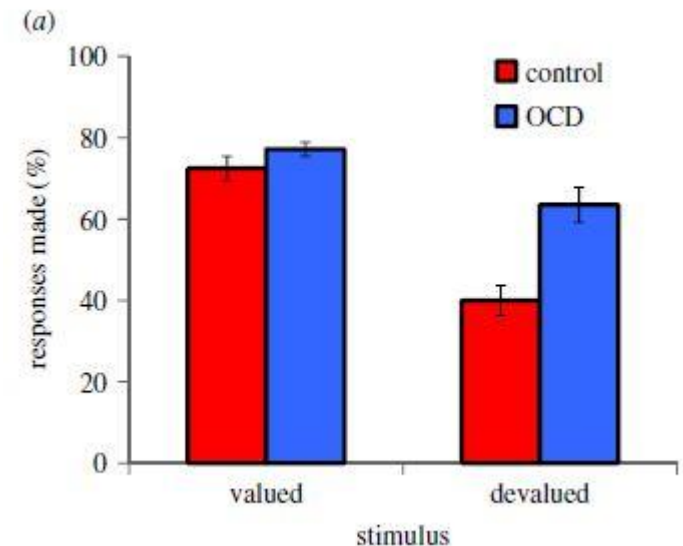
3. The putamen for habit learning, the caudate for goal-directed

PART2. GOAL-DIRECTED DYSFUNCTION AND OCD (1/6)

- ▶ OCD patients have stimulus-response learning bias
 - ▶ A series of test, following trial and error learning of positively reinforced stimulus-response-outcome association
- ▶ Experimental evidences (in OCD patients)

I. Outcome-devaluation test

- ▶ Deficit in ability to refrain from responding to the worthless outcome
- ▶ Impaired the action-outcome knowledge
- ▶ Intact the stimulus-response knowledge



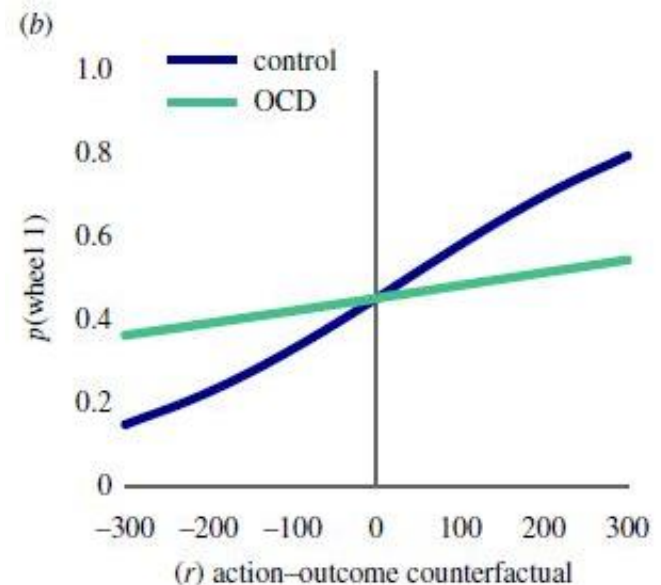
PART2. GOAL-DIRECTED DYSFUNCTION AND OCD (2/6)

2. Counterfactual decision-making

▶ Potential regret

- Goal-directed computation using comparison of prospective action-outcome states
- The ability to simulate and compare options in a decision tree.
- Influence goal-directed behaviours

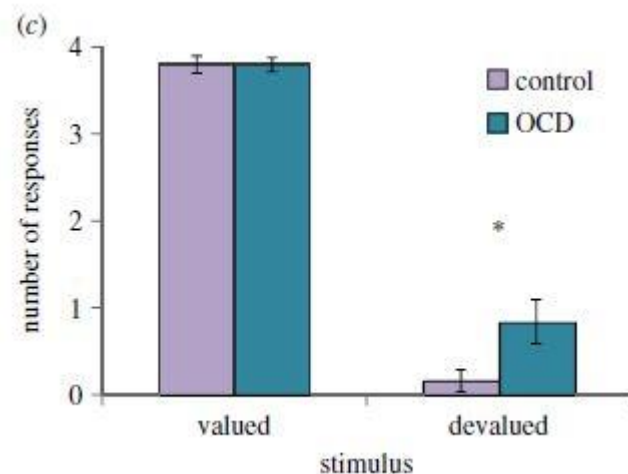
- ▶ OCD patients have a deficit in goal-directed control over action, the influence of this computation on decision-making was attenuated



PART2. GOAL-DIRECTED DYSFUNCTION AND OCD (3/6)

3. Avoidance

- ▶ Tested whether the deficits in appetitive goal-directed behaviour
- ▶ Trained to avoid aversive electrical shocks by performing the correct response to a predictive stimulus (then have training period)
- ▶ Stimulus of valued shock : no differ btw. OCD and control
→ the same number of avoidance response made
- ▶ Stimulus of devalued shock : OCD significant more responses
- ▶ OCD patients were proficient in their goal-directed control prior over-training.
- ▶ Then their behaviour became excessively habit-based over the course of over-training



PART2. GOAL-DIRECTED DYSFUNCTION AND OCD (4/6)

▶ Imbalance

- ▶ In OCD patients, there is a consistent shift in balance away from goal-directed associative control over action towards stimulus-response habits

▶ Potential Causes for imbalance

I. deficit in action-outcome associative learning

- ▶ Rely excessively on stimulus-response links that were reinforced
- ▶ For deficient knowledge of action-outcome associations, patients fail to show sensitivity to devaluation

PART2. GOAL-DIRECTED DYSFUNCTION AND OCD (5/6)

2. Excessive stimulus-response learning

- ▶ For this, patients lose their sensitivity to action-outcome links
- ▶ A fundamental problem is not dependent on excessive habit formation in the disorder
- ▶ OCD's habit biases are not necessarily driven by deficits on goal-directed contingency knowledge
- ▶ It is plausible that both habit-based and goal-directed learning may be affected in OCD

3. Arbitration between goal-directed and habit control

- ▶ Dysfunctional goal-directed learning processes associated with the caudate and medial OFC are responsible for biases towards habitual responding in OCD

PART2. GOAL-DIRECTED DYSFUNCTION AND OCD (6/6)

- ▶ **Reinforcement learning schema**
 - ▶ Model-based : map onto goal-directed action
 - ▶ Model-free : supports habit learning
 - ▶ In OCD patients, model-based control over action is selectively diminished

PART3. HABIT AND 'COD' (1 / 6)

▶ Classic cognitive models of OCD

- ▶ Obsessions precede compulsions
- ▶ 'I fear contamination and therefor I feel compelled to clean excessively'

▶ Recent observations

- ▶ The reverse may better capture the OCD phenomenon
- ▶ 'I feel compelled to clean excessively and therefor I must be afraid of contamination'
- ▶ Rearrangement of the letters OCD to COD
 - ▶ Concept of functional relationship btw. Obsession and Compulsion

PART3. HABIT AND 'COD' (2 / 6)

▶ Two problems in the OCD model

- ▶ Existing cognitive models : obsessions drive OCD and compulsions are secondary phenomena.

1. There is a purely behavioural disturbance in OCD that is independent of obsessionality

2. OCD is an ego-dystonic disorder

- ▶ patients have insight into the irrationality of their compulsive actions. They want to stop but cannot exert control over the urge to act

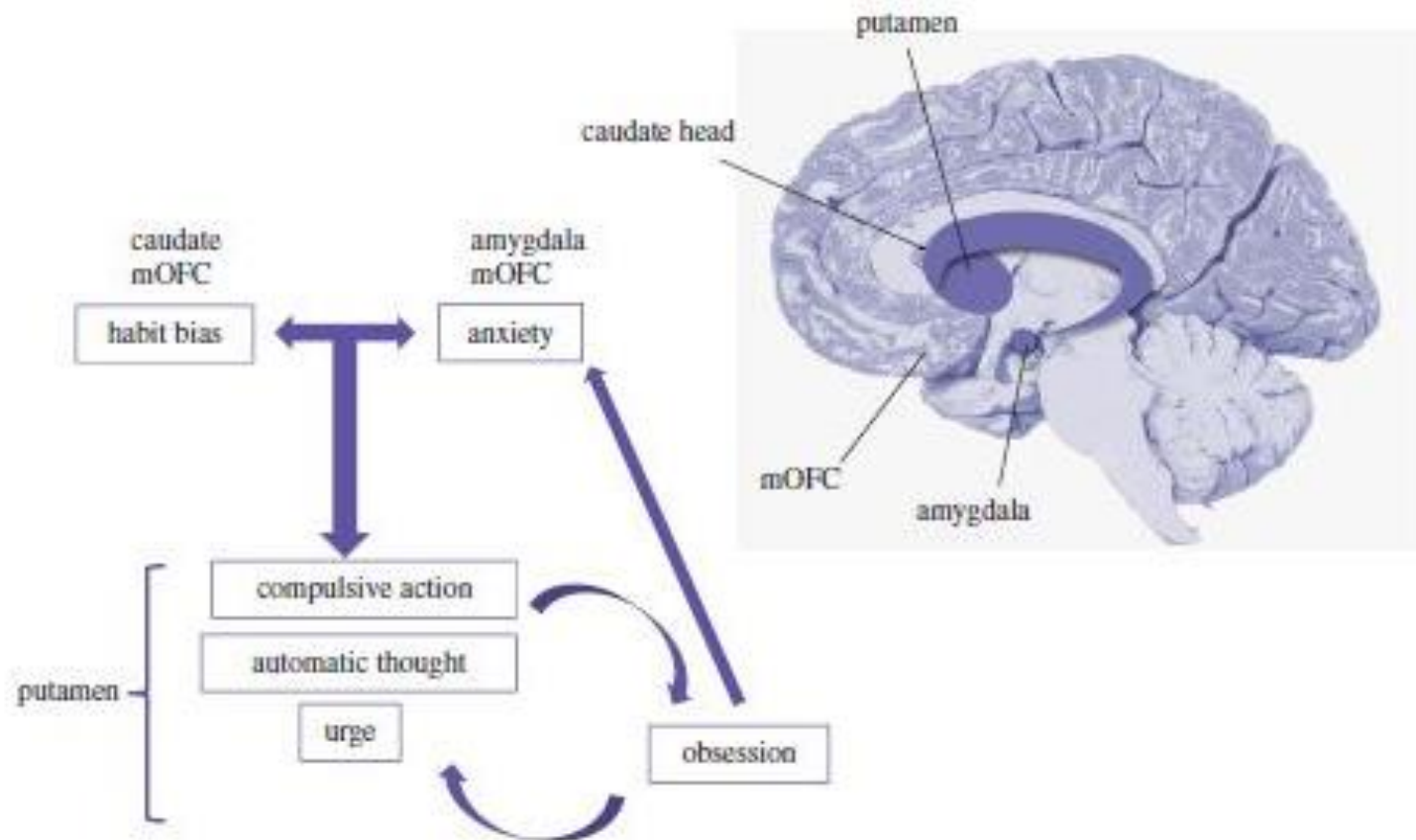
- **Egosyntonic** is a term referring to behaviors, values, and feelings that are in harmony with or acceptable to the needs and goals of the ego.

- **Egodystonic** is a term referring to thoughts and behaviors (e.g., dreams, compulsions, desires, etc.) that are in conflict, dissonant with the needs and goals of the ego.

[@ wikipedia.org]

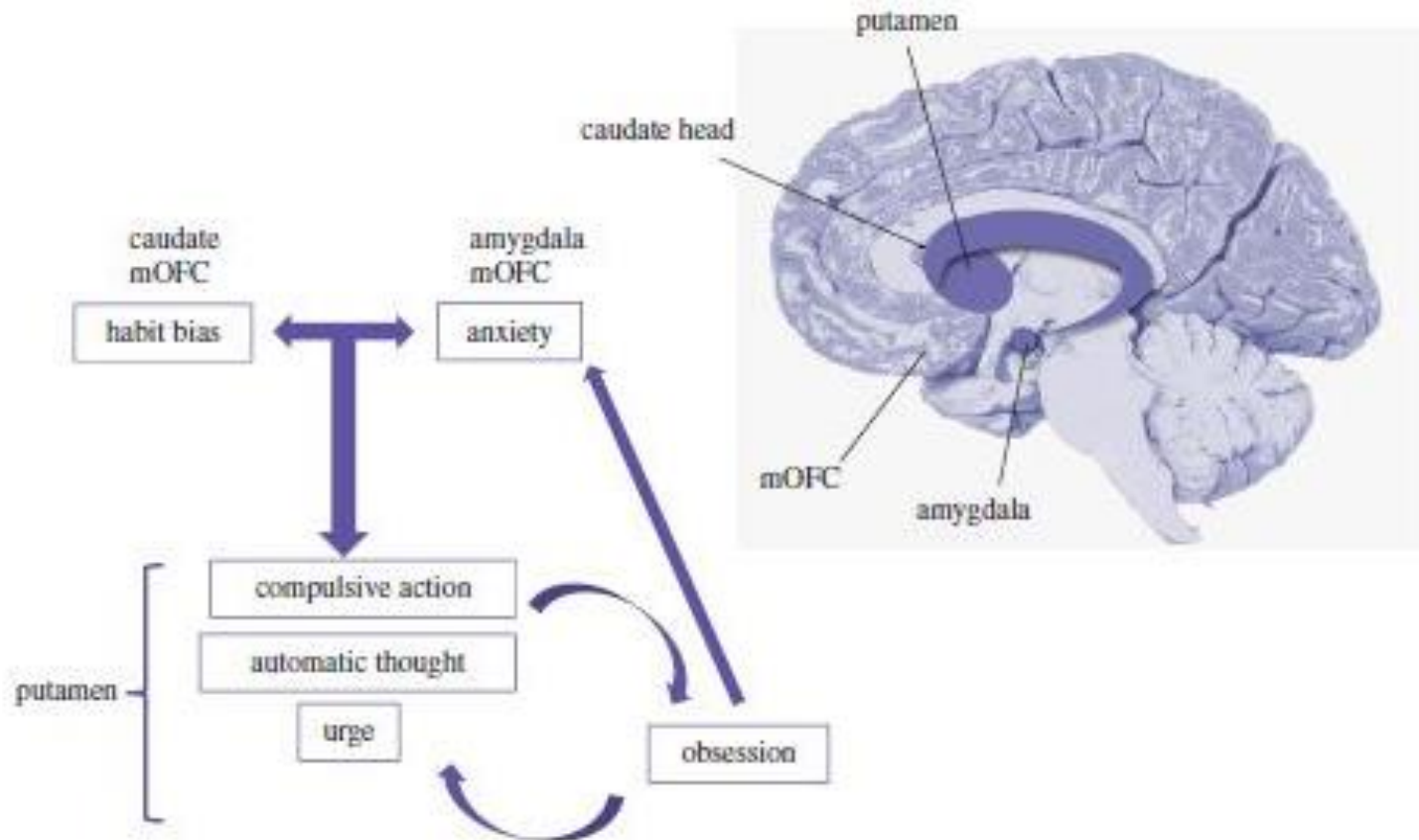
PART3. HABIT AND 'COD' (3/6)

- ▶ How compulsive behaviours could give rise to obsessional thinking?



Proposed model of OCD. Biases towards habit formation and trait anxiety act in concert to foster compulsive urges, probably supported by the putamen, where action control is transferred from a misfiring caudate and OFC.

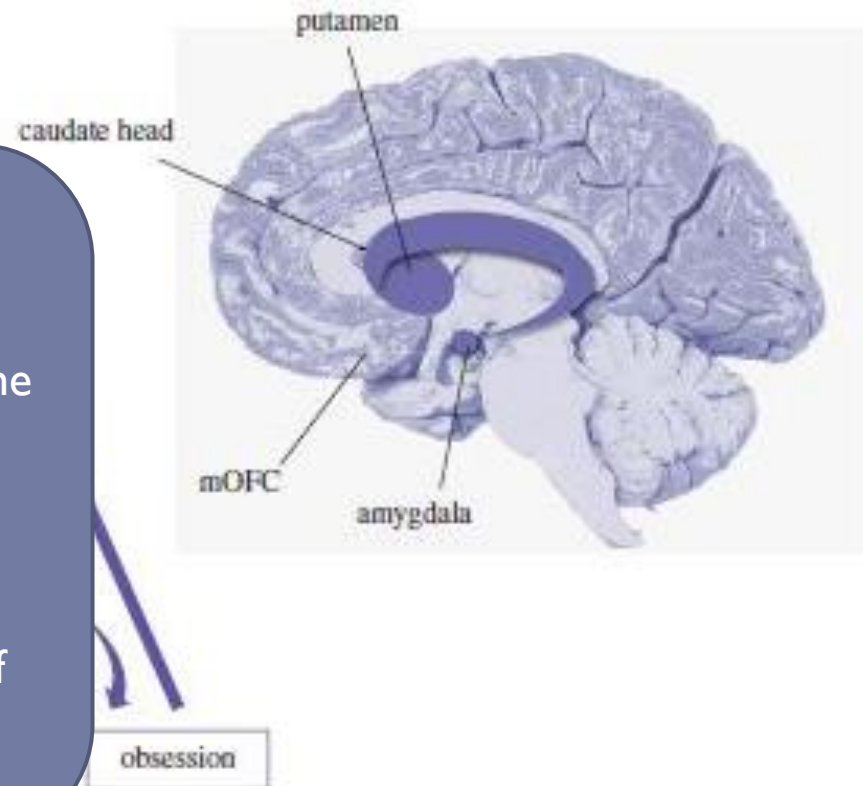
Obsessions may be a cognitive interpretation of compulsive urge, which ultimately interacts with anxiety and reinforces the desire to perform compulsions through cognitive dissonance.



Proposed model of OCD. Biases towards habit formation and trait anxiety act in concert to foster compulsive urges, probably supported by the putamen, where action control is transferred from a misfiring caudate and OFC.

Obsessions may be a cognitive interpretation of compulsive urge, which ultimately interacts with anxiety and reinforces the desire to perform compulsions through cognitive dissonance.

Brain schematic illustrates important nodes in the **fronto-striatal circuits** implicated in OCD, of which the mOFC and the caudate are most consistently implicated. Disruption in these regions may be necessary and sufficient for OCD diagnosis, but probably contribute to a range of disorders along the anxious and compulsive spectrums



PART3. HABIT AND 'COD' (4/6)

- ▶ **Cognitive dissonance : a state of conflict**
 - ▶ When two or more competing beliefs are held, Humans are motivated to reduce conflict by altering one of these beliefs
 - ▶ In situations of cognitive dissonance, when behaviour contradicts belief, humans alter their beliefs to match their behaviours – that is 'actions create preferences'
 - ▶ In OCD, the irrational thoughts often considered to induce compulsive responding, may product of the mind's attempt to resolve the discrepancy between cognitions and urge to perform compulsive behaviours.
 - ▶ And compulsive avoidance behaviours may engender cognitive dissonance that is reconciled by development of a new irrational belief. New 'fear' makes sense of the need to compulsive responses and contribute to the motivation of subsequent avoidance responding

PART3. HABIT AND 'COD' (5/6)

- ▶ **Habit formation by irrational thought**
 - ▶ They continued to make avoidance responses to the stimulus that predicted the now devalued outcome. For 'habit'
 - ▶ Reporting very low likelihood that they could still be shocked following devaluation and having intact knowledge of the contingency structure of the task
 - ▶ These irrational threat beliefs may sometimes be a consequence of habit formation

PART3. HABIT AND 'COD' (6 / 6)

▶ Anxiety

- ▶ Maladaptive cycle of compulsions, obsessions and anxiety maybe cyclically maintained and reinforced, allowing for irrational fears to propagate and develop into more persistent obsessions over time
- ▶ Anxiety-related mechanisms may contribute to habit biases in some patients, but not fully account for them
- ▶ The relationship among obsessions, anxiety and compulsions, that can coexist with a 'COD' account
- ▶ There is a bidirectional mechanism of maladaptive symptom reinforcement

SUMMARY & CONCLUSION

- ▶ A shift from goal-directed to habitual control over action mediates compulsivity in OCD ties well with the neurobiological and pharmacological basis of habit learning in rodents and humans
- ▶ The 'COD' model of OCD is plausible interpretation that the experience of premonitory 'want', or 'urge', reported in not only OCD but also substance-dependent individuals and tic disorder, may be a consequence of excessive stimulus-response associations

ANY QUESTION?

