



Trinity College Dublin
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The University of Dublin



GLOBAL
BRAIN HEALTH
INSTITUTE

Model-Based Planning, Metacognition and Compulsivity

Claire Gillan, PhD

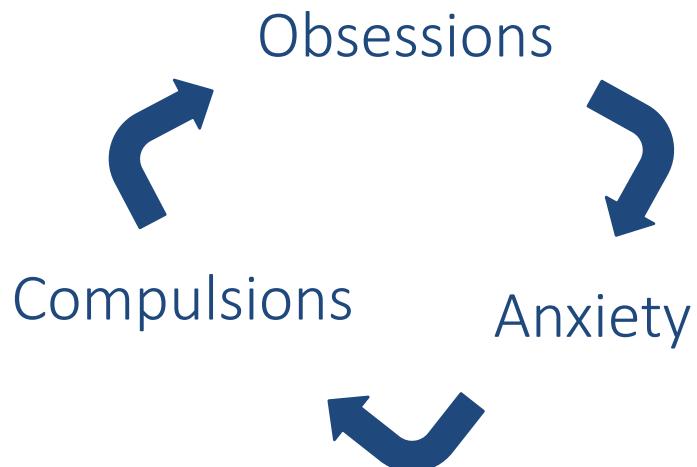
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Obsessive-compulsive disorder



Are these just bad habits?



**"Just checking that I've turned off
the lights, dear!"**

Habits vs. Goal-Directed Behavior



Habits vs. Goal-Directed Behavior

Devaluation



Habits are automatic stimulus-response' behaviors
-- they are NOT sensitive to devaluation



Goal-directed behaviours are actions that rely on linking actions to outcomes
-- they are sensitive to devaluation

Do OCD patients form habits excessively?

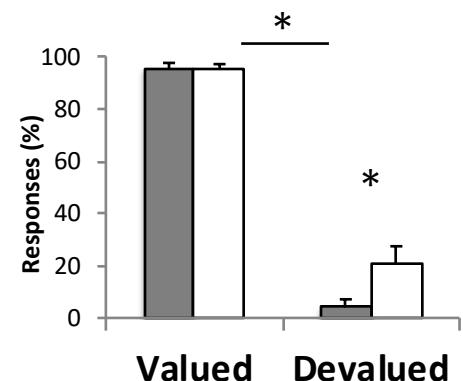
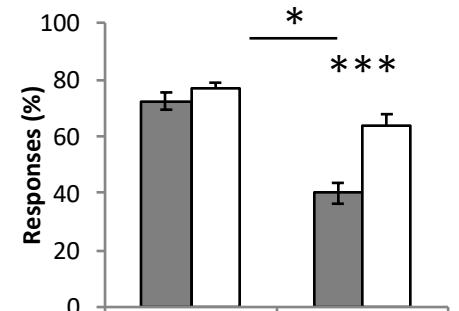
Controls
OCD

- Appetitive Devaluation

Gillan et al., American Journal of Psychiatry, 2011

- Aversive Devaluation

Gillan et al., Biological Psychiatry, 2014a



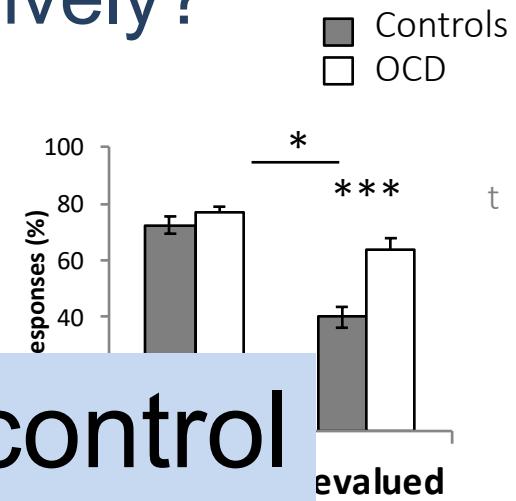
Do OCD patients form habits excessively?

- Appetitive Devaluation

Gillan et al., American Journal of Psychiatry, 2011

- Aversive Devaluation

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Deficits in goal-directed control

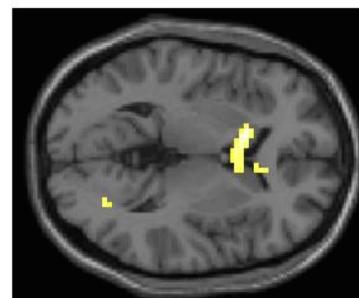
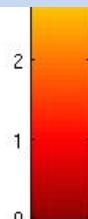
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Excessive habit

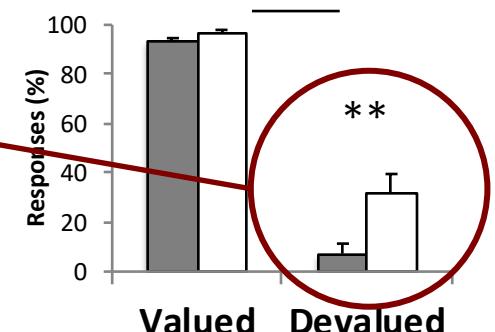
Potential Mechanism?

-- caudate activity linked to goal-directed learning across species

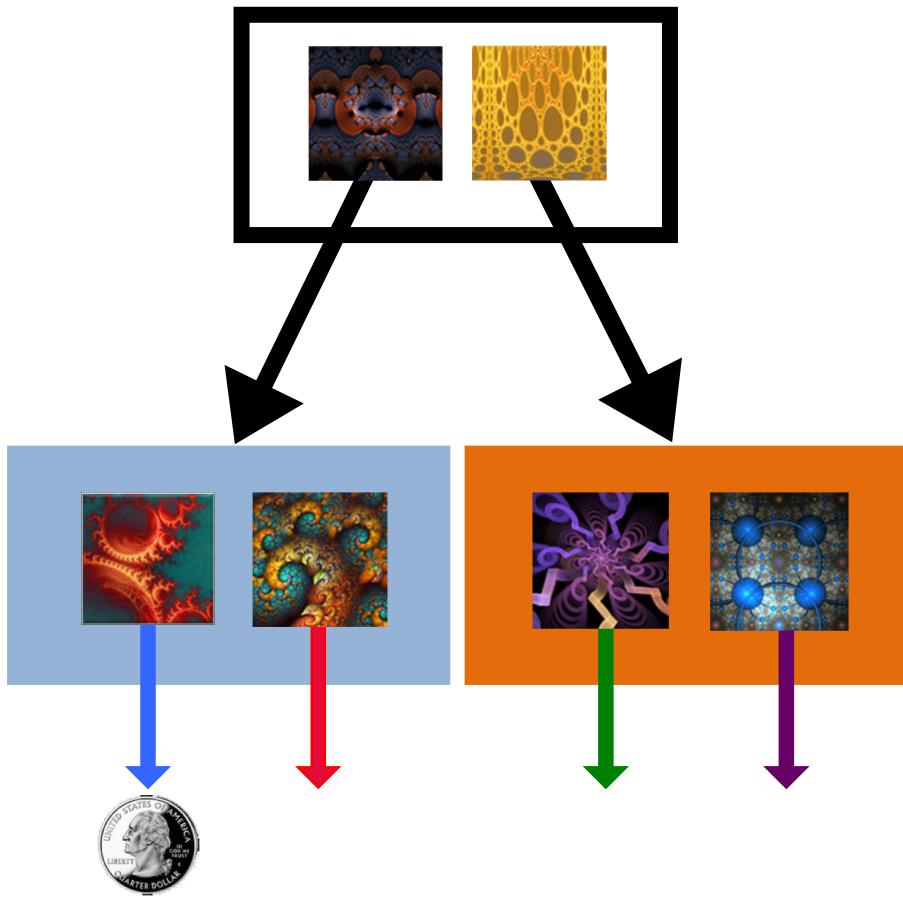
Dolan & Dayan, 2013



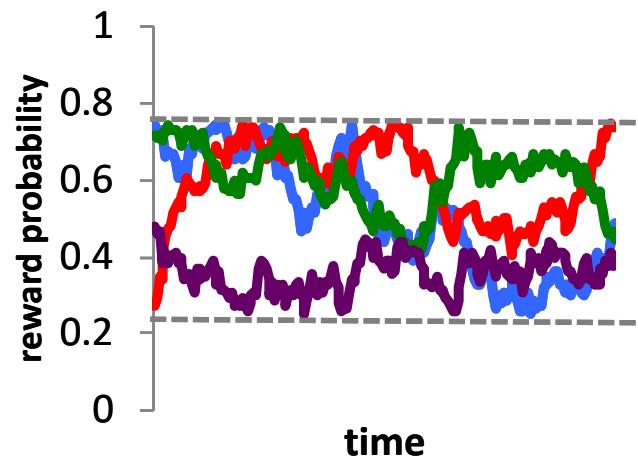
p<.05 FWE

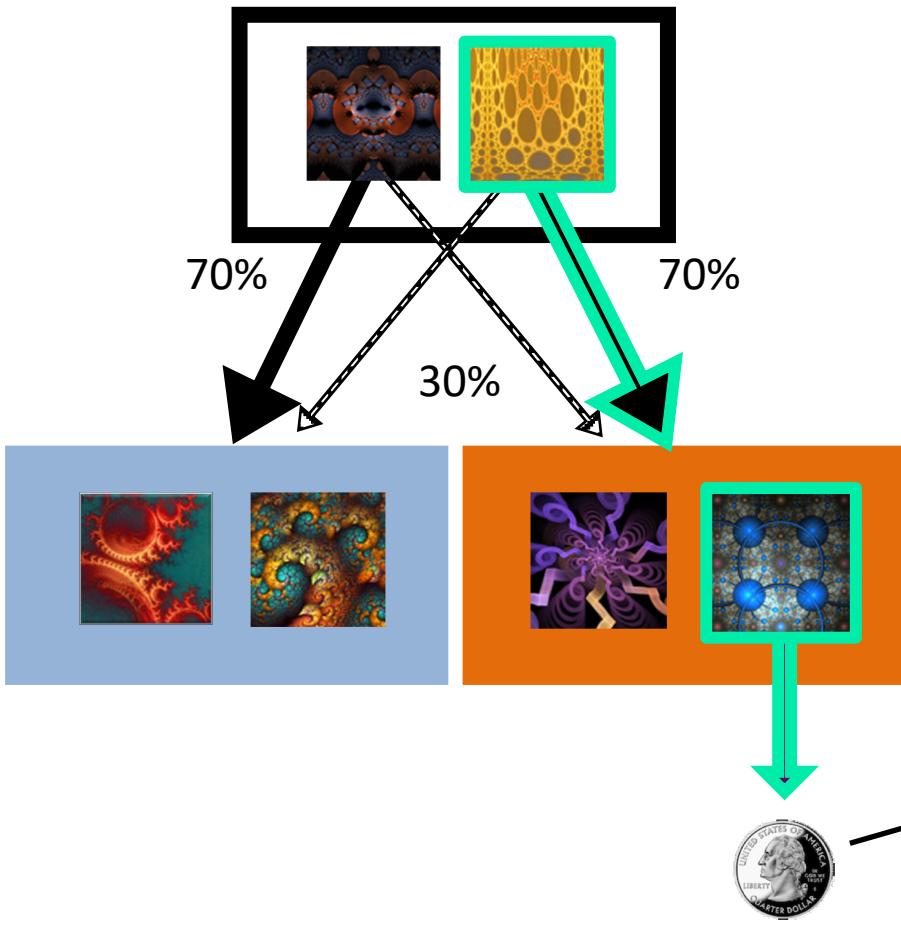


*p<.05 ** p<.01 ***p<.001



Can we separate **goal-directed control** from **habits**...
using a computational model?





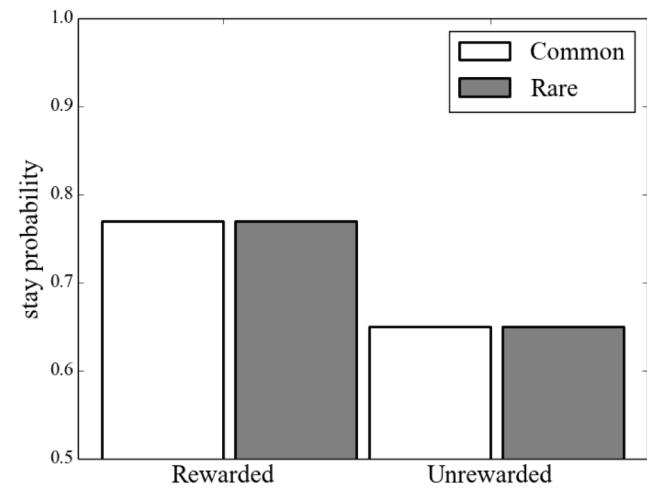
“Model-Free” Learning (putatively habit)

$$Q_{MF}(S_{start,t} a_{right,t}) = Q_{MF}(S_{start,t} a_{right,t}) + \alpha \delta_t$$

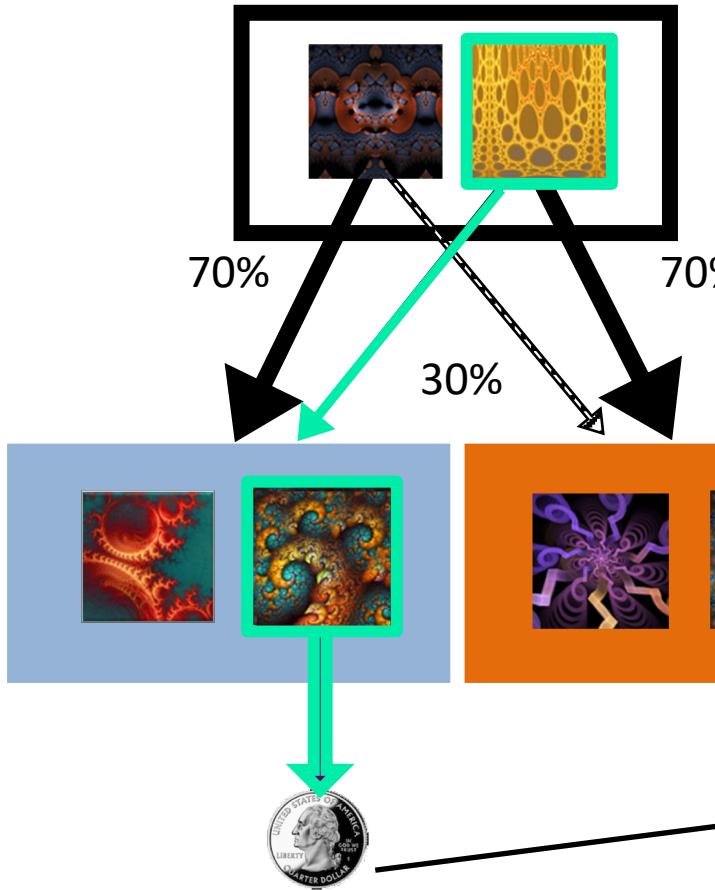
$$Q_{MF}(S_{orange,t} a_{right,t}) = Q_{MF}(S_{orange,t} a_{right,t}) + \alpha \delta_t$$

α = learning rate; *how much do I take new info into account?*

δ_t = prediction error; *difference between expectation and reality*

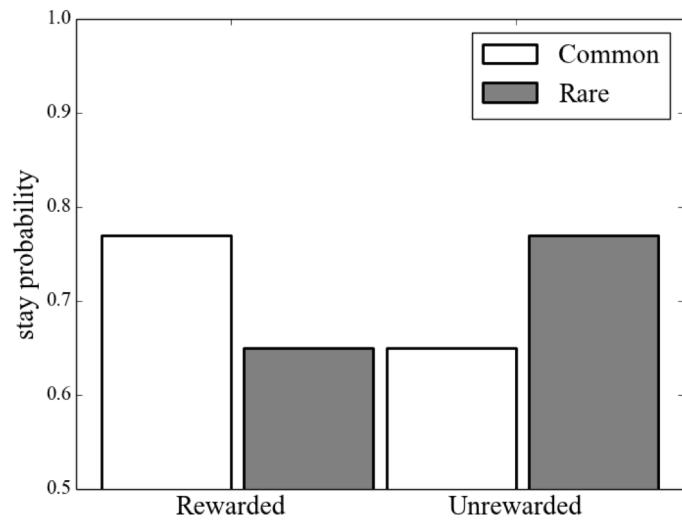


“Model-Based” Learning (putatively goal-directed)

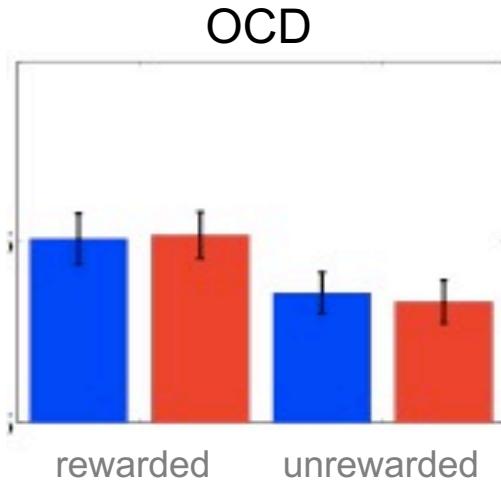


$$Q_{\text{MF}}(S_{\text{start},t} a_{[\max \text{ trans to blue}],t}) = Q_{\text{MF}}(S_{\text{start},t} a_{\text{right},t}) + \alpha \delta_t$$

$$Q_{\text{MF}}(S_{\text{blue},t} a_{\text{right},t}) = Q_{\text{MF}}(S_{\text{blue},t} a_{\text{right},t}) + \alpha \delta_t$$

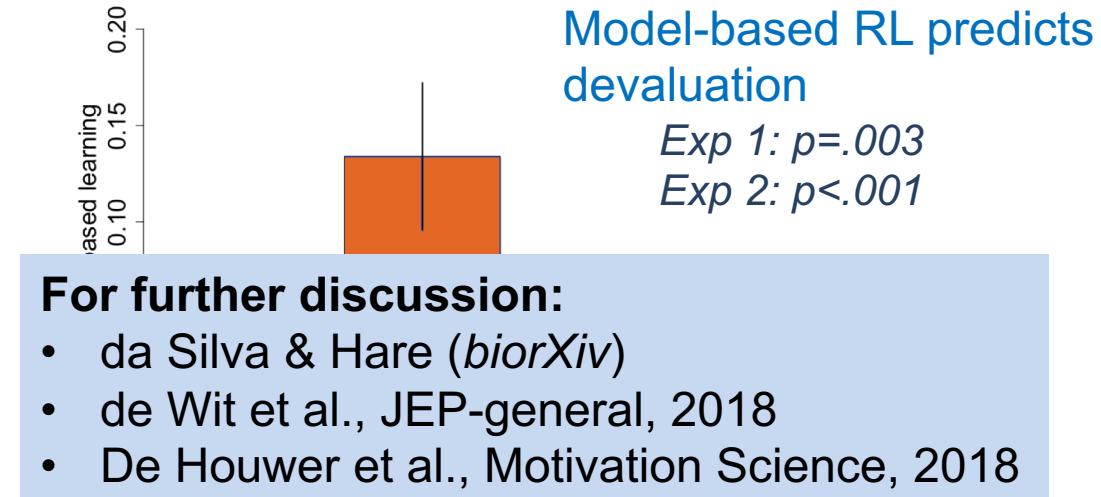


OCD patients have deficits in model-based not model-free RL.



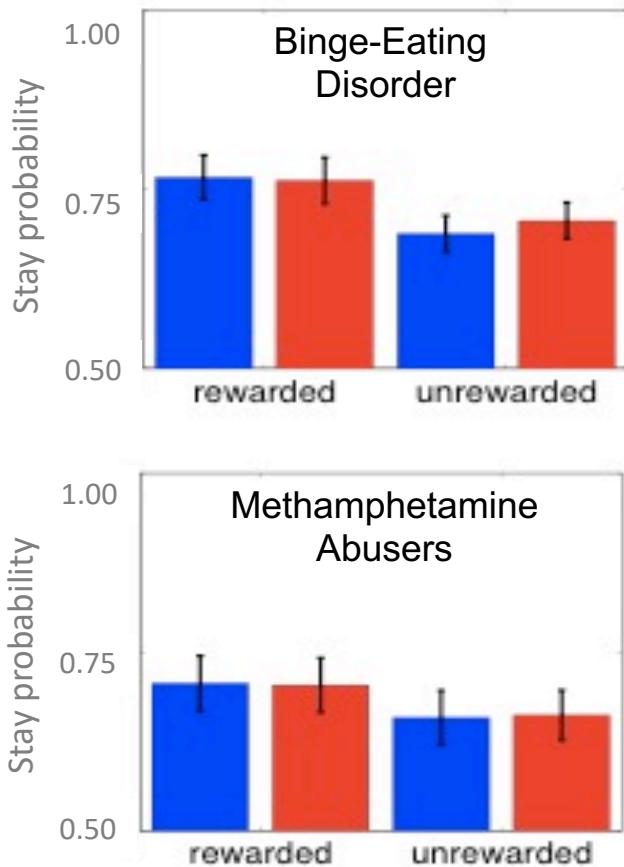
- Model-based RL linked to OCD
 $p=.004$
- Model-free RL is not
 $p=.52$

- Converges with earlier neuroimaging work implicating goal-directed control
 - Gillan et al., Biological Psychiatry 2014a
 - Gillan et al., American Journal of Psychiatry 2015
- But **not too fast**: reason to think we still don't fully understand how habits are slowly learned

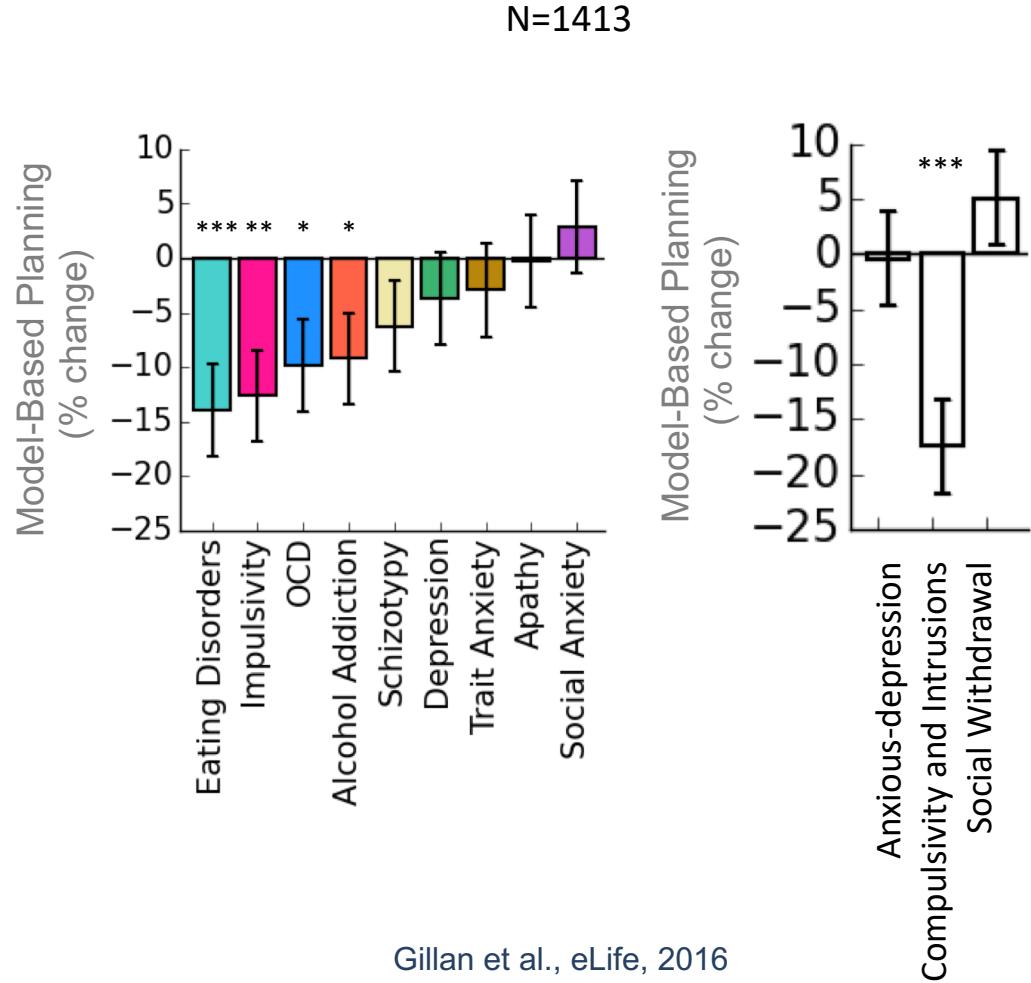


Model-based planning as a transdiagnostic marker of compulsivity

Patients



General Population



Data under embargo

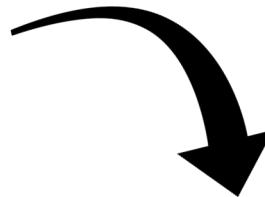
Interim Summary

- OCD patients are susceptible to getting stuck in habits -> i.e. fail a devaluation test
- Computational modeling reveals a disruption in **goal-directed** computations and associated brain regions
- Do patients differ in the formation of stimulus-response habits themselves?
 - We simply don't know
- Model-based planning deficits are characteristic of individual differences in a transdiagnostic dimension of **compulsivity**.

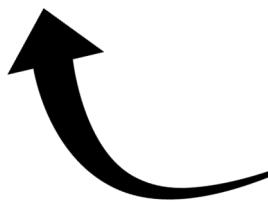
How do **habits** relate to distorted beliefs?



Compulsions

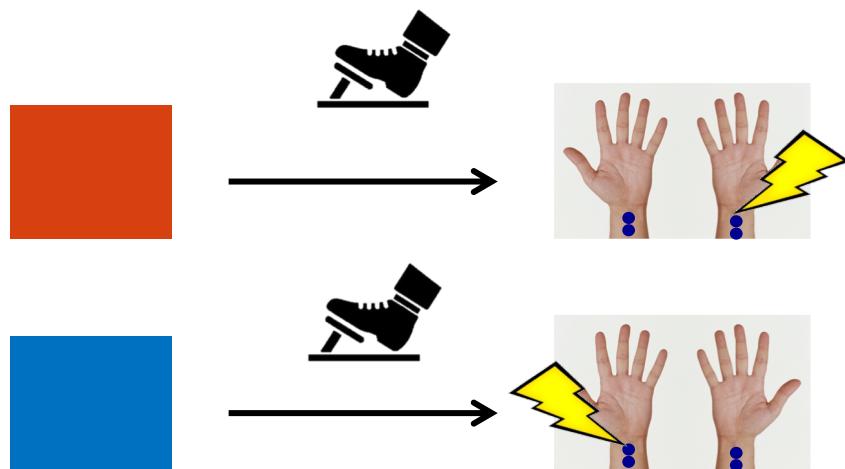


Obsessions

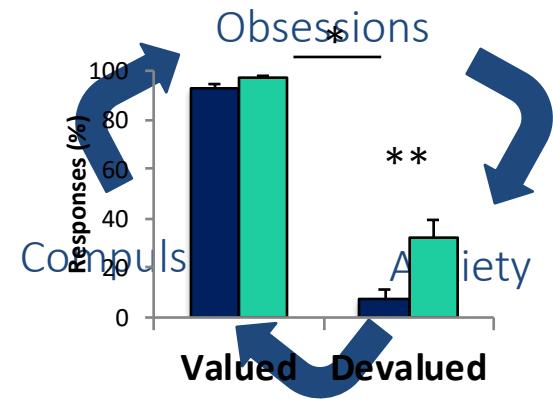
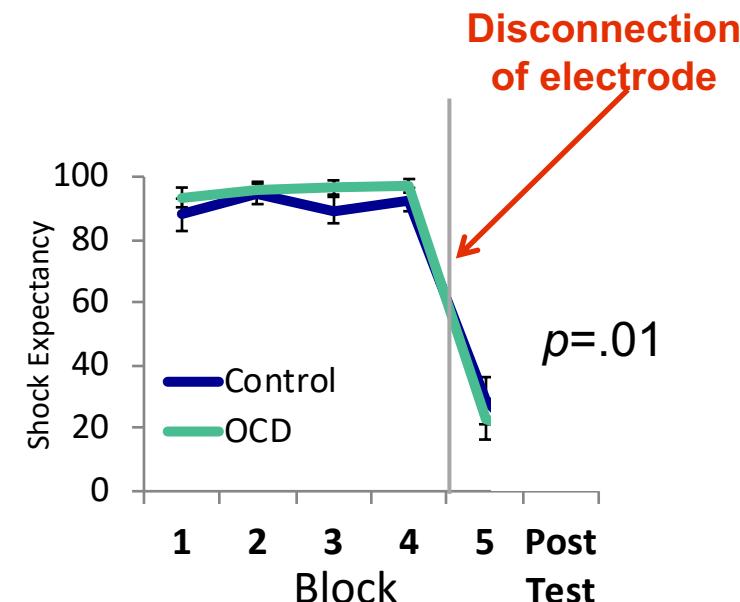
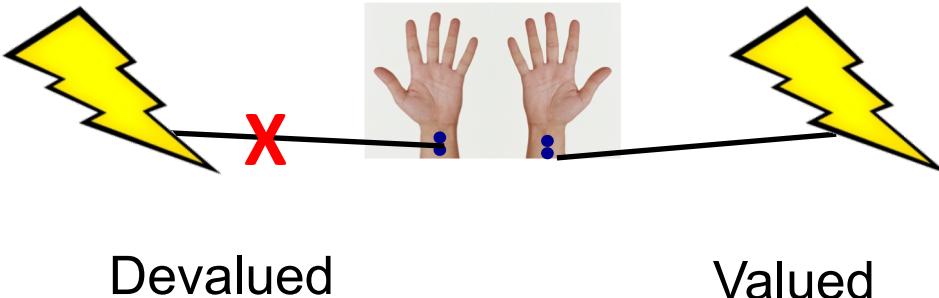


Habits and belief

Avoidance Training



Devaluation Test



Is there a metacognitive deficit in OCD?

↓ confidence OCD vs HC

↓ confidence with repeated checking

== confidence OCD vs anxious controls

↓ confidence

↓ confidence OCD vs HC under high responsibility

== confidence OCD vs HC

== confidence OCD vs HC

Compulsivity loads with schizotypy,
linked to over-confidence

↓ confidence

S1, S2 & S3

S1, S2 & S3

↓ confidence

↓ confidence

↓ confidence

↓ confidence

↓ confidence

OCD commonly co-morbid with
depression... which has low
confidence

ability

control groups with

HC

↓ confidence OCD vs HC

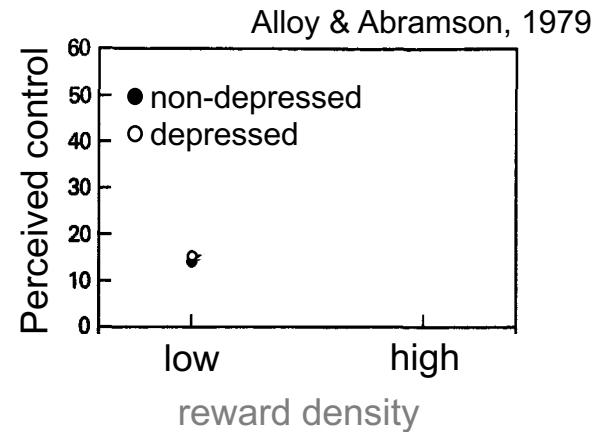
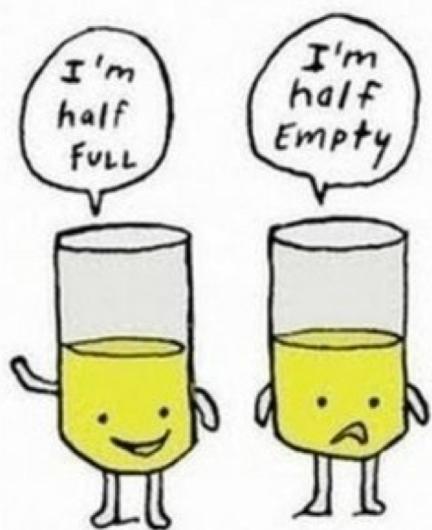
↓ confidence OCD vs HC

== confidence OCD vs HC

- 19/25 studies show **reduced confidence**
- 6/25 studies show **no difference**

Could anxious-depression be confounding these results?

Depressed individuals don't show the same optimism biases as non-depressed
“depressive realism”



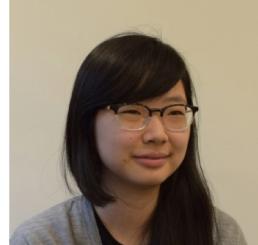
Can a transdiagnostic approach resolve this?



Steve Fleming

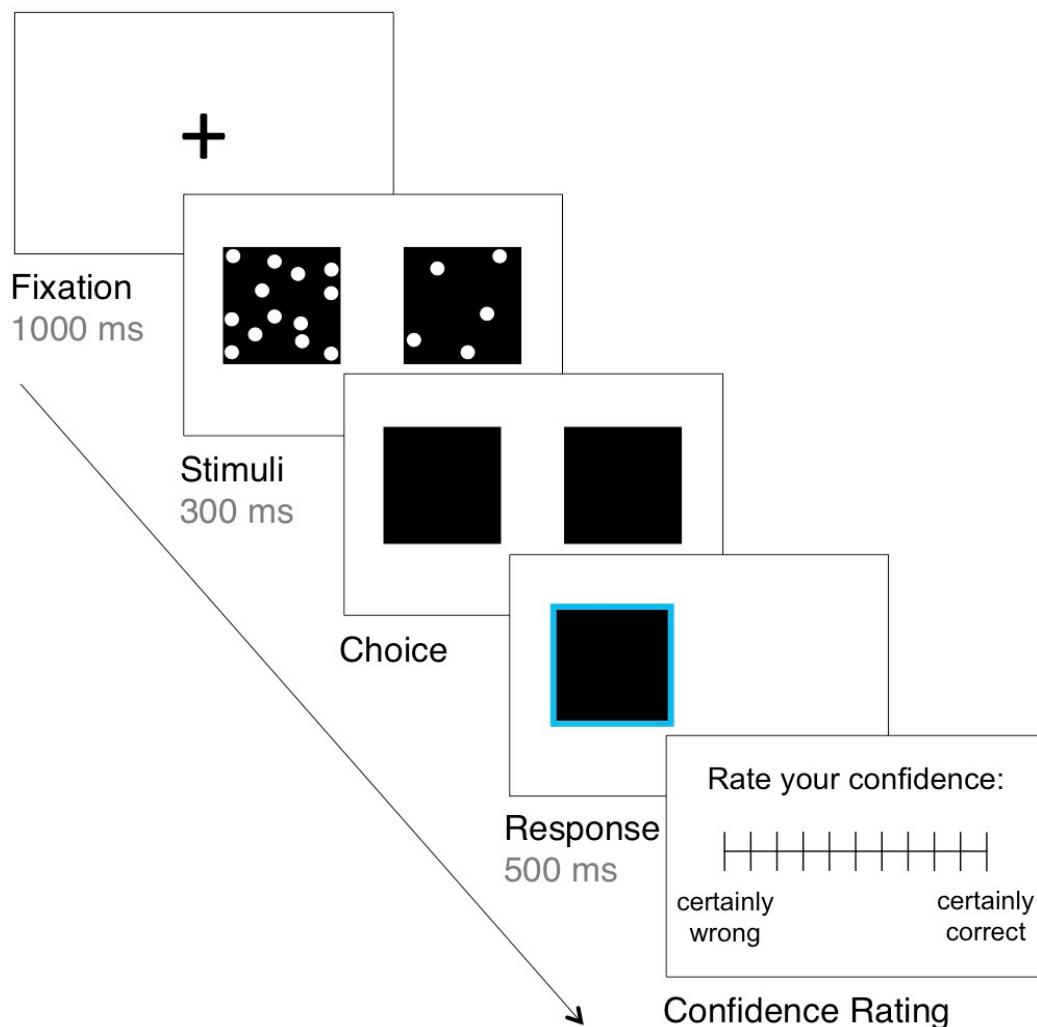


Marion Rouault



Tricia Seow

Perceptual Decision Making Task

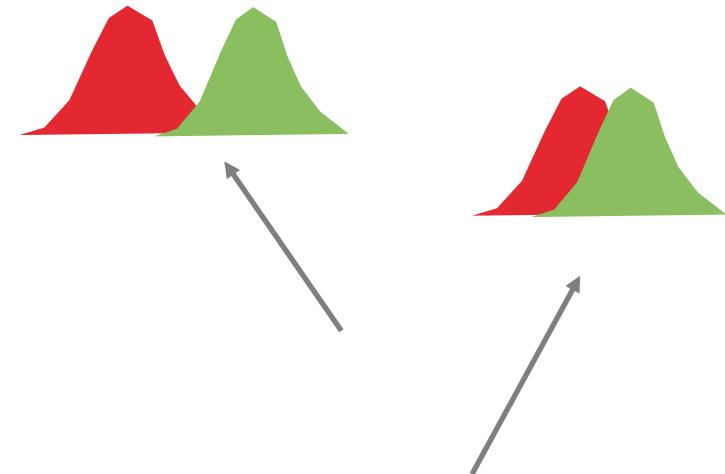
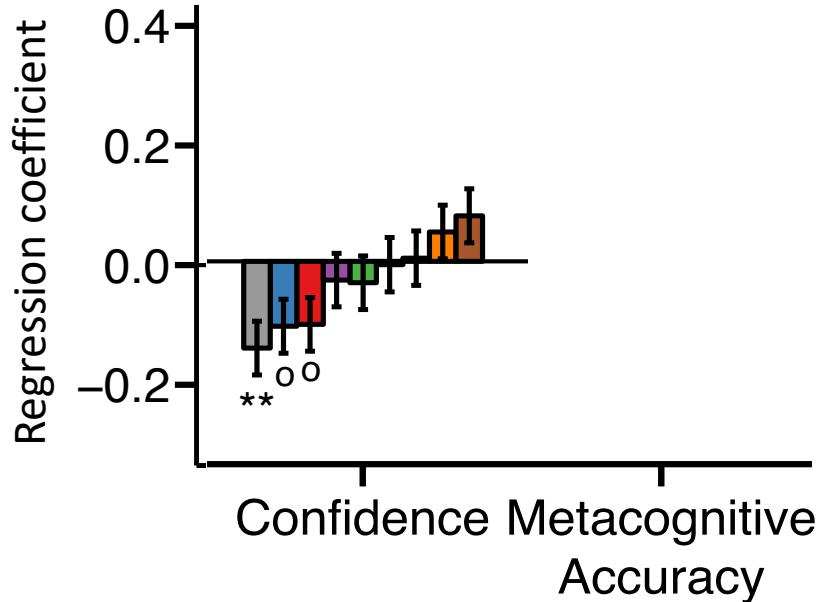


Amazon's Mechanical Turk
Exp 1: N=498
Exp 2: N=497

Using subjective confidence to assess metacognition



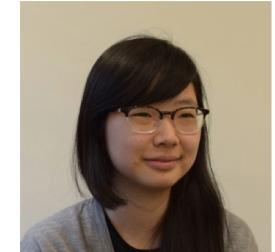
Metacognition in transdiagnostic psychiatric traits



- Apathy
- Social Anxiety
- Generalised Anxiety
- Impulsivity
- Depression
- Alcoholism
- Schizotypy
- OCD
- Eating Disorders

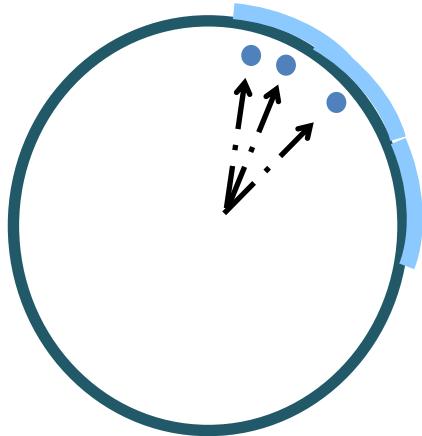
^o $p < .05$ uncorrected

How does behavior and belief respond to feedback in compulsivity?



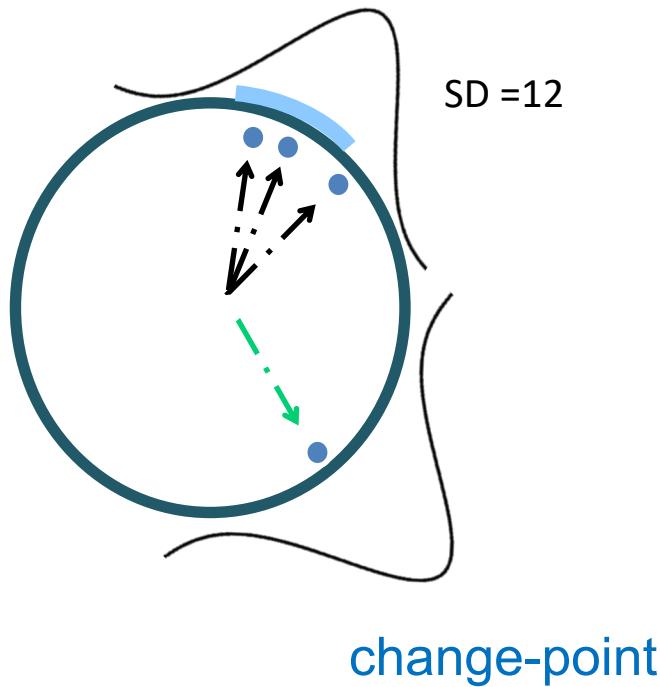
feedback-driven (reinforcement) learning

Tricia Seow



How do **behavior** and **belief** respond to feedback in compulsion?

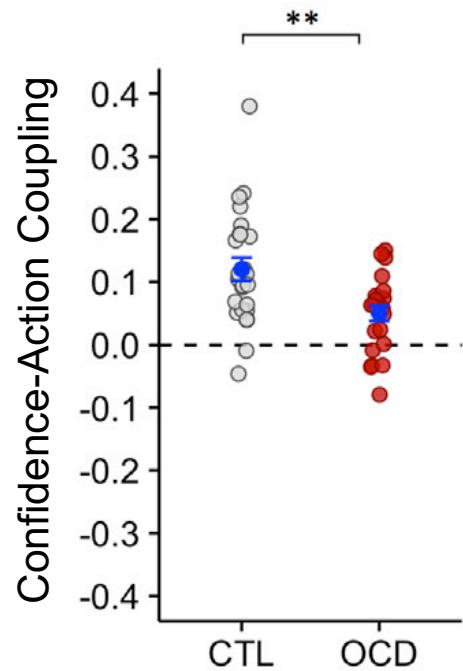
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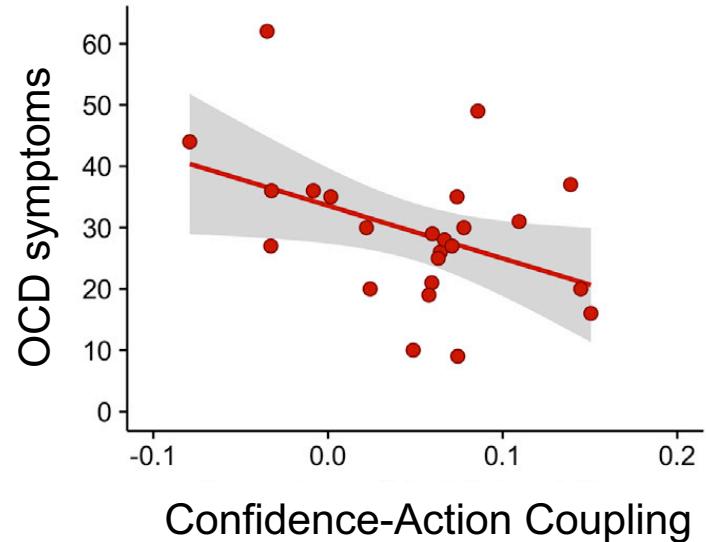
- How does **confidence** relate to **behavior**?
- And how do **confidence** and **behavior** respond to feedback

Confidence-Action Coupling

24 OCD
25 Control

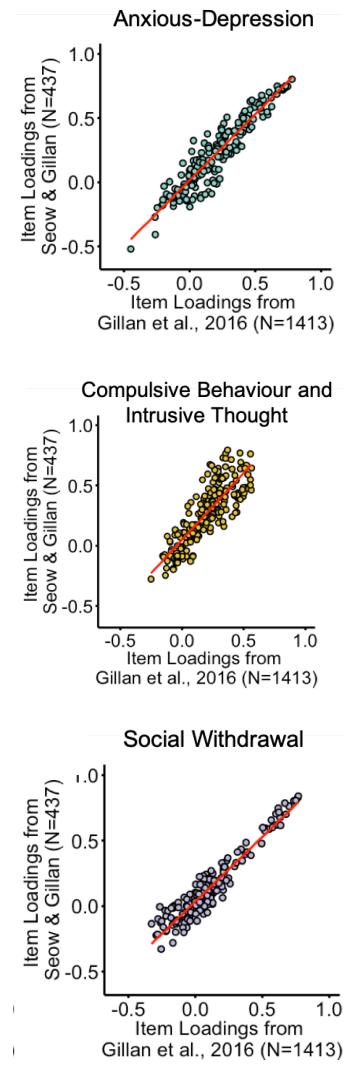
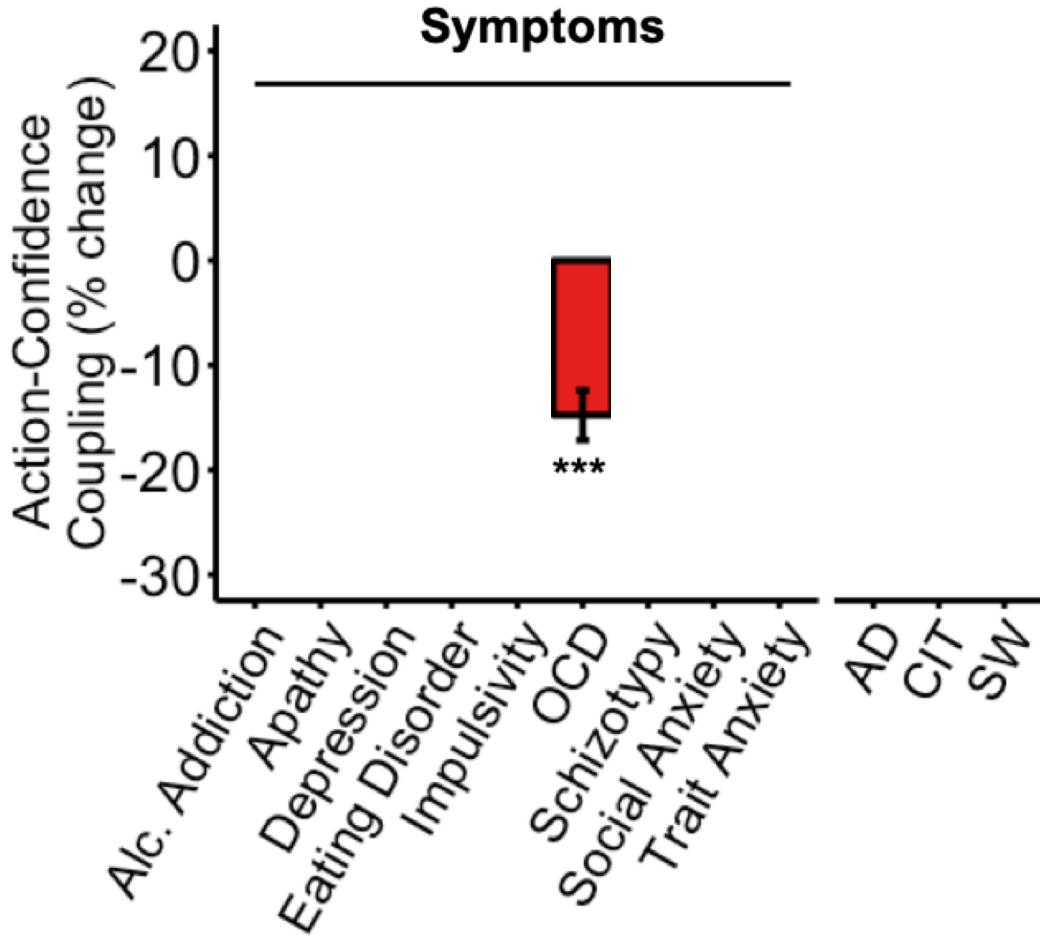


OCD patients have lower confidence-action coupling



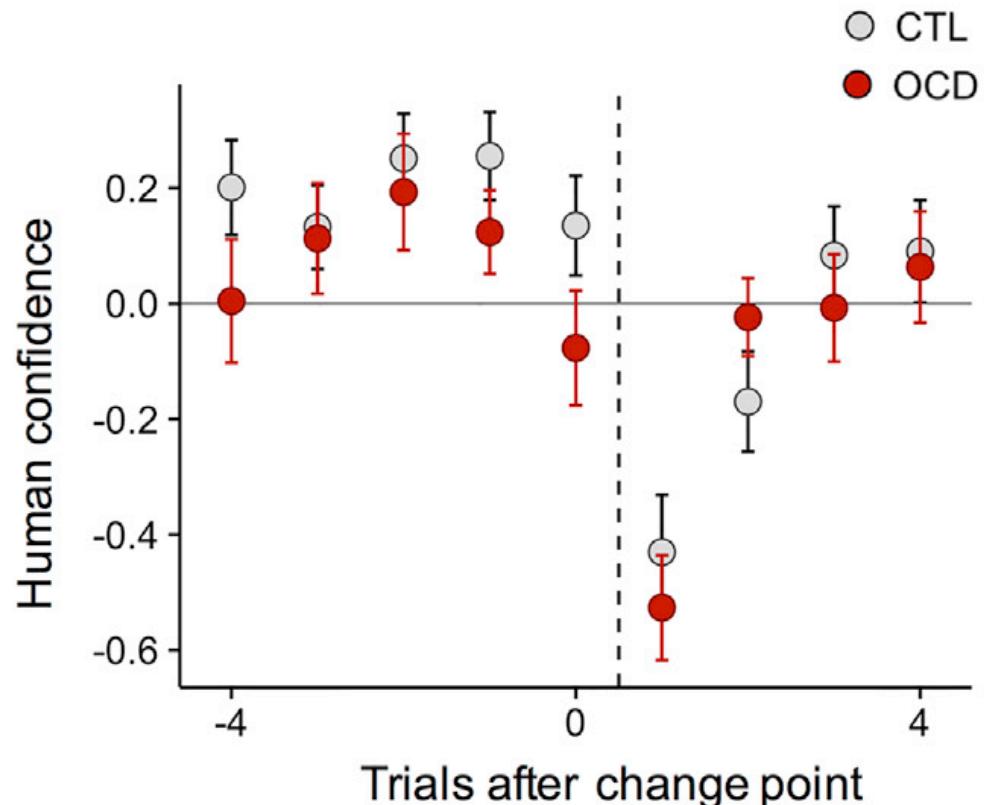
And this correlates with symptom severity

Is this specific to OCD, or compulsivity more broadly?

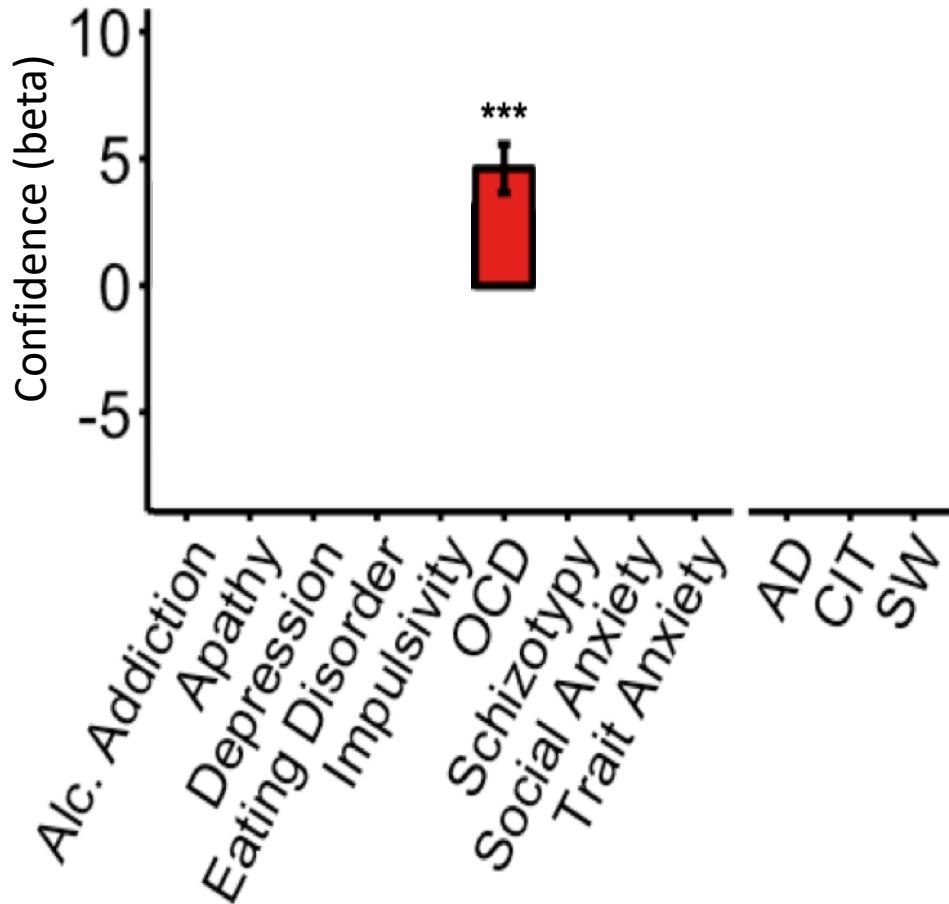


Do confidence abnormalities explain this?

Prior work using this task found **no association** between OCD and confidence



Do confidence abnormalities explain this?

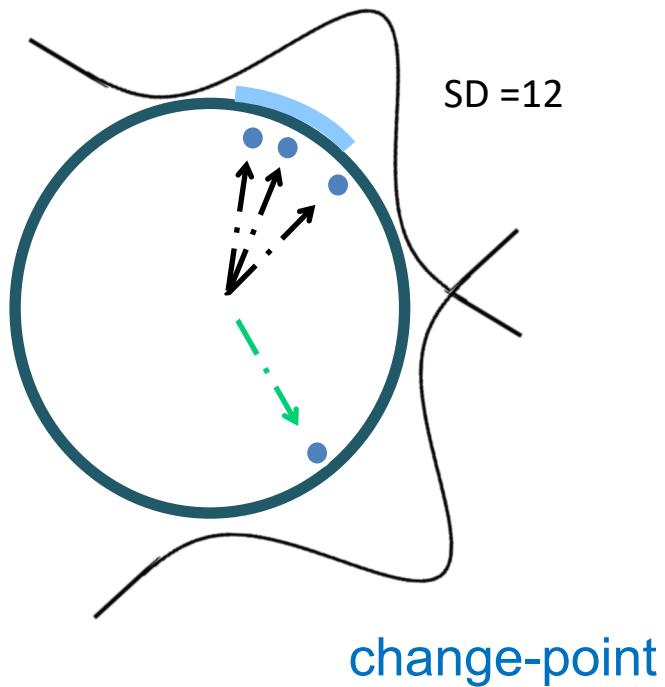


Compulsivity is linked to inflated confidence

Anxious-depression is linked to lower confidence

Full replication of:
Rouault*/Seow* et al., 2018

What causes inflated confidence estimates in compulsivity?

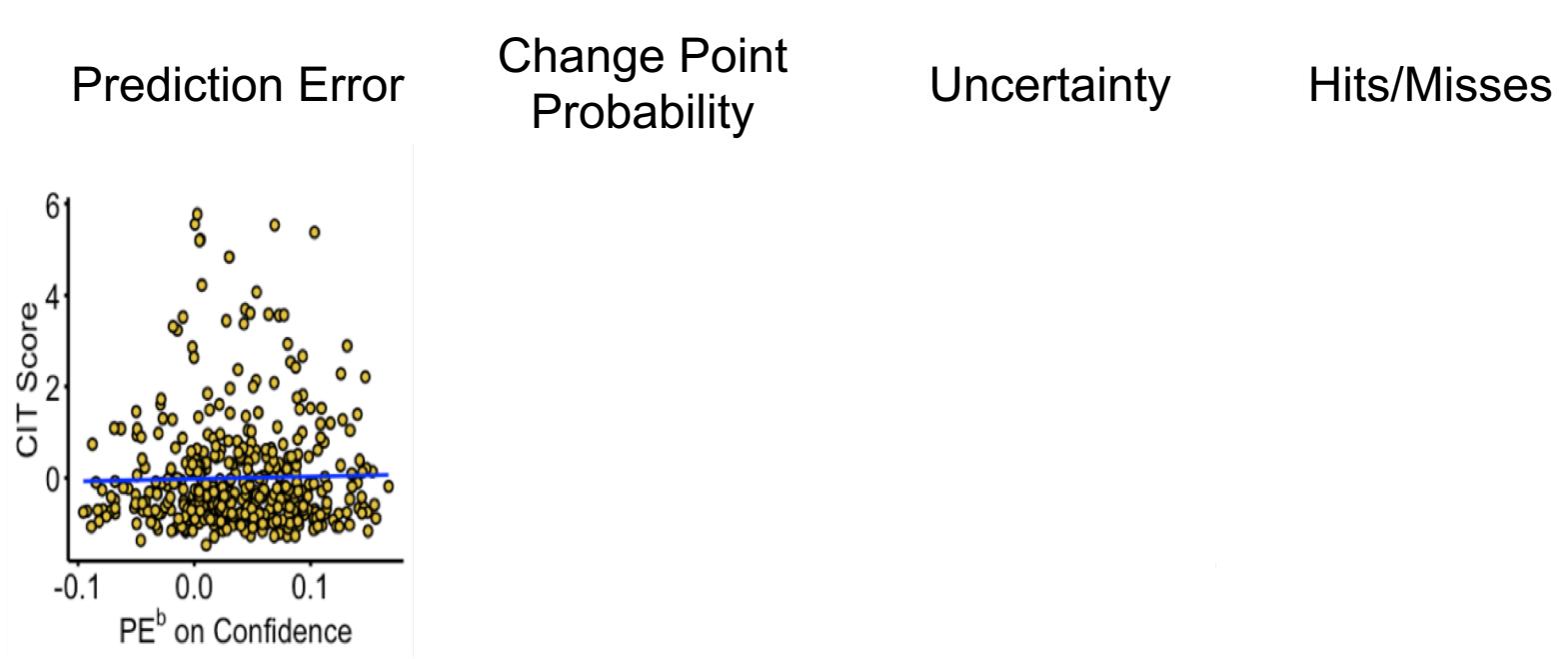


Using a formal model to test alternatives

- Prediction error
- Change-point probability
- Uncertainty
- Hits/Misses

Nassar et al., 2010

What causes confidence-action decoupling in compulsivity?



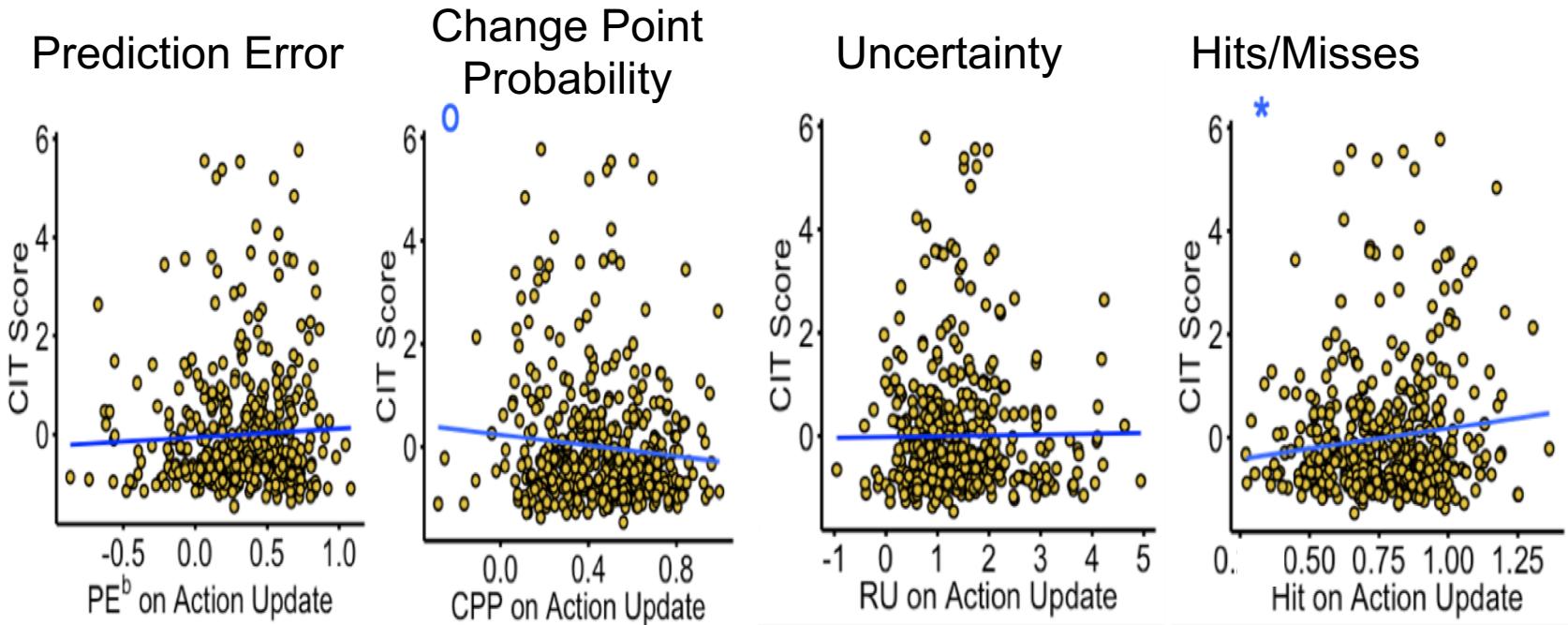
expectation (**bucket position**) -reality
(**where the particle went**)

a same gaussian or
a uniform distribution
around the circle?

(Inverse) precision of
current estimate of the
mean

Did you catch it?

Action-updating in response to feedback is not altered.



Consistent with model-free RL findings in OCD, etc,
(but not with Vaghi et al., 2017)

Second Half Summary

- A transdiagnostic ‘compulsivity’ dimension is associated with **inflated confidence**:
 - *Perception*
 - *Decision-making*
- Confidence is **less informed** by multiple of sources of evidence:
 - *Change points*
 - *Uncertainty*
 - *Hits/Misses*

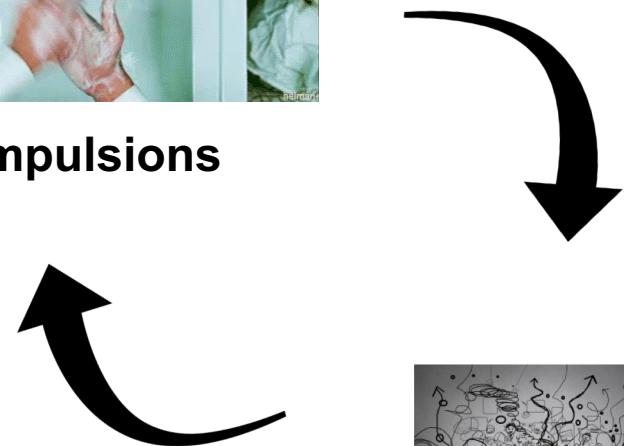
Final Thoughts

Deficits in Goal-Directed Control
Metacognitive Impairments

Dynamic, longitudinal
models are needed



Compulsions



Obsessions

Thank You

Gillan Lab

Tricia Seow
Andrew Pringle
Kevin Lynch
Eoghan Gallagher
Sean Kelley



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wellcome trust



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