Anxiety and depression through the lens of Computational Psychiatry

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A New Model for Mental Illness

Mental illness is the result of an impairment in prediction, due to having a distorted internal model of the world, possibly due to an impairment in learning.

Applications of RL models to Computational Psychiatry

- RL models have been used to model almost all psychiatric disorders.
- **idea**: disorder can be understood as impairment in learning/decision-making.

- Today:
  - Depression
  - Anxiety

Depressive disorders are very common (and very costly)

• Depression is a common, high-burden disorder, not just “low mood”: it affects motivation, pleasure, learning, decision-making, sleep, appetite, and social functioning.

• Globally, WHO estimates that 280 million people experienced depression in 2019 (about 5% of adults)

• In the UK: ONS reported that in autumn 2022, 16% of adults had moderate to severe depressive symptoms on the PHQ-8 screen. This was higher in young adults aged 16–29 (28%) and in women (19%) than men (14%). Among women aged 16–29, the figure was 35%.

• In 2024/2025 Roughly 1 in 6 adults in England are estimated to be on antidepressant medications, with women twice as likely to be prescribed them as men

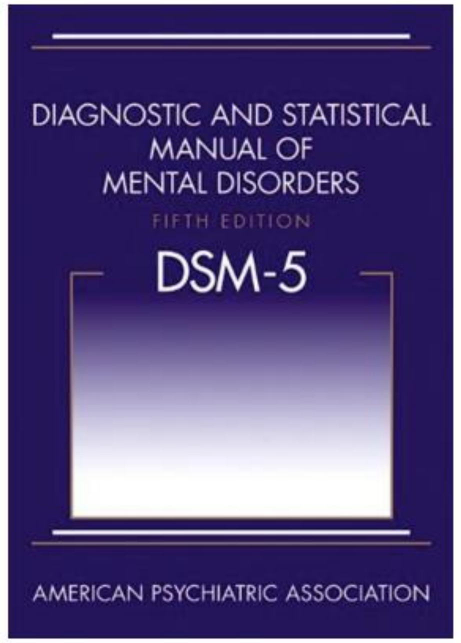
Millions of people in England taking medicines they can find hard to stop

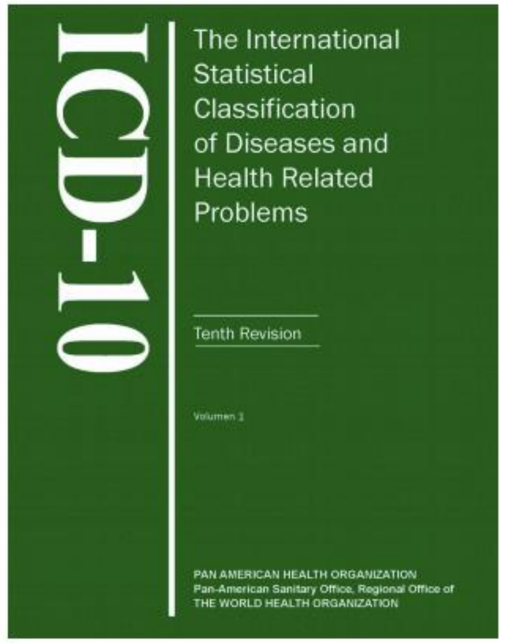
NHS must take action to avoid US-style opioid crisis, says co-author of government study

Poor people are more likely to be at risk of long-term prescription, the research shows. Photograph: Derek Croucher/Alamy

Nearly 12 million people - about one in four adults in England - are taking medicines for pain, depression or insomnia, which they can find hard to stop, according to a government review.

Major Depression Disorder (MDD) - a heterogeneous disorder





- Core symptoms:
  - **Depressed mood**
  - **Anhedonia** (inability to experience pleasure)
  - Loss of energy
  - Change in weight or appetite
  - Insomnia / Hypersomnia
  - Psychomotor agitation / retardation
  - Concentration difficulties
  - Suicidal thoughts / ideation

Major Depressive Disorder

Diagnostic Criteria

A. Five (or more) of the following symptoms have been present during the same 2-week period and represent a change from previous functioning; at least one of the symptoms is either (1) depressed mood or (2) loss of interest or pleasure.

Note: Do not include symptoms that are clearly attributable to another medical condition.

1. Depressed mood most of the day, nearly every day, as indicated by either subjective report (e.g., feels sad, empty, hopeless) or observation made by others (e.g., appears tearful). (**Note:** In children and adolescents, can be irritable mood.)
2. Markedly diminished interest or pleasure in all, or almost all, activities most of the day, nearly every day (as indicated by either subjective account or observation).
3. Significant weight loss when not dieting or weight gain (e.g., a change of more than 5% of body weight in a month), or decrease or increase in appetite nearly every day. (**Note:** In children, consider failure to make expected weight gain.)
4. Insomnia or hypersomnia nearly every day.
5. Psychomotor agitation or retardation nearly every day (observable by others, not merely subjective feelings of restlessness or being slowed down).
6. Fatigue or loss of energy nearly every day.
7. Feelings of worthlessness or excessive or inappropriate guilt (which may be delusional) nearly every day (not merely self-reproach or guilt about being sick).
8. Diminished ability to think or concentrate, or indecisiveness, nearly every day (either by subjective account or as observed by others).
9. Recurrent thoughts of death (not just fear of dying), recurrent suicidal ideation without a specific plan, or a suicide attempt or a specific plan for committing suicide.

Treatments

- Cognitive Behavioural Therapy (CBT)
- Antidepressant medication
  - Selective Serotonin Reuptake Inhibitors (SSRIs)
    - Primary first line treatment
  - Serotonin-Norepinephrine Reuptake Inhibitor (SNRIs)
  - Tricyclic Antidepressants (TCAs)
- Electroconvulsive therapy (ECT), Surgery
  - Very severe, treatment-resistant cases

Theories: Cognitive Theory

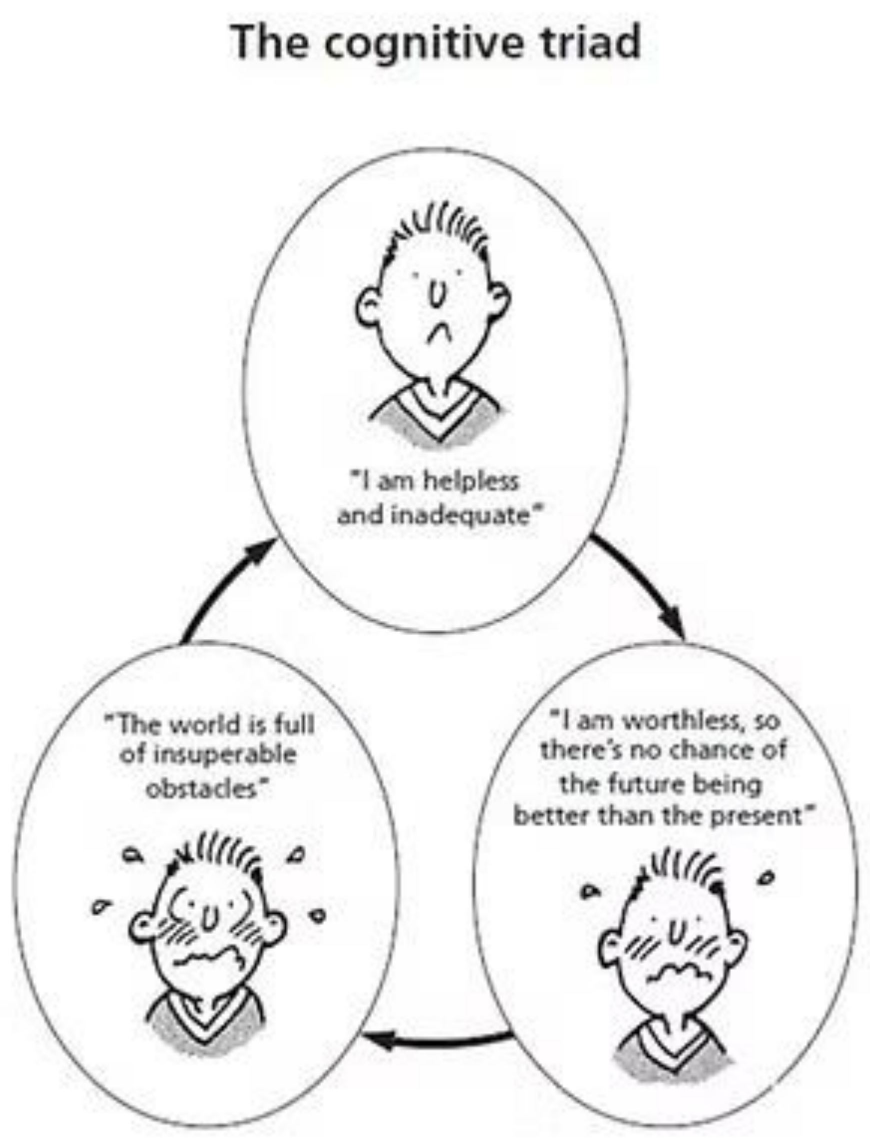
- **Aaron Beck 2008**

Depression results from **negative thinking patterns**, known as the cognitive triad:

1. Negative views of oneself
2. Negative views of the world
3. Negative views of the future

Cognitive distortions, such as overgeneralization and catastrophizing, reinforce depression.

Cognitive Behavioral Therapy (CBT) helps change these thought patterns



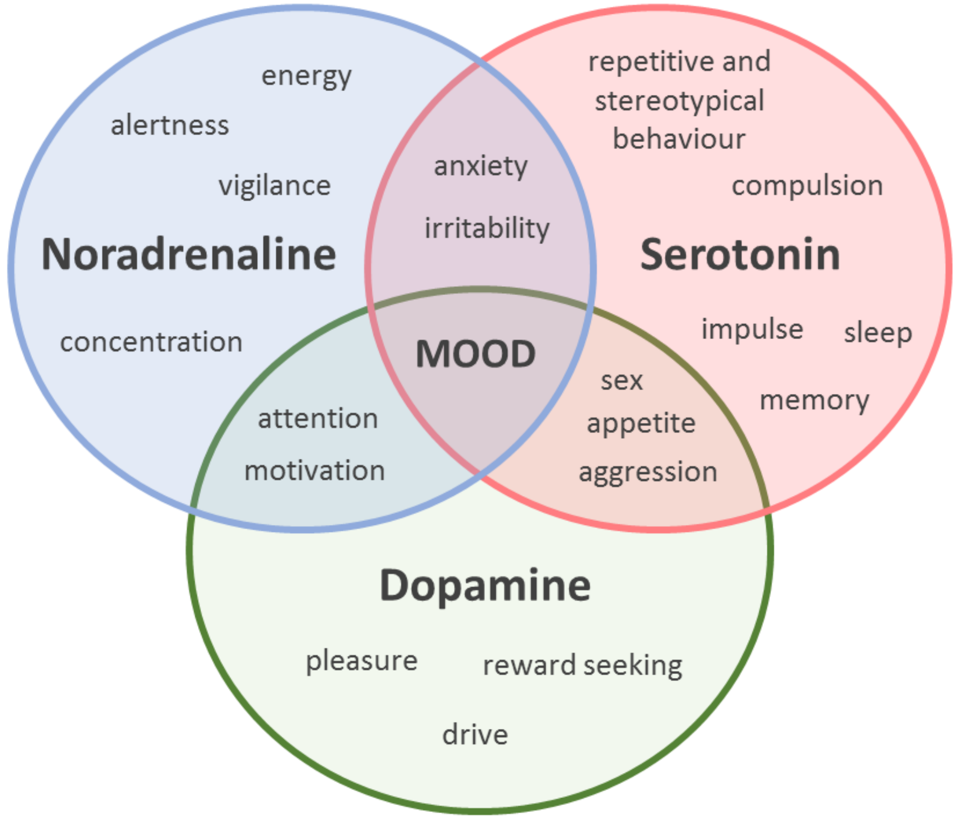
Theories: “Chemical imbalance”

Neurochemical (Monoamine) Theory

- linked to low levels of **serotonin, dopamine, and norepinephrine**—neurotransmitters that regulate mood, motivation, and pleasure.

- Antidepressants like **SSRIs (e.g., Prozac)** work by increasing serotonin levels.

- However, theory is incomplete since antidepressants take weeks to work, suggesting other mechanisms are involved.
- Despite popularity, serotonin theory of depression is highly debated



Theories: the role of stress

Neuroendocrine and stress theories

- Depression associated with **overactivity of the Hypothalamic-Pituitary-Adrenal (HPA) axis, leading to high cortisol levels (stress hormone)**.

- **Chronic stress** may damage brain regions like the hippocampus, impairing memory and emotion regulation.

- Stress could lead to deficit in reinforcement /**reward processing** and anhedonia (Pizzagalli, 2014).

- 70-80% of major depression events preceded by **major life event** (e.g., loss of a loved one, financial problems, trauma).

Anxiety

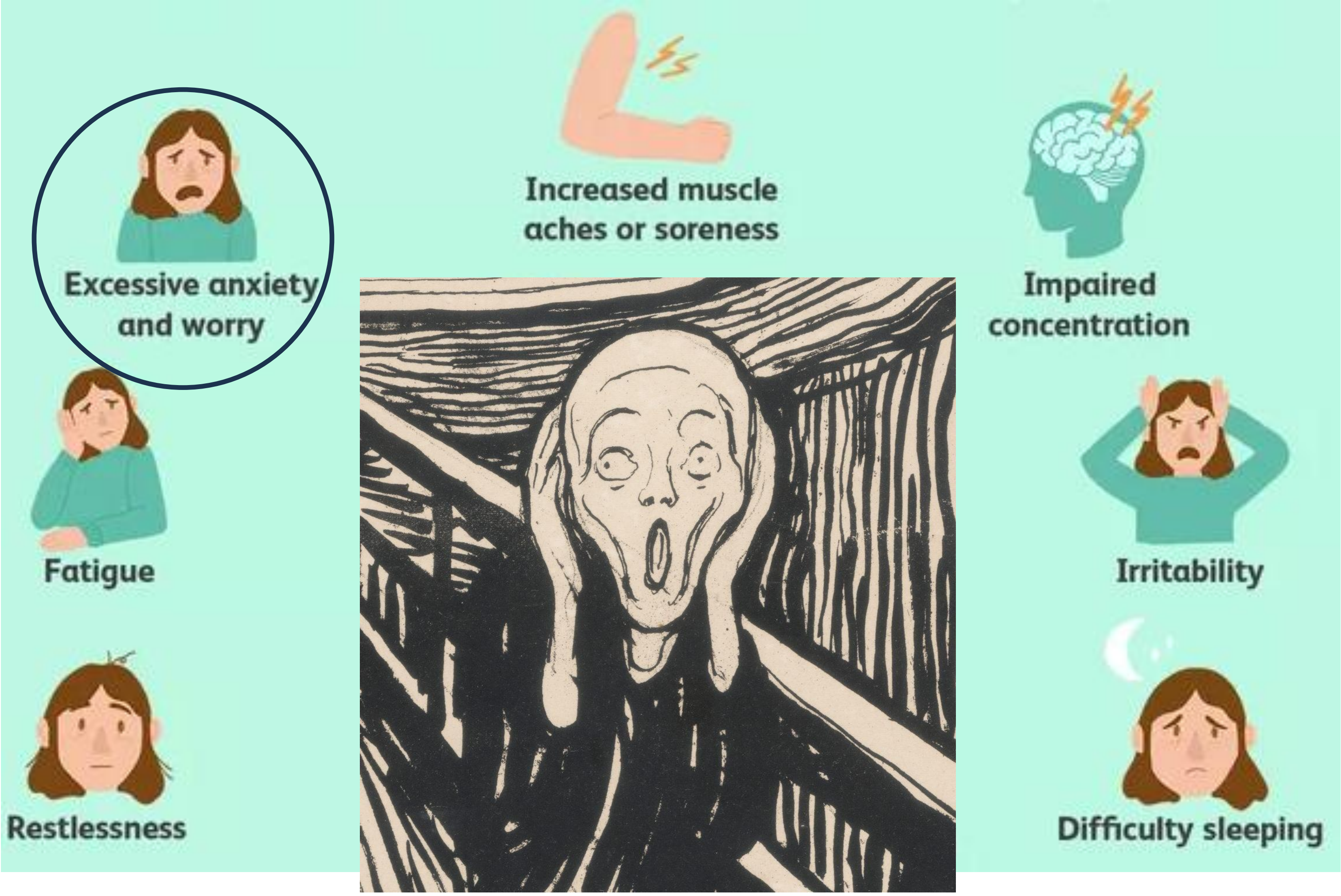
- **Different types**: Generalized anxiety disorder, Panic disorder, social anxiety disorder, specific phobia, agoraphobia, separation anxiety, selective mutism
(OCD and PTSD no longer diagnosed under anxiety disorders).

- In UK, **6%** of people with a diagnosis of Generalised Anxiety

- More common in **young people** and **women**

- Covid made it worse: In 2022/23, in UK, an average of **37.1%** of women and **29.9%** of men reported high anxiety levels, a significant rise from 21.8% and 18.3%, respectively, between 2012 and 2015.

Symptoms of General Anxiety Disorder



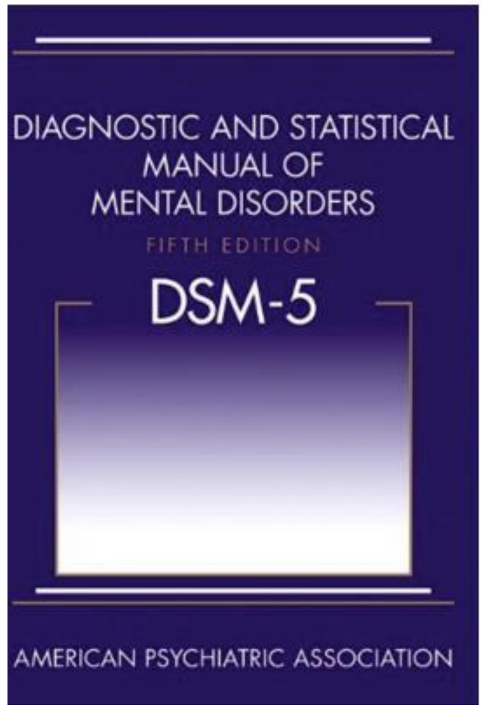


Table 1. Diagnostic Criteria for Generalized Anxiety Disorder

A. Excessive anxiety and worry (apprehensive expectation), occurring more days than not for at least 6 months, about a number of events or activities (such as work or school performance).

B. The individual finds it difficult to control the worry.

C. The anxiety and worry are associated with three (or more) of the following six symptoms (with at least some symptoms having been present for more days than not for the past 6 months):

Note: Only one item is required in children.

1. Restlessness or feeling keyed up or on edge.
2. Being easily fatigued.
3. Difficulty concentrating or mind going blank.
4. Irritability.
5. Muscle tension.
6. Sleep disturbance (difficulty falling or staying asleep, or restless, unsatisfying sleep).

D. The anxiety, worry, or physical symptoms cause clinically significant distress or impairment in social, occupational, or other important areas of functioning.

E. The disturbance is not attributable to the physiological effects of a substance (e.g., a drug of abuse, a medication) or another medical condition (e.g., hyperthyroidism).

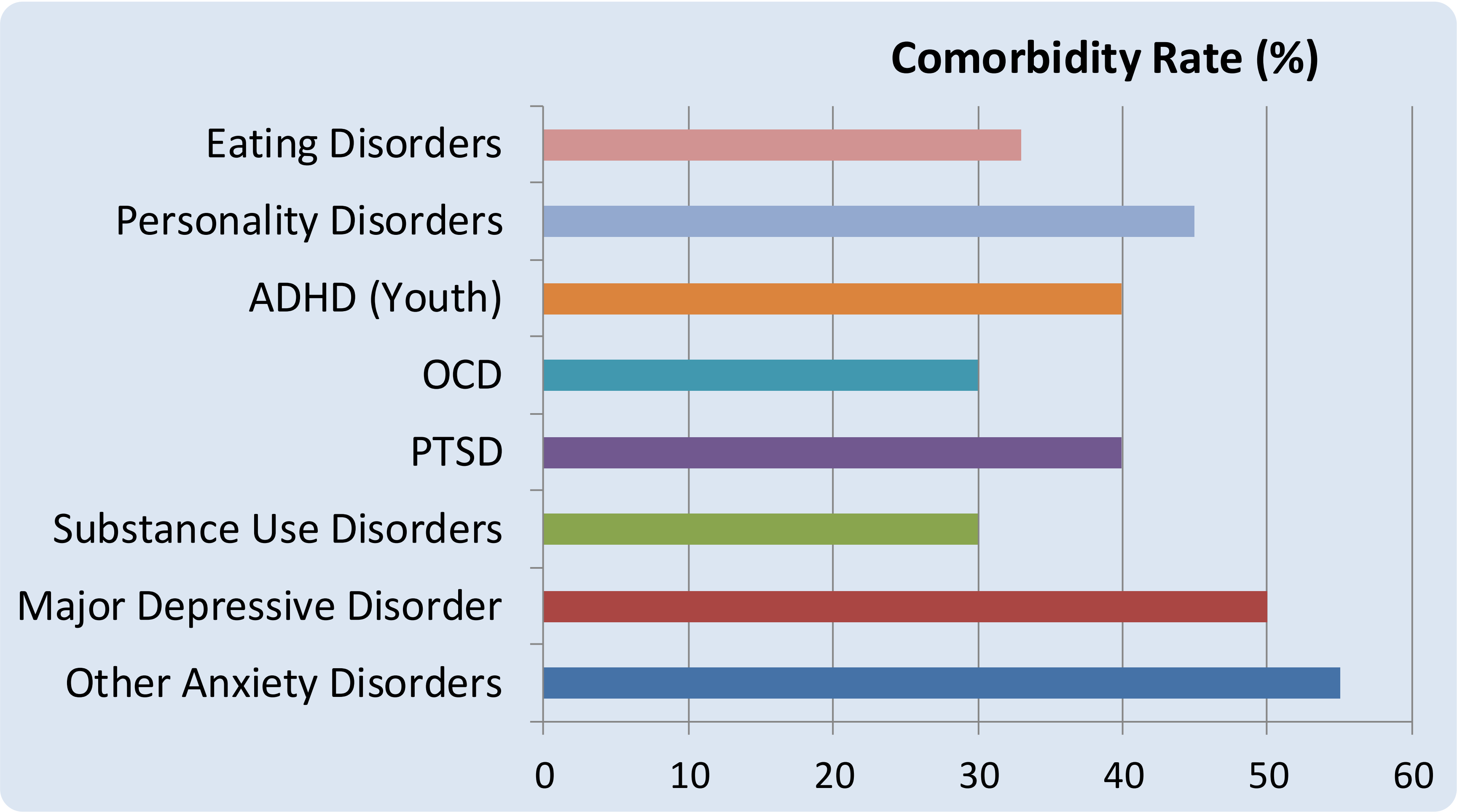
F. The disturbance is not better explained by another mental disorder (e.g., anxiety or worry about having panic attacks in panic disorder, negative evaluation in social anxiety disorder [social phobia], contamination or other obsessions in obsessive-compulsive disorder, separation from attachment figures in separation anxiety disorder, reminders of traumatic events in posttraumatic stress disorder, gaining weight in anorexia nervosa, physical complaints in somatic symptom disorder, perceived appearance flaws in body dysmorphic disorder, having a serious illness in illness anxiety disorder, or the content of delusional beliefs in schizophrenia or delusional disorder).

Anxiety Disorders are highly comorbid with other disorders

- Anxiety and depression are highly **comorbid**: about 50% diagnosed with one will also have the other one.

- Anxiety is also comorbid with most other disorders, e.g. approximately 40% of individuals with ASD are diagnosed with at least one anxiety disorder

Comorbidity of Anxiety Disorders (U.S. Estimates)



Could Depression and Anxiety be explained as disorders of prediction, related to maladaptive RL?

- <u>General ideal:</u> distortions/bias in valuation, learning/prediction, and decision-making under uncertainty

- Could depression be related to an impairment in learning and an underestimation of rewarding/positive outcomes?

  That could potentially explain anhedonia, lack of motivation, negative biases etc..

- Similarly, could anxiety be related to an overestimation/learning of negative outcomes? And underlearning of safety signals (that could perhaps be maintained due to avoidance behaviours)

1. Depression as a disorder of prediction

Is Depression related to an impairment in RL?

- Depressed patients have shown deficits in RL (Chen et al 2015 for a review): important windows on the disease?
- Are impairments related to lower reward sensitivity, greater punishment sensitivity, or an inability to learn from reward (learning rate) or increased learning from punishment?
- All could explain a negative bias towards the processing of punishment
- but different implications for therapies (focus on experience quality of reward/punishment or focus on change in behaviour following reward or punishment)

Is Depression related to an impairment in RL?

- A task that has been extensively used is the Signal detection task (Pizzagalli et al, *Biol Psychiatry*, 2004)

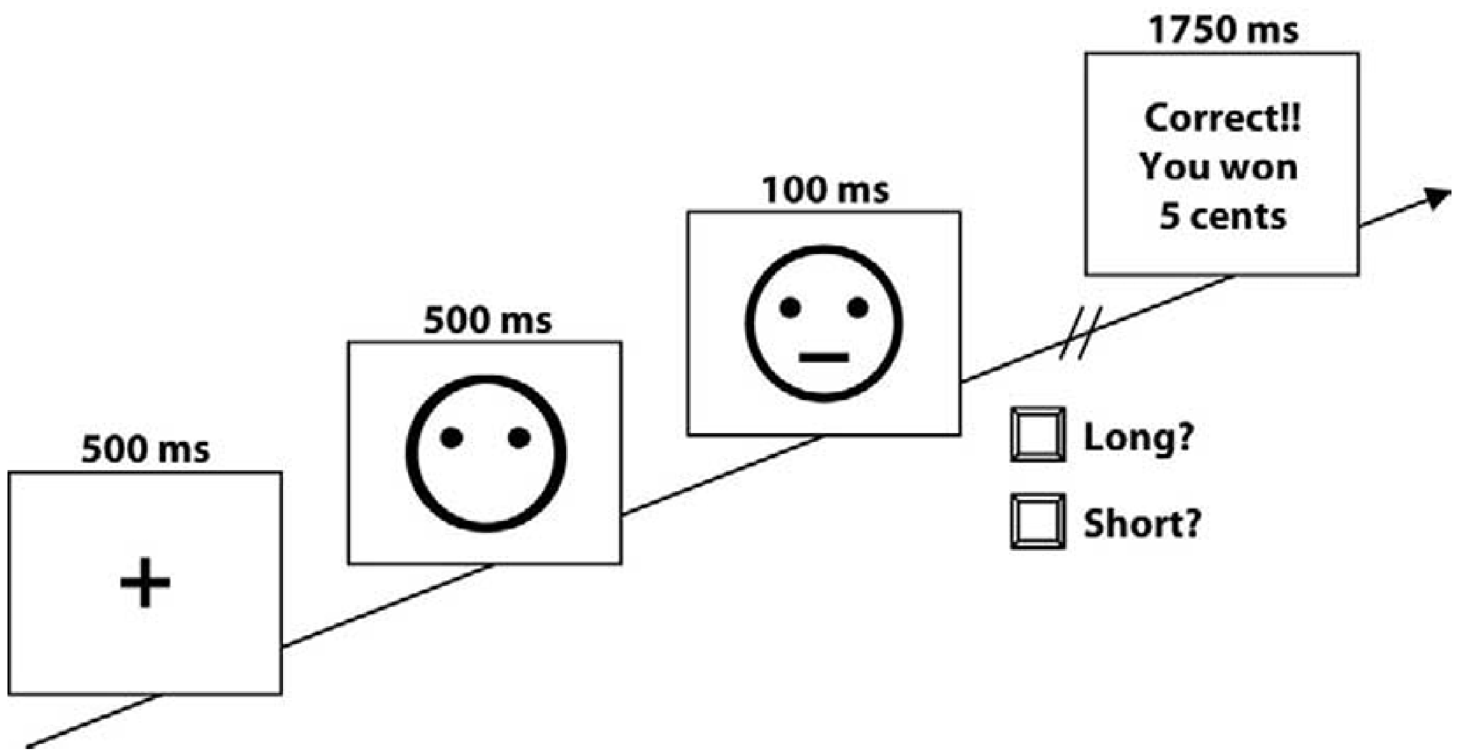
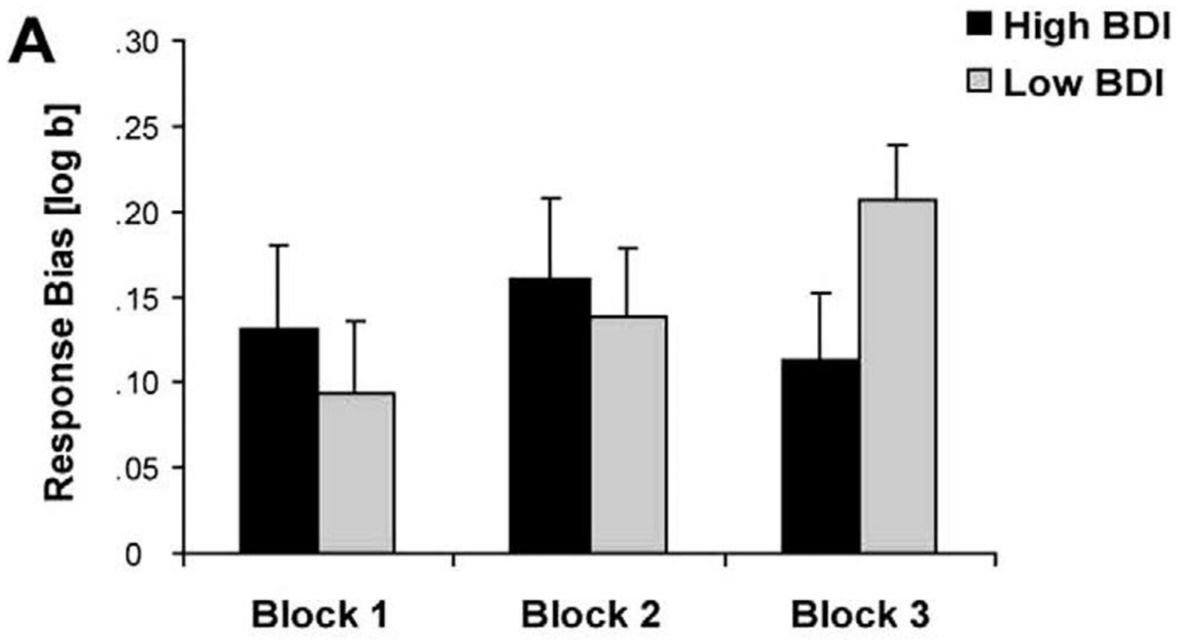


Figure 1. Schematic diagram of the task. After presentation of the mouth stimulus, subjects selected which type of mouth had been presented by pressing either the "z" or the "/" key (counterbalanced across subjects).

- One stimulus rewarded more often
  - (healthy) participants become biased towards it



Is Depression related to an impairment in RL?

- In general, use probabilistic reinforcement learning models such as Rescorla-Wagner to fit the task
- Each option V_a and V_b is associated with reward or not, and is iteratively updated over trials using,

$$V(t+1) = m \times V(t) + \varepsilon \times (\rho \times r(t) - V(t))$$

- Decide between the two options:

$$p(a \mid V, \theta) = \frac{1}{1 + \exp(-\beta \times (V_a - V_b))}$$

If learning from rewards is what is impaired in depression, what differs between controls and patients: **learning rate** (ϵ), **reward sensitivity** (ρ), or **stochasticity** in the response (β), or **memory parameter** (m)?

Different versions of the model can be written, e.g. Huys et al 2013

Choice rule

$$P(a_t = a \mid s_t) = \frac{\exp(W_t(s_t, a))}{\exp(W_t(s_t, a)) + \exp(W_t(s_t, \bar{a}))}$$

Choice weight

$$W_t(s_t, a) = \gamma\, c(s_t, a) + \zeta\, Q_t(s_t, a) + (1 - \zeta)\, Q_t(\bar{s}_t, a)$$

with

$$c(s_t, a) = \begin{cases} 1, & \text{if } a = a^{\backslash *}(s_t) \\ 0, & \text{if } a \neq a^{\backslash *}(s_t) \end{cases}$$

Prediction error

$$\delta_t = \rho\, r_t - Q_t(s_t, a_t)$$

Value update

$$Q_{t+1}(s_t, a_t) = Q_t(s_t, a_t) + \varepsilon\, \delta_t$$

The belief model used by Huys et al uses an extra term and parameter (gamma) to capture how well participants can do the **perceptual discrimination** itself (independently from reward learning).

C is 1 for the correct answer, 0 otherwise.

γ: instruction / perceptual term

ζ: belief (stimulus-certainty) term

ρ: reward sensitivity

ε: learning rate

Huys *et al. Biology of Mood & Anxiety Disorders* 2013, **3**:12
http://www.biolmoodanxietydisord.com/content/3/1/12

Biology of Mood & Anxiety Disorders

RESEARCH **Open Access**

Mapping anhedonia onto reinforcement learning: a behavioural meta-analysis

Quentin JM Huys[1,2,3,4*], Diego A Pizzagalli[5], Ryan Bogdan[6] and Peter Dayan[1]

Abstract

Background: Depression is characterised partly by blunted reactions to reward. However, tasks probing this deficiency have not distinguished insensitivity to reward from insensitivity to the prediction errors for reward that determine learning and are putatively reported by the phasic activity of dopamine neurons. We attempted to disentangle these factors with respect to anhedonia in the context of stress, Major Depressive Disorder (MDD), Bipolar Disorder (BPD) and a dopaminergic challenge.

Methods: Six behavioural datasets involving 392 experimental sessions were subjected to a model-based, Bayesian meta-analysis. Participants across all six studies performed a probabilistic reward task that used an asymmetric reinforcement schedule to assess reward learning. Healthy controls were tested under baseline conditions, stress or after receiving the dopamine D_2 agonist pramipexole. In addition, participants with current or past MDD or BPD were evaluated. Reinforcement learning models isolated the contributions of variation in reward sensitivity and learning rate.

A: the reward sensitivity

The issue is not completely settled: different tasks and conditions have led to different results.

SCIENTIFIC REPORTS

OPEN

Major Depression Impairs the Use of Reward Values for Decision-Making

Samuel Rupprechter[1], Aistis Stankevicius[1], Quentin J. M. Huys[2,3], J. Douglas Steele[4] & Peggy Seriès[1]

Received: 2 November 2017
Accepted: 16 August 2018
Published online: 14 September 2018

Depression is a debilitating condition with a high prevalence. Depressed patients have been shown to be diminished in their ability to integrate their reinforcement history to adjust future behaviour during instrumental reward learning tasks. Here, we tested whether such impairments could also be observed in a Pavlovian conditioning task. We recruited and analysed 32 subjects, 15 with depression and 17 healthy controls, to study behavioural group differences in learning and decision-making. Participants had to estimate the probability of some fractal stimuli to be associated with a binary reward, based on a few passive observations. They then had to make a choice between one of the observed fractals and another target for which the reward probability was explicitly given. Computational modelling was used to succinctly describe participants' behaviour. Patients performed worse than controls at the task. Computational modelling revealed that this was caused by behavioural impairments during both learning and decision phases. Depressed subjects showed lower memory of observed rewards and had an impaired ability to use internal value estimations to guide decision-making in our task.

A: the beta of the softmax and memory parameter
(patients are more random and more forgetful)

With more recent studies focussing on bigger samples and better model comparisons.

Research

JAMA Psychiatry | Original Investigation

Reinforcement Learning in Patients With Mood and Anxiety Disorders vs Control Individuals

A Systematic Review and Meta-analysis

Alexandra C. Pike, DPhil; Oliver J. Robinson, PhD

Supplemental content

IMPORTANCE Computational psychiatry studies have investigated how reinforcement learning may be different in individuals with mood and anxiety disorders compared with control individuals, but results are inconsistent.

OBJECTIVE To assess whether there are consistent differences in reinforcement-learning parameters between patients with depression or anxiety and control individuals.

DATA SOURCES Web of Knowledge, PubMed, Embase, and Google Scholar searches were performed between November 15, 2019, and December 6, 2019, and repeated on December 3, 2020, and February 23, 2021, with keywords (*reinforcement learning*) AND (*computational* OR *model*) AND (*depression* OR *anxiety* OR *mood*).

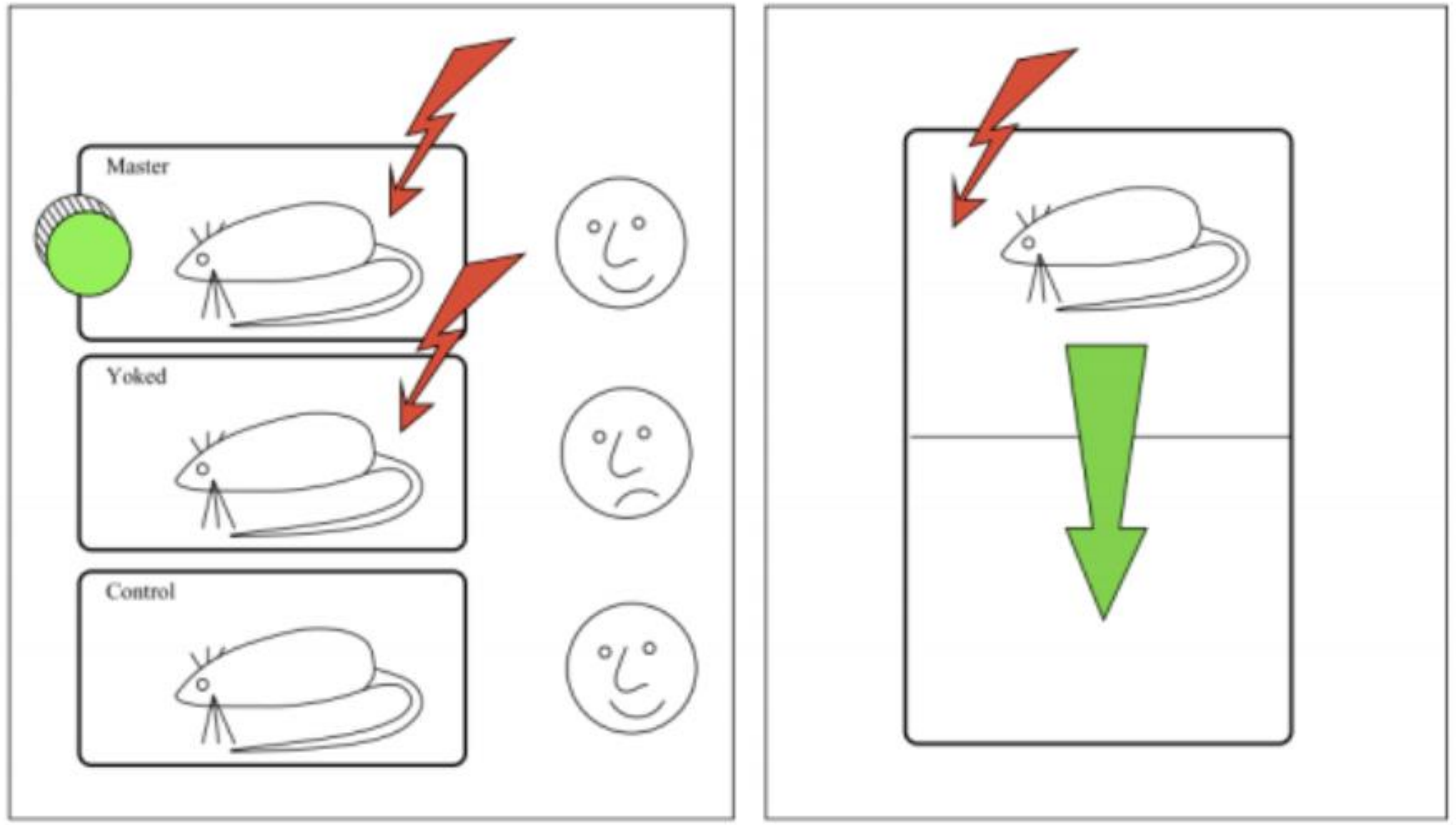
STUDY SELECTION Studies were included if they fit reinforcement-learning models to human choice data from a cognitive task with rewards or punishments, had a case-control design including participants with mood and/or anxiety disorders and healthy control individuals, and included sufficient information about all parameters in the models.

DATA EXTRACTION AND SYNTHESIS Articles were assessed for inclusion according to MOOSE guidelines. Participant-level parameters were extracted from included articles, and a

A: higher sensitivity to punishment, lower sensitivity to reward, the beta of the softmax

Major Depression Disorder (MDD): Learned Helplessness

- Psychological concept developed by Martin Seligman and coll. in 1960s.
- The state in which an individual, after experiencing repeated, negative events, which it is unable to escape from or avoid, stops trying to change their situation—even when opportunities to escape or improve things become available.
- **Animal model of depression**: mirrors loss of motivation, passivity, resignation, feelings of hopelessness, cognitive impairments: emotional distress.



Not (only) about reward/values, but control?

Cognition
Volume 113, Issue 3, December 2009, Pages 314-328

A Bayesian formulation of behavioral control

Quentin J.M. Huys [a] [b], Peter Dayan [a]

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https://doi.org/10.1016/j.cognition.2009.01.008 Get rights and content

Abstract

Helplessness, a belief that the world is not subject to behavioral control, has long been central to our understanding of depression, and has influenced cognitive theories, animal models and behavioral treatments. However, despite its importance, there is no fully accepted definition of helplessness or behavioral control in psychology or psychiatry, and the formal treatments in engineering appear to capture only limited aspects of the intuitive concepts. Here, we formalize controllability in terms of characteristics of prior distributions over affectively charged environments. We explore the relevance of this notion of control to

Neuroscience & Biobehavioral Reviews
Volume 102, July 2019, Pages 371-381

Motivation and cognitive control in depression

Ivan Grahek [a], Amitai Shenhav [b], Sebastian Musslick [c], Ruth M. Krebs [d], Ernst H.W. Koster [a]

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Highlights

- Review of motivational and cognitive impairments in depression.
- Impairments in key components of motivation contribute to cognitive control deficits in depression.
- Proposed framework focuses on the reduced value of control in depression.

"The environment is not controllable, so why bother."

Not (only) about reward/values, but the cost of effort?

Elevated Effort Cost Identified by Computational Modeling as a Distinctive Feature Explaining Multiple Behaviors in Patients With Depression

Fabien Vinckier, Claire Jaffre, Claire Gauthier, Sarah Smajda, Pierre Abdel-Ahad, Raphaël Le Bouc, Jean Daunizeau, Mylène Fefeu, Nicolas Borderies, Marion Plaze, Raphaël Gaillard, and Mathias Pessiglione

ABSTRACT

BACKGROUND: Motivational deficit is a core clinical manifestation of depression and a strong predictor of treatment failure. However, the underlying mechanisms, which cannot be accessed through conventional questionnaire-based scoring, remain largely unknown. According to decision theory, apathy could result either from biased subjective estimates (of action costs or outcomes) or from dysfunctional processes (in making decisions or allocating resources).

METHODS: Here, we combined a series of behavioral tasks with computational modeling to elucidate the motivational deficits of 35 patients with unipolar or bipolar depression under various treatments compared with 35 matched healthy control subjects.

RESULTS: The most striking feature, which was observed independent of medication across preference tasks (likeability ratings and binary decisions), performance tasks (physical and mental effort exertion), and instrumental learning tasks (updating choices to maximize outcomes), was an elevated sensitivity to effort cost. By contrast, sensitivity to action outcomes (reward and punishment) and task-specific processes were relatively spared.

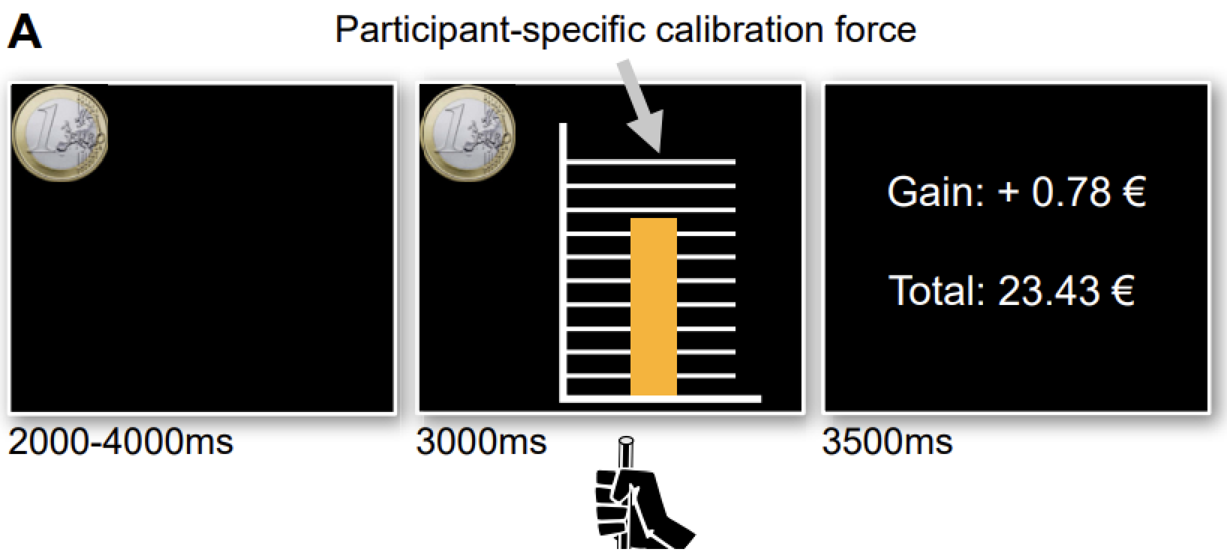
CONCLUSIONS: These results highlight effort cost as a critical dimension that might explain multiple behavioral changes in patients with depression. More generally, they validate a test battery for computational ph motivational states, which could orientate toward specific medication or rehabilitation therapy, and there the way for more personalized medicine in psychiatry.

https://doi.org/10.1016/j.bpsc.2022.07.011

e.g. Participants decide whether to accept or reject an option that combines two dimensions, e.g. **a reward in exchange for effort**, or avoiding punishment at some cost. This is the most direct "cost–benefit" preference task.

$$P(\text{accept}) = \sigma(\beta\,[V_{\text{benefit}} - V_{\text{cost}}] + \text{bias})$$

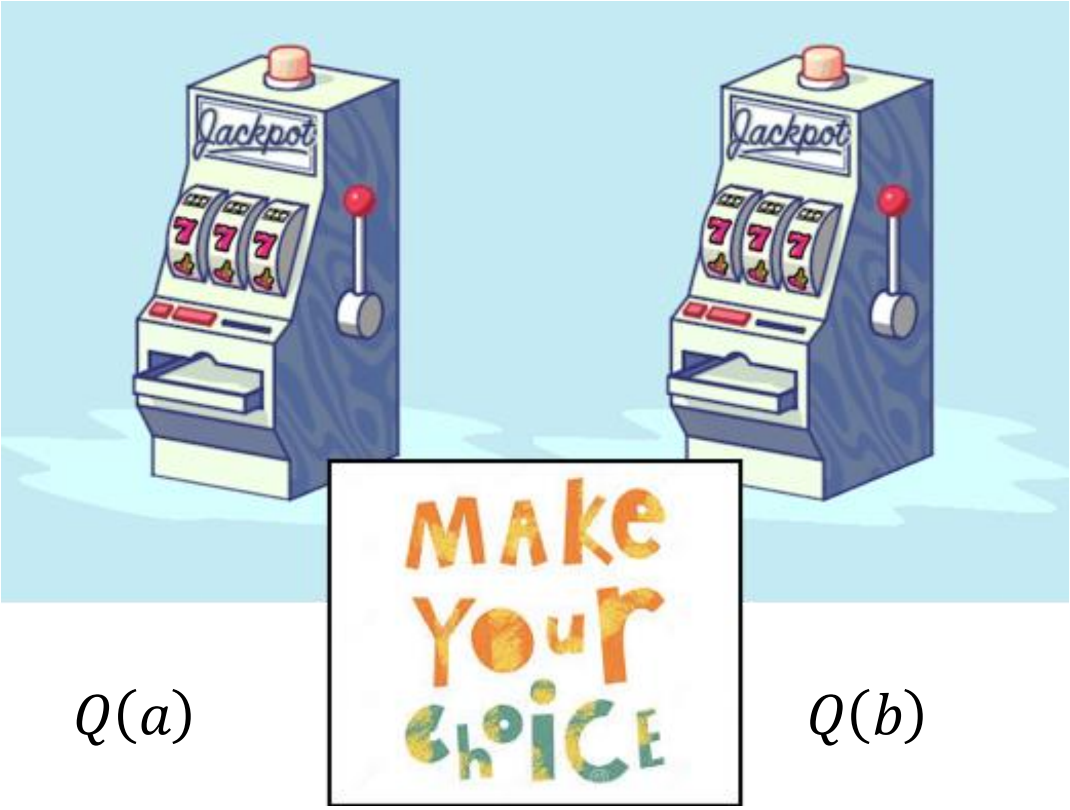
Depressed patients behave as if effort carries a larger subjective penalty



2. Anxiety as a disorder of prediction

1. Is anxiety more about an overestimation of negative outcomes?

As opposed to an undersensitivity/learning to safety/reward signals?



$Q(a)$ $Q(b)$

> Separate the **learning rates for reward and punishment**:

$$Q_{t+1}(a) = \begin{cases} Q_t(a) + \alpha_{\text{rew}}\, \delta_t(a), & \text{if } R_t(a) > 0 \\ Q_t(a) + \alpha_{\text{pun}}\, \delta_t(a), & \text{if } R_t(a) < 0 \end{cases}$$

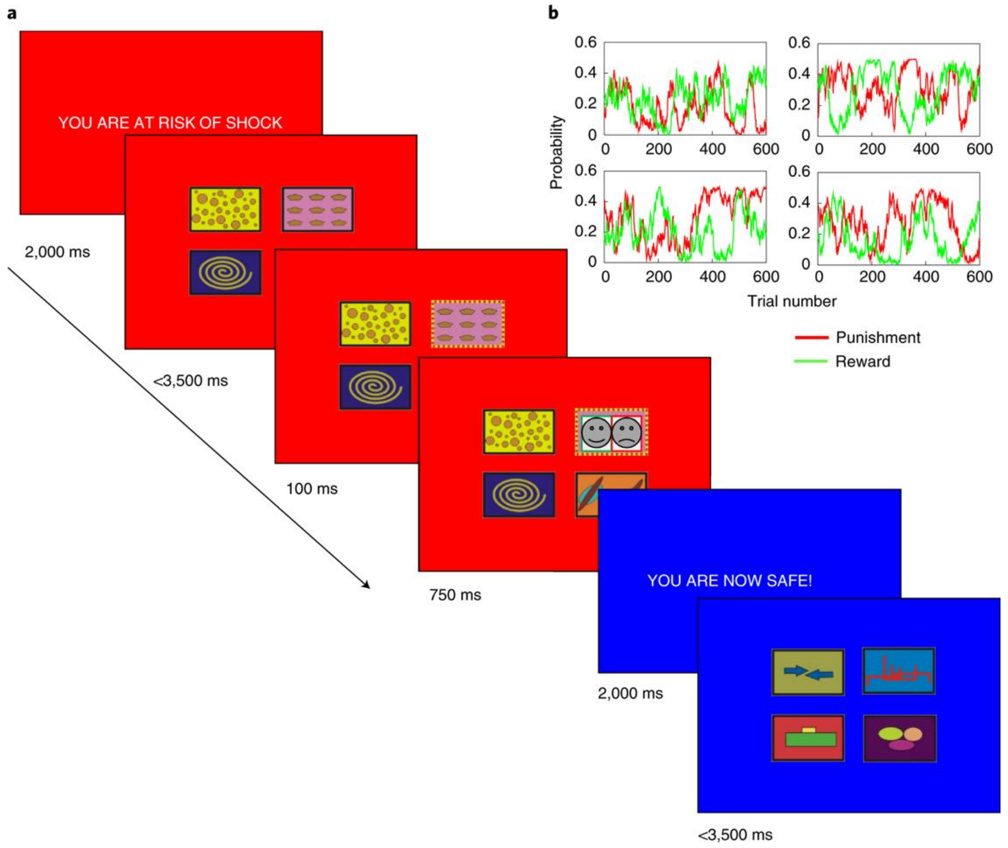
where:

- α_{rew} = reward learning rate
- α_{pun} = punishment learning rate

> And also disentangle learning rates from **sensitivity** to reward and punishment:

$$Q_{t+1}(a) = Q_t(a) + \begin{cases} \alpha_{\text{rew}}\left(s_{\text{rew}} R_t(a) - Q_t(a)\right), & R_t(a) > 0 \\ \alpha_{\text{pun}}\left(s_{\text{pun}} R_t(a) - Q_t(a)\right), & R_t(a) < 0 \end{cases}$$

1. Increased learning from punishment, reduced for reward



Anxious individuals:

- Are <u>not</u> more sensitive to negative outcomes per se but..
- **update quicker from bad outcomes** (**higher learning rates**)
- and sometimes too slowly from good ones,
- leading to **over-pessimistic value estimates**.

ARTICLES
https://doi.org/10.1038/s41562-019-0628-0
nature human behaviour

Altered learning under uncertainty in unmedicated mood and anxiety disorders

2019

Jessica Aylward[1], Vincent Valton[1], Woo-Young Ahn[2], Rebecca L. Bond[1], Peter Dayan[3], Jonathan P. Roiser[1] and Oliver J. Robinson[1,4*]

Anxiety is characterized by altered responses under uncertain conditions, but the precise mechanism by which uncertainty changes the behaviour of anxious individuals is unclear. Here we probe the computational basis of learning under uncertainty in healthy individuals and individuals suffering from a mix of mood and anxiety disorders. Participants were asked to choose between four competing slot machines with fluctuating reward and punishment outcomes during safety and stress. We predicted that anxious individuals under stress would learn faster about punishments and exhibit choices that were more affected by those punishments, thus formalizing our predictions as parameters in reinforcement learning accounts of behaviour. Overall, the data suggest that anxious individuals are quicker to update their behaviour in response to negative outcomes (increased punishment learning rates). When treating anxiety, it may therefore be more fruitful to encourage anxious individuals to integrate information over longer horizons when bad things happen, rather than try to blunt their responses to negative outcomes.

JAMA Psychiatry | Original Investigation

Reinforcement Learning in Patients With Mood and Anxiety Disorders vs Control Individuals
A Systematic Review and Meta-analysis

2022

Alexandra C. Pike, DPhil; Oliver J. Robinson, PhD

RESULTS A total of 27 articles were included (3085 participants, 1242 of whom had depression and/or anxiety). In the conventional meta-analysis, patients showed lower inverse temperature than control individuals (standardized mean difference [SMD], −0.215; 95% CI, −0.354 to −0.077), although no parameters were common across all studies, limiting the ability to infer differences. In the simulation meta-analysis, patients showed greater punishment learning rates (SMD, 0.107; 95% CI, 0.107 to 0.108) and slightly lower reward learning rates (SMD, −0.021; 95% CI, −0.022 to −0.020) relative to control individuals. The simulation meta-analysis showed no meaningful difference in inverse temperature between patients and control individuals (SMD, 0.003; 95% CI, 0.002 to 0.004).

2. Inability to learn from changing environments?

Healthy participants adapt their learning rates to the volatility of the environments:

- 2 choices gambling task with probability of rewards stable or switching every 30 trials (volatile).

- Higher learning rate in more volatile environments.

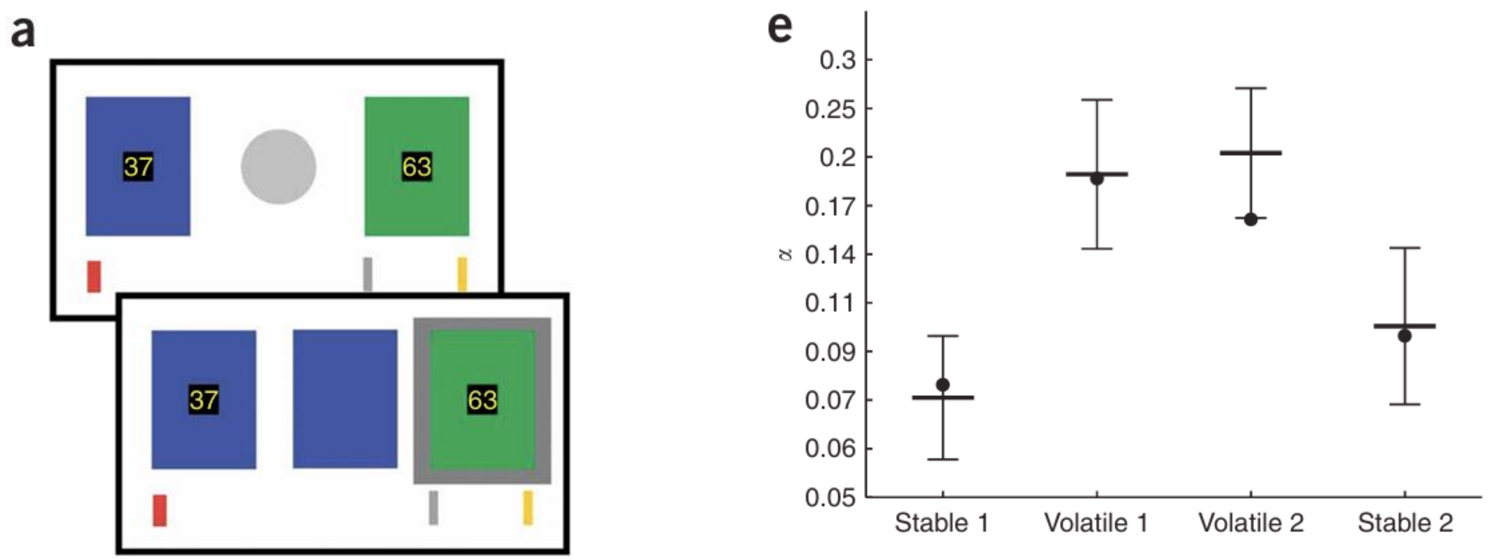
ARTICLES

2007 nature neuroscience

Learning the value of information in an uncertain world

Timothy E J Behrens[1,2], Mark W Woolrich[1], Mark E Walton[2] & Matthew F S Rushworth[1,2]

Our decisions are guided by outcomes that are associated with decisions made in the past. However, the amount of influence each past outcome has on our next decision remains unclear. To ensure optimal decision-making, the weight given to decision outcomes should reflect their salience in predicting future outcomes, and this salience should be modulated by the volatility of the reward environment. We show that human subjects assess volatility in an optimal manner and adjust decision-making accordingly. This optimal estimate of volatility is reflected in the fMRI signal in the anterior cingulate cortex (ACC) when each trial outcome is observed. When a new piece of information is witnessed, activity levels reflect its salience for predicting future outcomes. Furthermore, variations in this ACC signal across the population predict variations in subject learning rates. Our results provide a formal account of how we weigh our different experiences in guiding our future actions.



2. Inability to learn from changing environments?

31 participants screened with S-STAI

RW and Bayesian learner models fit to data using ML.

Anxious individuals:

- High trait anxious individuals showed reduced learning rate adaptation, learning similarly in both stable and volatile conditions

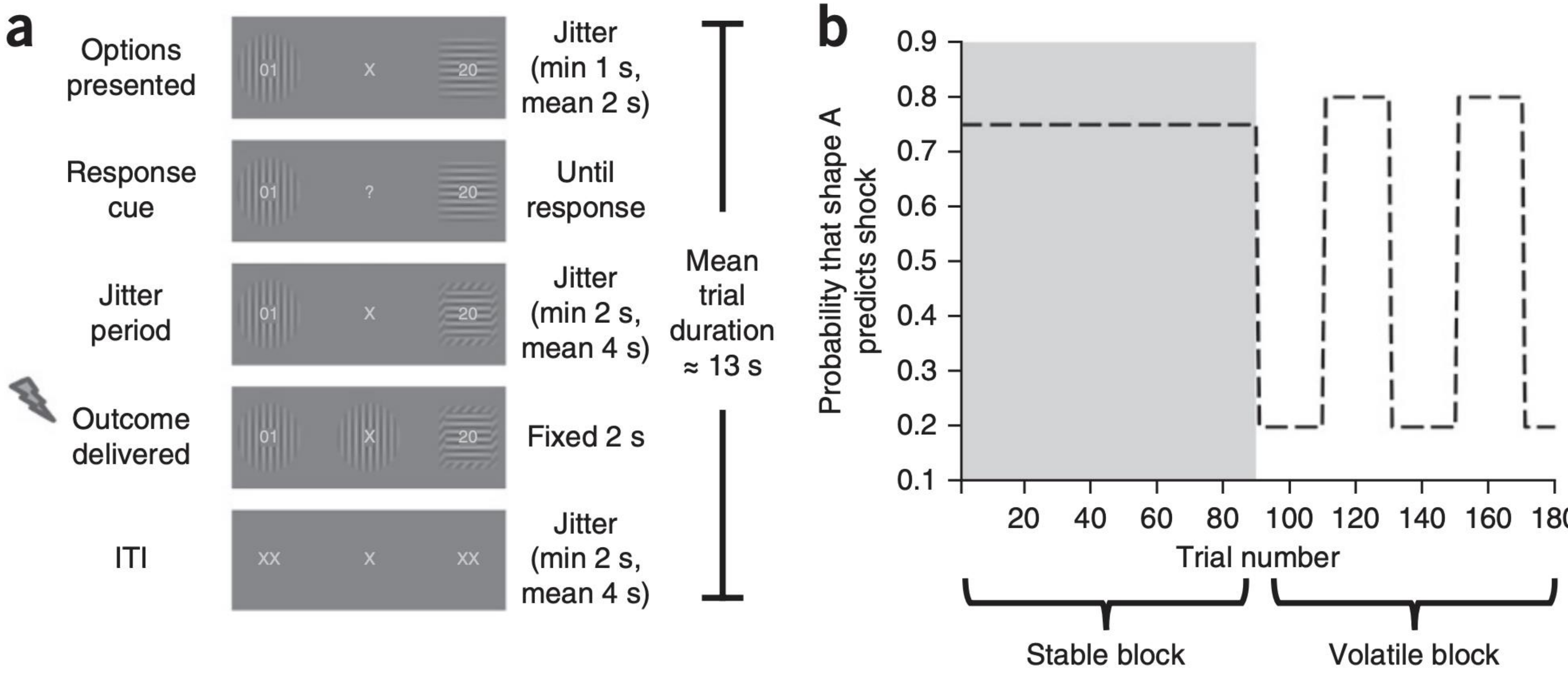
- Other studies support this idea of an overestimation of volatility in anxiety (at least superficially).

Anxious individuals have difficulty learning the causal statistics of aversive environments

2015

Michael Browning[1], Timothy E Behrens[1], Gerhard Jocham[1,2], Jill X O'Reilly[1] & Sonia J Bishop[1,3]

Statistical regularities in the causal structure of the environment enable us to predict the probable outcomes of our actions. Environments differ in the extent to which action-outcome contingencies are stable or volatile. Difficulty in being able to use this information to optimally update outcome predictions might contribute to the decision-making difficulties seen in anxiety. We tested this using an aversive learning task manipulating environmental volatility. Human participants low in trait anxiety matched updating of their outcome predictions to the volatility of the current environment, as predicted by a Bayesian model. Individuals with high trait anxiety showed less ability to adjust updating of outcome expectancies between stable and volatile environments. This was linked to reduced sensitivity of the pupil dilatory response to volatility, potentially indicative of altered norepinephrinergic responsivity to changes in this aspect of environmental information.



2. Inability to learn from changing environments? Specificity?

ARTICLES

nature neuroscience

Adults with autism overestimate the volatility of the sensory environment

2017

Rebecca P Lawson[1–3], Christoph Mathys[1,4–6] & Geraint Rees[1,2]

Insistence on sameness and intolerance of change are among the diagnostic criteria for autism spectrum disorder (ASD), but little research has addressed how people with ASD represent and respond to environmental change. Here, behavioral and pupillometric measurements indicated that adults with ASD are less surprised than neurotypical adults when their expectations are violated, and decreased surprise is predictive of greater symptom severity. A hierarchical Bayesian model of learning suggested that in ASD, a tendency to overlearn about volatility in the face of environmental change drives a corresponding reduction in learning about probabilistically aberrant events, thus putatively rendering these events less surprising. Participant-specific modeled estimates of surprise about environmenta
noradrenergic responsivity in line with co
and physiological mechanisms underlyin

computational psychiatry

Altered Perception of Environmental Volatility During Social Learning in Emerging Psychosis

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RESEARCH ARTICLE

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ABSTRACT

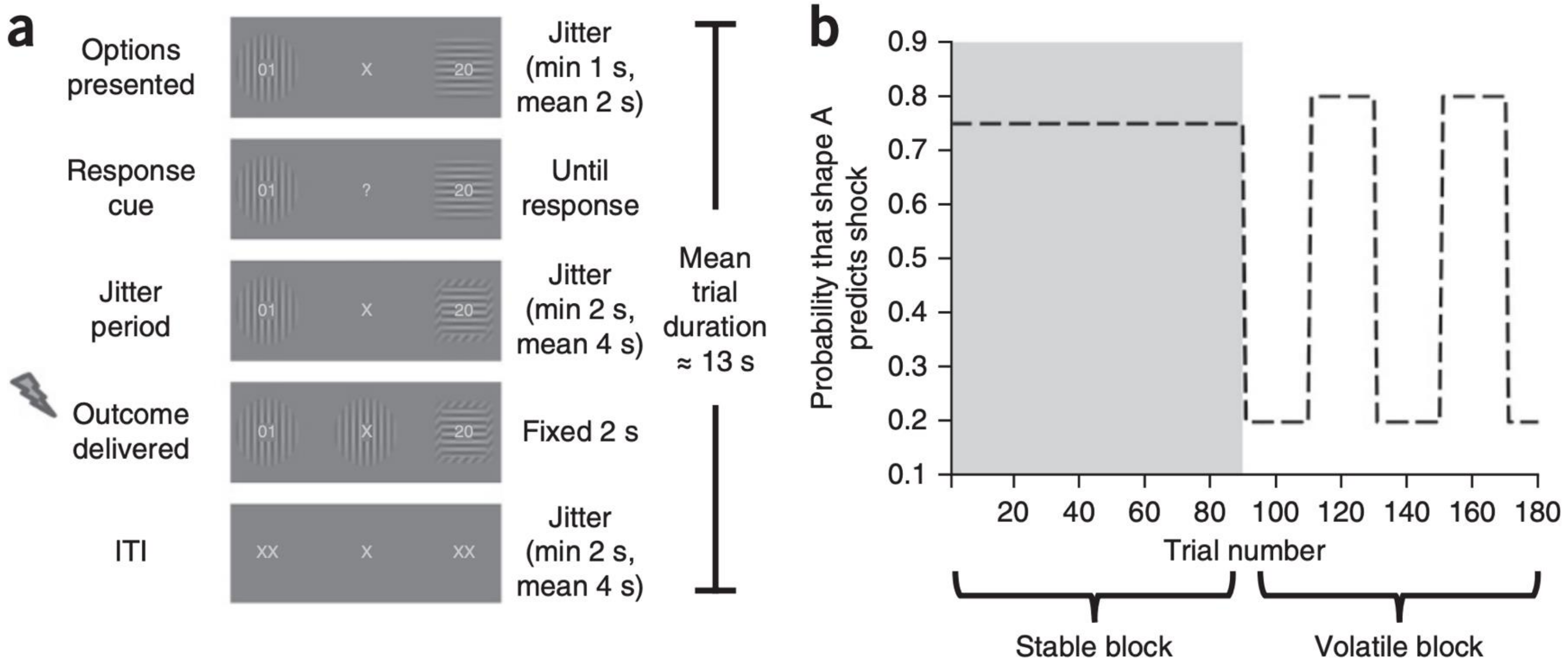
Paranoid delusions or unfounded beliefs that others intend to deliberately cause harm are a frequent and burdensome symptom in early psychosis, but their emergence and consolidation still remains opaque. Recent theories suggest that overly precise prediction errors lead to an unstable model of the world providing a breeding ground for delusions. Here, we employ a Bayesian approach to test for such an unstable model of the world and

Anxious individuals have difficulty learning the causal statistics of aversive environments

2015

Michael Browning[1], Timothy E Behrens[1], Gerhard Jocham[1,2], Jill X O'Reilly[1] & Sonia J Bishop[1,3]

Statistical regularities in the causal structure of the environment enable us to predict the probable outcomes of our actions. Environments differ in the extent to which action-outcome contingencies are stable or volatile. Difficulty in being able to use this information to optimally update outcome predictions might contribute to the decision-making difficulties seen in anxiety. We tested this using an aversive learning task manipulating environmental volatility. Human participants low in trait anxiety matched updating of their outcome predictions to the volatility of the current environment, as predicted by a Bayesian model. Individuals with high trait anxiety showed less ability to adjust updating of outcome expectancies between stable and volatile environments. This was linked to reduced sensitivity of the pupil dilatory response to volatility, potentially indicative of altered norepinephrinergic responsivity to changes in this aspect of environmental information.



Conclusions (1- Depression)

• **Promising theories:** Depression has been consistently linked to altered reward processing.

• in many studies, especially around anhedonia, blunted reward sensitivity

• This could potentially explain anhedonia, lack of motivation, negative biases etc..

• But **heterogeneity of results and methods** findings vary across tasks, with some studies emphasizing reward blunting, others negative bias, punishment learning, or increased choice noise.

• Current challenge: task behavior often reflects more than RL alone (e.g. perception and decision dynamics), and parameter meanings are often task-dependent, which limits biomarker use right now.

Conclusions (2- Anxiety)

• **Promising theories:** Believing the world is more unstable that it really is and overlearning from negative outcomes leads to overestimation of threat & risk/loss aversion.

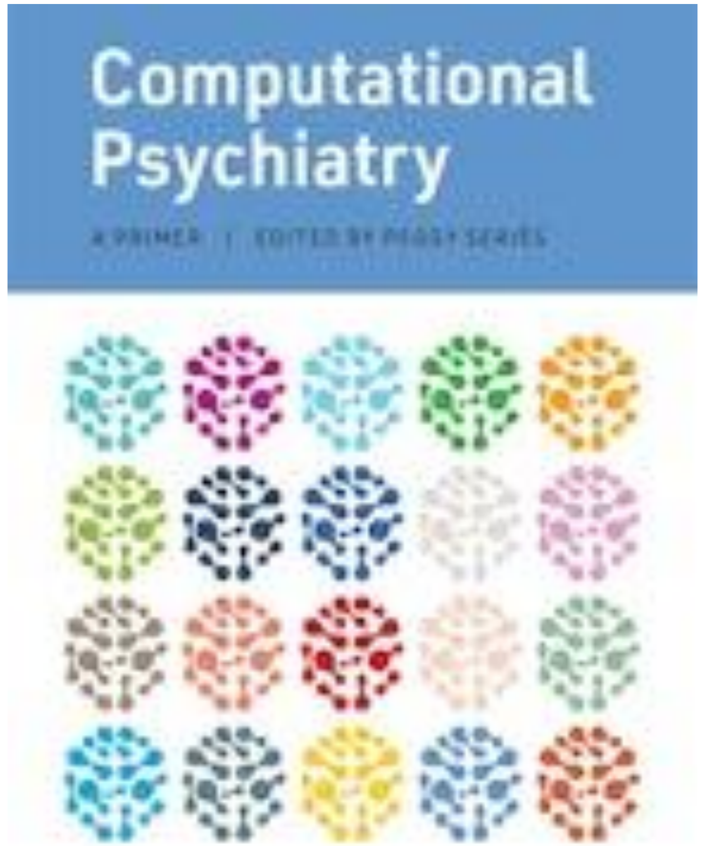
-- Naturally relate with symptoms such as worry, hypervigilance, avoidance, catastrophizing, and intolerance of uncertainty

But **heterogeneity** of results and methods

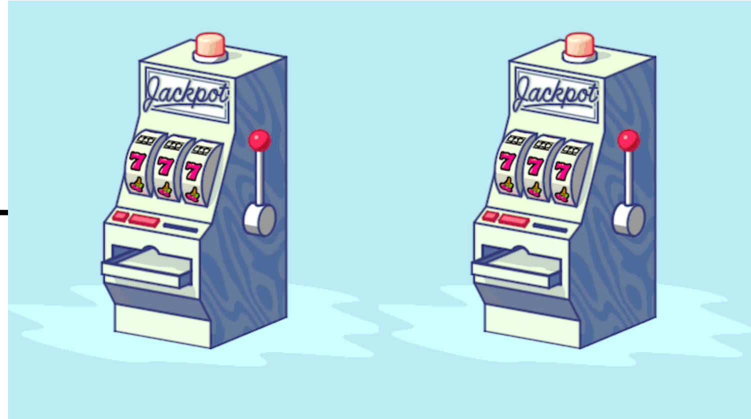
- Experimental designs, types of ”punishments"
- Choice of models that are fit to data
- Experimental groups – general population or patients group
- How anxiety is measured (DSM, GAD, STAI (T or S?), task-related anxiety?)
- Parameters showing differences (learning rates, sensitivity, learning rate adaptation).

Recommended Readings

- Chapters 7 and 8, about depression and anxiety



Example code in Python



Example: define a model

- Assume participants keep track of value of each stimulus, update values via prediction errors
    - Note that here we include a reward sensitivity parameter (rho)

$$V_{t+1}^{(s)} = V_t^{(s)} + \varepsilon(\rho \times r_t - V_t^{(s)})$$

$$p(a = A|V^{(A)}, V^{(B)}) = \frac{1}{1 + \exp(-(V^{(A)} - V^{(B)}))}$$

Simulate the model

```
def model_simulate(theta):
    eps, rho = theta[0], theta[1]
    V = np.array([0.0, 0.0])  # Initialize values for two choices
    data = {"choices": [], "rewards": []}

    for t in range(100):
        p_choose_B = 1 / (1 + np.exp(-(V[1] - V[0])))  # Softmax-like probability
        c = 1 + (p_choose_B > np.random.rand())  # Choose 1 or 2

        if c == 1:
            r = 0.8 > np.random.rand()  # Reward probability for choice 1
        else:
            r = 0.2 > np.random.rand()  # Reward probability for choice 2

        V[c - 1] = V[c - 1] + eps * (rho * r - V[c - 1])  # Update value

        data["choices"].append(c)
        data["rewards"].append(r)

    return data
```

% simulate data for parameters theta

% Values initialised at 0

% for all trials

% compute prob choice given values

% draw a choice

% if choice 1 draw reward with prob 80%

% if choice 2 draw reward with prob 20%

% update values based on reward

% record choices and reward