

Computations in Psychotherapy

COMPUTATIONAL PSYCHIATRY COURSE ZURICH 2019



m.moutoussis@ucl.ac.uk

Clinical Lecturer, Dolan Lab,

Max Plank – UCL Centre for Computational Psychiatry,

&

Honorary Consultant in Medical Psychotherapy, Neuropsychiatry department,

National Hospital for Neurology and Neurosurgery, UCLH

wellcome trust

translational
neuroscience

psychotherapy



Overview

- Introducing psychological therapy (Psychotherapy for short)
- What psychotherapy needs from Computational Psychiatry
- The paradigmatic case of Cognitive-Behavioural Therapy
- The psychodynamic viewpoint
- Empowering patients - already!
- Conclusion :

psychotherapy



translational
neuroscience

Psychotherapy and what it needs

suffering due to unwarranted inferences
psychiatric disorder

suffering due to unwarranted inferences
psychiatric disorder

precise mechanisms behind inferences
computational psychiatry

suffering due to unwarranted inferences
psychiatric disorder

precise mechanisms behind inferences
computational psychiatry

learning new, benign, personalized inferences
psychotherapy

Psychological therapy (psychotherapy for short)



- 'Psychotherapy' involves:
 - **Long-lasting effect on mental health, i.e. LEARNING**
 - Theoretical frameworks (Cognitive-behavioural, psychodynamic ...) overlap a lot →
 - **the examples we'll use generalize.**

Key gaps that need addressing

- Therapy theories (e.g. CBT, modern psychodynamic) postulate many **untested, likely unimportant or false, mechanisms** to account for inferential biases
- Postulated inferential biases **inaccessible to technological tests**
- Poor biological grounding - 'Do I have a disease or is it all in my mind?'

Computational psychiatry can help rigorously address these.

Com Psy super-mini recap

Computations in the mind

'Computational' :

- ◆ Formal account of how information is incorporated into feelings, beliefs and, in the end, behaviours (Nothing to do with computers).
- ◆ Maximal use of Machine Learning ideas (Everything to do with computers - we won't touch on this).

Computations in the mind

'Computational' :

- ◆ Formal account of how information is incorporated into feelings, beliefs and, in the end, behaviours (Nothing to do with computers).
- ◆ Maximal use of Machine Learning ideas (Everything to do with computers - we won't touch on this).

Forming beliefs and values:

★ Inference (Bayes' rule):

Existing belief + evidence → new belief

'Belief' here may be evaluative – but is a very precise concept

Computations in the mind

'Computational' :

- ◆ Formal account of how information is incorporated into feelings, beliefs and, in the end, behaviours (Nothing to do with computers).
- ◆ Maximal use of Machine Learning ideas (Everything to do with computers - we won't touch on this).

Forming beliefs and values:

- ★ Inference (Bayes' rule):

Existing belief + evidence → new belief

'Belief' here may be evaluative – but is a very precise concept

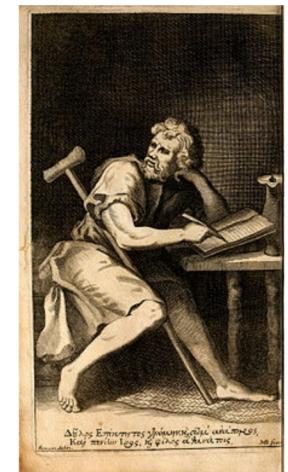
- ★ Prediction error learning:

**Expected evaluation + un/pleasant surprise →
worse/better new expectation**

The Cognitive-Behavioural lens

Nutshell CBT

*"the notions people have about
events, not the events
themselves, is what causes
distress"*



Epictetus, c. 100 CE

Nutshell CBT

Dysfunctional
assumptions
(models)

Triggering
Stimuli

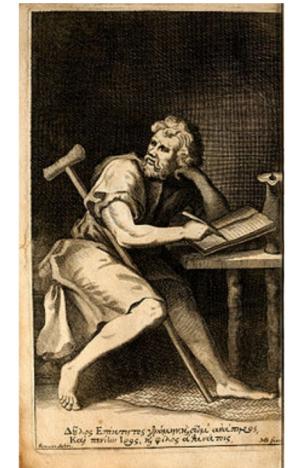
What does it
mean?
(inference)

distress
(symptoms)

*"the notions people have about
events, not the events
themselves, is what causes*

distress"

Epictetus, c. 100 CE



i. Dysfunctional cognitive style

↓
ii. Trigger event(s)

↓
iii. Interpretation: what does it mean?

↓
iv. Worse mood: sad, anxious etc.

↓
v. Activation of cognitive biases

↓
vi. Maladaptive beliefs

↓
vi. Maladaptive Behaviour
Avoidance: withdrawal, putting things off ...

↓
vii. Fewer positive experiences
& confirmation of negative beliefs

↓
viii. negative thoughts (now habitual)



CBT

i. Dysfunctional cognitive style

↓
ii. Trigger event(s)

↓
iii. Interpretation: what does it mean?

↓
iv. Worse mood: sad, anxious etc.

Social Phobia:
Core fear of negative evaluation by others

↓
v. Activation of cognitive biases

↓
vi. Maladaptive beliefs

↓
vi. Maladaptive Behaviour
Avoidance: withdrawal, putting things off ...

↓
vii. Fewer positive experiences
& confirmation of negative beliefs

↓
viii. negative thoughts (now habitual)

i. Dysfunctional cognitive style

↓
ii. Trigger event(s)

↓
iii. Interpretation: what does it mean?

↓
iv. Worse mood: sad, anxious etc.

↓

v. Activation of cognitive biases

vi. Maladaptive beliefs

↓
vi. Maladaptive Behaviour

Avoidance: withdrawal, putting things off ...

↓
vii. Fewer positive experiences
& confirmation of negative beliefs

↓
viii. negative thoughts (now habitual)

Experimental task

Evaluation of the self
by an Other



Expectations about future Evaluation



i. Dysfunctional cognitive style**ii. Trigger event(s)****iii. Interpretation: what does it mean?****iv. Worse mood: sad, anxious etc.****v. Activation of cognitive biases****vi. Maladaptive beliefs****vi. Maladaptive Behaviour**

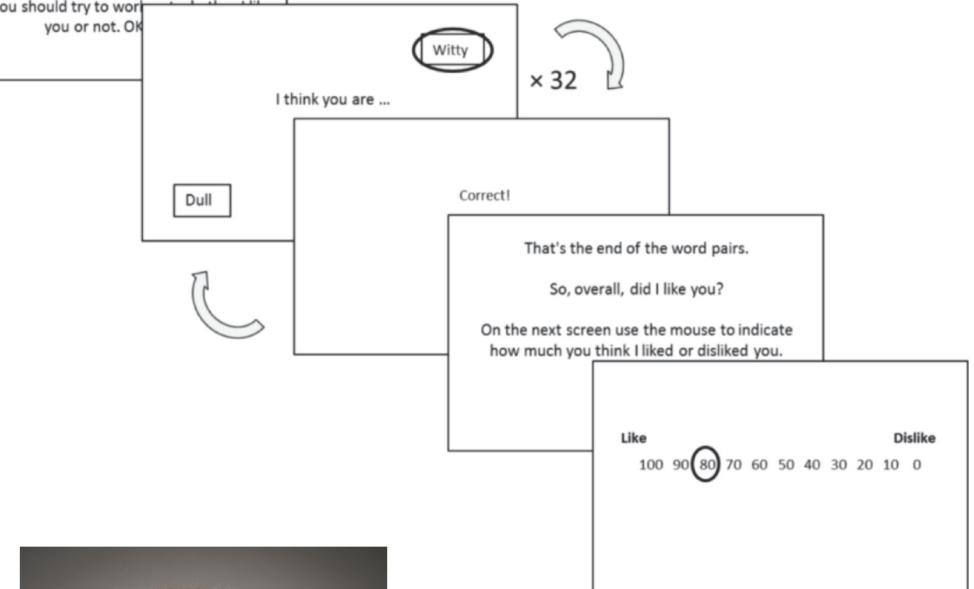
Avoidance: withdrawal, putting things off ...

**vii. Fewer positive experiences
& confirmation of negative beliefs****viii. negative thoughts (now habitual)**

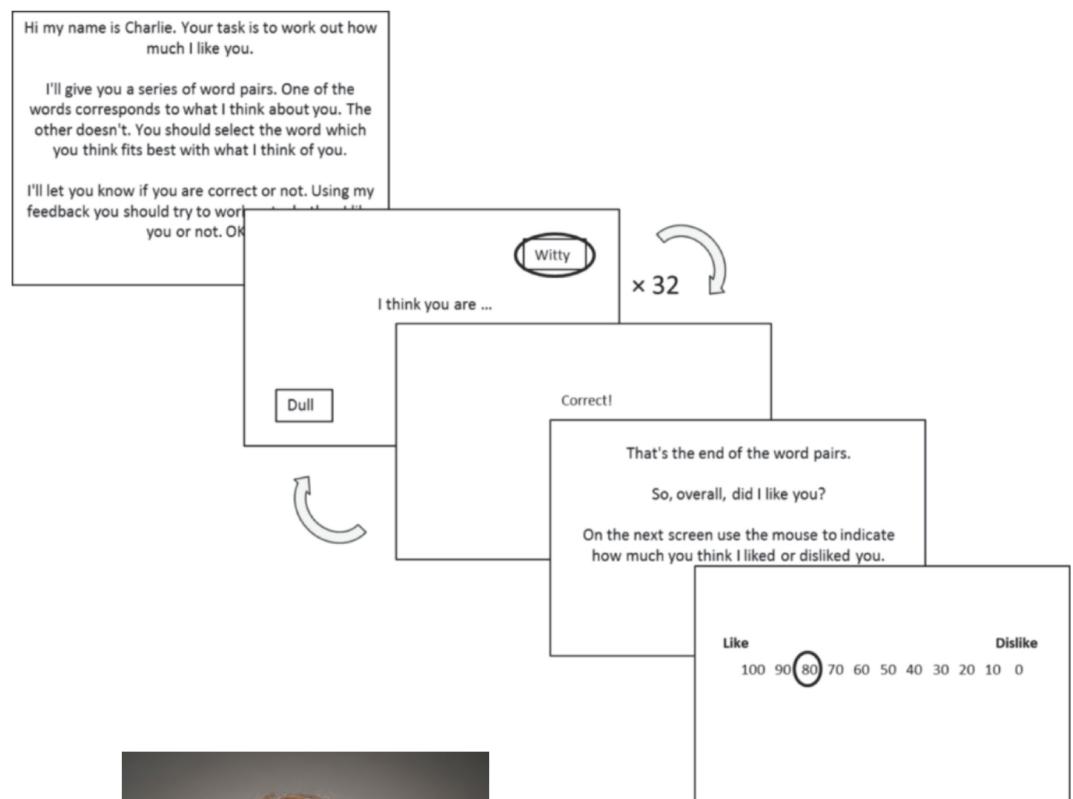
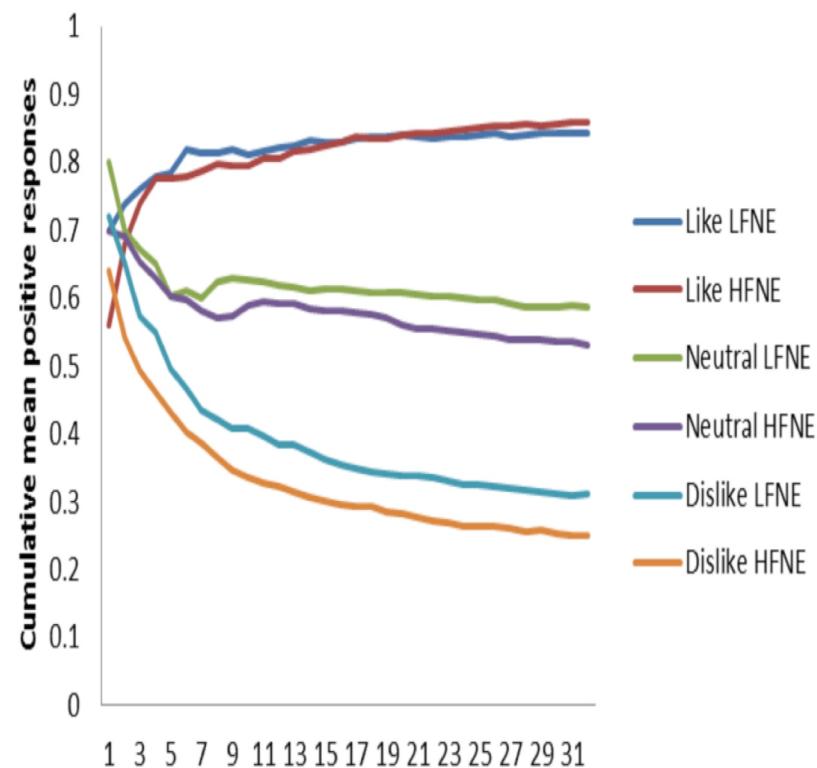
Hi my name is Charlie. Your task is to work out how much I like you.

I'll give you a series of word pairs. One of the words corresponds to what I think about you. The other doesn't. You should select the word which you think fits best with what I think of you.

I'll let you know if you are correct or not. Using my feedback you should try to work out who I am.
you or not. Ok



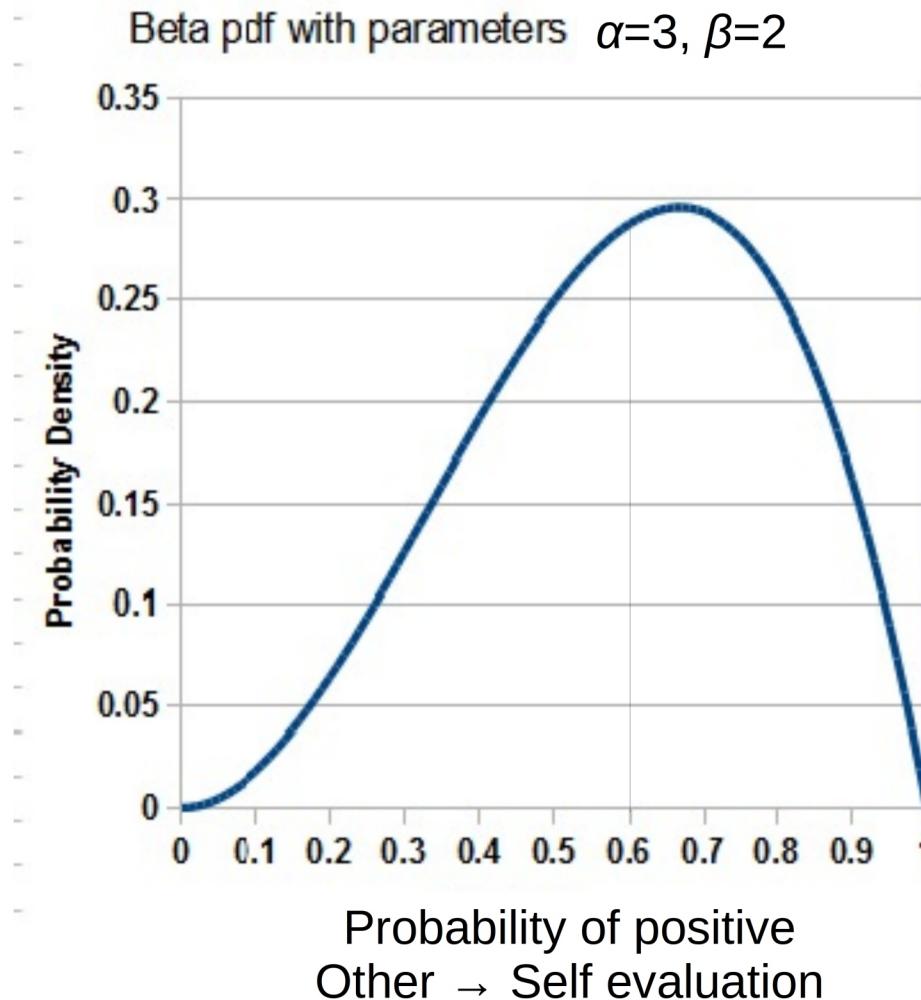
Self-referential



Activation of negative cognitive bias about the self

The belief about how the Self will be evaluated by the Other is represented by a beta distribution, defined by positive evidence about the self α , and negative evidence, β , so that the expected evaluation is $\alpha/(\alpha+\beta)$

Example:



Activation of negative cognitive bias about the self

The belief about how the Self will be evaluated by the Other is represented by a beta distribution, defined by positive evidence about the self α , and negative evidence, β , so that the expected evaluation is $\alpha/(\alpha+\beta)$

Upon entering a context where the self is evaluated, beliefs about the self, a self-schema, is activated:

This consists both of a trait-like representation of the self, which is resistant to updating, and a state-like expectation, which will be updated by evidence:

$$\alpha_{t=0} = \alpha_{trait} + \alpha_{state,t=0} = \alpha_{trait} + \alpha_{initial}$$

Similarly for β . The 'initial' and 'trait' values are free parameters of the model.

Activation of negative cognitive bias about the self

The belief about how the Self will be evaluated by the Other is represented by a beta distribution, defined by positive evidence about the self α , and negative evidence, β , so that the expected evaluation is $\alpha/(\alpha+\beta)$

Upon entering a context where the self is evaluated, beliefs about the self, a self-schema, is activated:

This consists both of a trait-like representation of the self, which is resistant to updating, and a state-like expectation, which will be updated by evidence:

$$\alpha_{t=0} = \alpha_{trait} + \alpha_{state,t=0} = \alpha_{trait} + \alpha_{initial}$$

Similarly for β . The 'initial' and 'trait' values are free parameters of the model.

Update proceeds via lossy evidence accumulation:

$$\alpha_{state,t+1} = (1 - \eta)\alpha_{state,t} + \eta + o_t$$



Activation of negative cognitive bias about the self

Key results:

- Overall, people activate positive trait-like schemas about the self
→ optimistic biases.
- Higher fear of negative evaluation is associated with a lower amount of trait-like positive evidence about the self, α_{trait} , in the activated schema.
- Lower proportion of such positive evidence + lower overall amount of trait-like evidence about the self ↔ faster learning from negative evaluations.



Activation of negative cognitive bias about the self

Importance:

- Directly links to CBT account
- Computational evidence for activated-schema account of CBT
- Pin-pointing how exactly optimistic bias is reduced in high FNE
- Psycho-education friendly
- Substantiates possible target for therapeutic CBT intervention
(specifically activate positive self-evidence upon exposure to negative feedback)



Formulation

CBT

Computational

Hypotheses and
testable predictions

**This approach can be applied to many, many aspects
of the Cognitive-Behavioural formulation!**

Formulation

CBT

i. **Dysfunctional cognitive style**
e.g. "Harmful causes of important setbacks will affect all areas of my life"

↓
ii. Trigger event(s)

↓

iii. Interpretation: what does it mean?

↓

iv. Worse mood: sad, anxious etc.

↓

v. Activation of cognitive biases

↓

vi. Maladaptive beliefs

↓

vi. Maladaptive Behaviour

Avoidance: withdrawal, putting things off ...

↓

vii. Fewer positive experiences & confirmation of negative beliefs

↓

viii. negative thoughts (now habitual)

Computational

i. Dysfunctional styles

- Do dysfunctional attitudes reflect **prior beliefs over models** of the world?

ii. Trigger event(s)

- How do recognised psychiatric **risk factors** influence cognition?
- In whom (**individual parameters**) ?

iii. Inference about key concern

[later depends on i, iv - viii]

iv. Computational role of emotion

- What is the **normative role** of emotions?
- Are there **specific distortions, esp. for interpersonal emotions**, in patients?

v. Cognitive biases:

- **Which are abnormal** in patients?
- When can biases sustain vicious cycles (**feedback gain**) ?

vi. Behaviour

- Avoidance: Do existing theories explain **therapy successes and failures**?
- Does avoidance explain symptom build-up at the **onset of disorders**?

viii. Negative thoughts as beliefs:

- Can **model-based theories** explain associated pathological beliefs?
- Can they be modeled well as part of **habitual (model-free) thinking** ?

Hypotheses and testable predictions

Hopeless attributions (but not dysfunctional assumptions) may be beliefs over world models.

Patients and controls should differ regarding probabilistic reasoning based on hopeless attributions etc., including statistical inversion.

Risk and protective exposures e.g. unemployment will interact with pre-existing effective beliefs expressing individual variation.

Effective beliefs will often be expressed as cognitive model parameters.

Emotions will function as beliefs over schemas, conditioned upon salient stimuli.

Specific distortions yet to be computationally formulated.

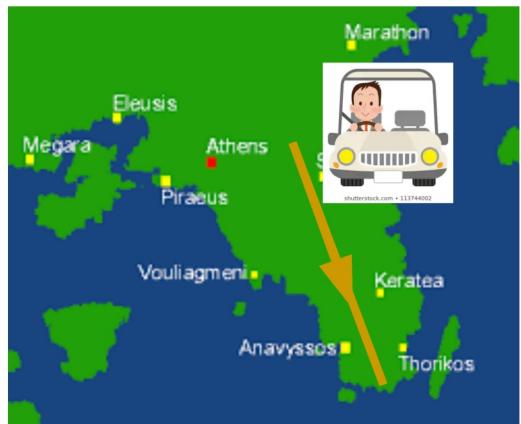
Feedback gain parameters will indeed be increased to the point of sustaining cycles in some patients (but not in health).

Extinction-with-response-prevention will be well explained in people. In some, parameter abnormalities will impair learning from therapy.

To explain the onset of disorders biased processing of counterfactuals will be necessary, including distorted inference about safety and exaggerated effect of 'near miss disasters'

Psychodynamic perspectives

Nutshell Psychoanalysis



Day 1:

I drive the
quick way to
a lovely
seaside

Nutshell Psychoanalysis



Day 1:

I drive the
quick way to
a lovely
seaside



Amongst the first on
scene in car crash.

Young driver trapped

He dies - I can't help

Nutshell Psychoanalysis



Day 1:

I drive the quick way to a lovely seaside

Day 2:

I drive the long, coastal way to the seaside



Amongst the first on scene in car crash.

Young driver trapped

He dies - I can't help

Nutshell Psychoanalysis



Day 1:

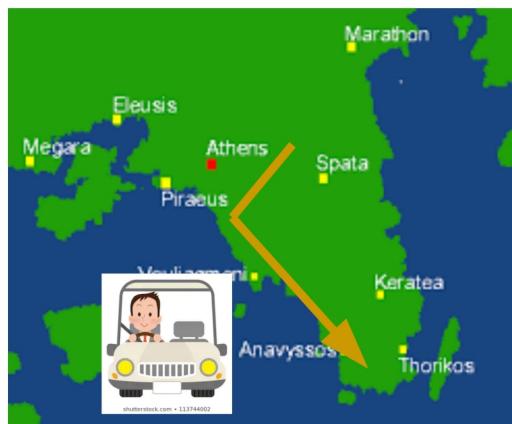
I drive the quick way to a lovely seaside



Amongst the first on scene in car crash.

Young driver trapped

He dies - I can't help



Day 2:

I drive the long, coastal way to the seaside



Why are you driving us the long way?

[in complete innocence]
- So we can see the coastal view

Nutshell Psychoanalysis

The most important element in psychopathology is

- ingrained **self-other models**, including
- emotional evaluation which



Day 1:

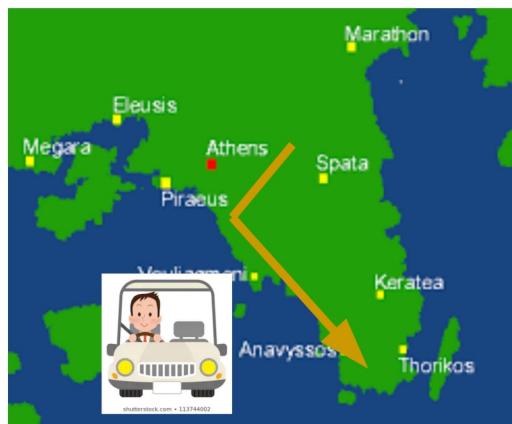
I drive the quick way to a lovely seaside



Amongst the first on scene in car crash.

Young driver trapped

He dies - I can't help



Day 2:

I drive the long, coastal way to the seaside

Why are you driving us the long way?

[in complete innocence]
- So we can see the coastal view



Nutshell Psychoanalysis

The most important element in psychopathology is

- ingrained **self-other models**, including
- **emotional evaluation** which
- powerfully affect outward behaviour but are



Day 1:

I drive the quick way to a lovely seaside



Amongst the first on scene in car crash.

Young driver trapped

He dies - I can't help



Day 2:

I drive the long, coastal way to the seaside

Why are you driving us the long way?



[in complete innocence]

- So we can see the coastal view

Nutshell Psychoanalysis

The most important element in psychopathology is

- ingrained **self-other models**, including
- **emotional evaluation** which
- powerfully affect outward behaviour but are
- largely unconscious



Day 1:

I drive the quick way to a lovely seaside

Day 2:

I drive the long, coastal way to the seaside



Amongst the first on scene in car crash.

Young driver trapped

He dies - I can't help

Why are you driving us the long way?



[in complete innocence]
- So we can see the coastal view

Angst ↔ Free Energy

- Negative emotion can be naturally described as Free Energy (Psychoanalytic Anxiety/Angst is a form of FE)



C. Mathys

- As neuroscientists, we would naturally expect most belief distributions and (generative) models encoded in synaptic connectivity to be unconscious.

Angst \leftrightarrow Free Energy

- Negative emotion can be naturally described as Free Energy (Psychoanalytic Anxiety/Angst is a form of FE)



C. Mathys

- As neuroscientists, we would naturally expect most belief distributions and (generative) models encoded in synaptic connectivity to be unconscious.

The Bayesian framework provides a rich language to think about Actively Inferring in relationships:

e.g. Relational needs and models can be represented as priors preferences (C matrix) and dynamics over a joint, me-you state space.



'Surprise' and the Bayesian Brain in psychodynamic therapy



T. Nolte

J. Holmes

Breathtakingly beautiful descriptions of relations from a FEM point of view!

- Patient and therapist (or group, I'd add!) take turns to speak
- In successful therapy, each is predictable enough to the other
- Analogous to turn-taking in bird-song, as modelled by Friston & Frith (2015)



'Surprise' and the Bayesian Brain in psychodynamic therapy



T. Nolte

J. Holmes

Breathtakingly beautiful descriptions of relations from a FEM point of view!

- Patient and therapist (or group, I'd add!) take turns to speak
- In successful therapy, each is predictable enough to the other
- Analogous to turn-taking in bird-song, as modelled by Friston & Frith (2015)
- This is a 'duet for one' - in that it belongs to neither participant, but to both.
- Hypothesised to underpin the 'brain borrowing' infants do (of parents) or suffering partners (of the Other)



'Surprise' and the Bayesian Brain in psychodynamic therapy

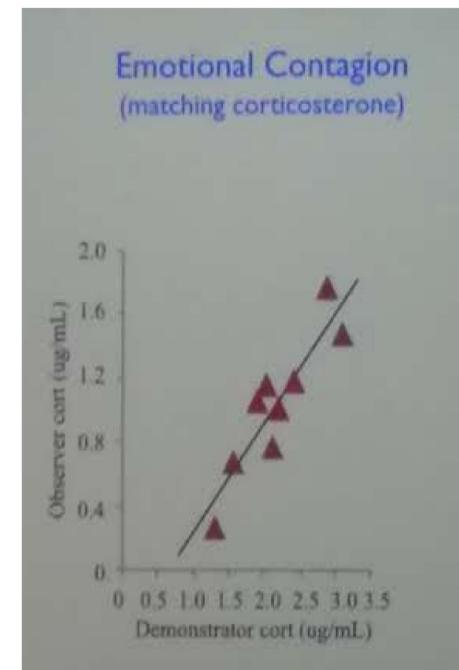


T. Nolte

J. Holmes

Breathtakingly beautiful descriptions of relations from a FEM point of view!

- Patient and therapist (or group, I'd add!) take turns to speak
- In successful therapy, each is predictable enough to the other
- Analogous to turn-taking in bird-song, as modelled by Firston & Frith (2015)
- This is a 'duet for one' - in that it belongs to neither participant, but to both.
- Hypothesised to underpin the 'brain borrowing' infants do (of parents) or suffering partners (of the Other)



... e.g. voles consoling each other
Frans de Waal, SANS 2019

Understanding Emotion

- Emotions such as 'sadness', 'regret', 'affection' etc., need to be inferred on the basis of
 - interoceptive and exteroceptive sensations
 - models of their joint occurrence
- Internal models of emotion may be impoverished in psychopathology



Ryan Smith

Simulating emotions: An active inference model of emotional state inference and emotion concept learning

R Smith, T Parr, KJ Friston - bioRxiv, 2019 - biorxiv.org

Understanding Emotion

- Emotions such as 'sadness', 'regret', 'affection' etc., need to be inferred on the basis of
 - interoceptive and exteroceptive sensations
 - models of their joint occurrence
- Internal models of emotion may be impoverished in psychopathology
- Therapy needs **to reduce precision** to shift strong beliefs in such models



Ryan Smith

Smith, Lane ,Nadel and Moutoussis (In 'Neuroscience of Enduring Change: Implications for Psychotherapy', OUP; in press)

Empowering patients - already!

For the practicing clinician: ‘mentalizing interoception’

Bare bones of a nuanced clinical paper:

Increasing attention to interoceptive sensation →
change the balance of precision between the current
interoceptive sensation and the ‘stubborn prior’.

Change in precision can allow consideration of alternative, more adaptive hypotheses about subjective experience.



Patrice Duquette

Duquette & Ainley, Frontiers 2019 (in print)

Talking and listening to patients about Com Psy

Psychoeducation, esp. re. prior beliefs *of* the brain: invaluable for overcoming 'brain disease or all in my mind' duality

Patient involvement in designing translational research, so patients can be active users of therapy, not simply consenting consumers of it.

Conclusions

translational neuroscience



psychotherapy

- ◆ Translational neuroscience provides methods to study **how beliefs are inferred and updated**, which is central to psychotherapy
- ◆ Promise to clarify the detailed dynamics of familiar psychological processes ...
- ◆ ... and **link them to neural level processes**
- ◆ Testing the **validity of postulated 'psychological mechanisms'**
- ◆ Empowering patients as an active agents, through
 - **Psychoeducation**
 - Involvement in **development of treatment & relevant theory.**



Thanks for your attention

**Acknowledgements,
in addition to all already named in the talk:**

The Zurich CPC team

Peter Dayan

Ray Dolan

Giles Story

Nitzan Shahar

Tobi Hauser

Cathy Price

Peter Fonagy

Alexis (An-Ye) Low

Will Hopper

Geert-Jan Will

Isabel Berwian

Joe Barnby

Yael Niv