Why metacognition matters for (computational) psychiatry

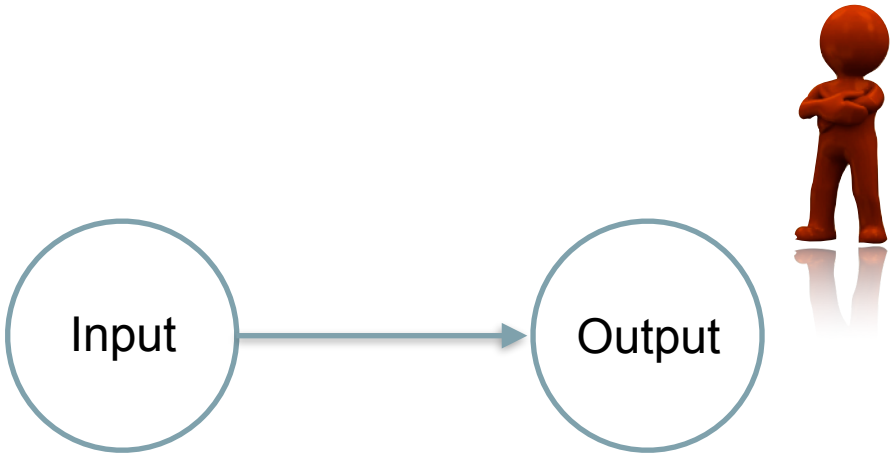
Steve Fleming

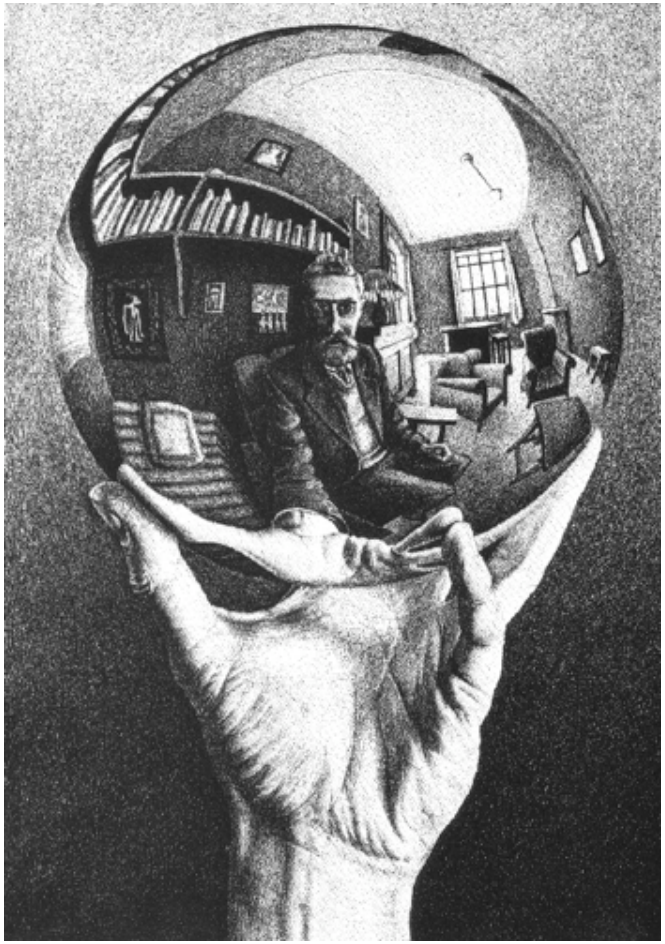
Wellcome Centre for Human Neuroimaging, UCL

stephen.fleming@ucl.ac.uk

metacoglab.org

Defining metacognition





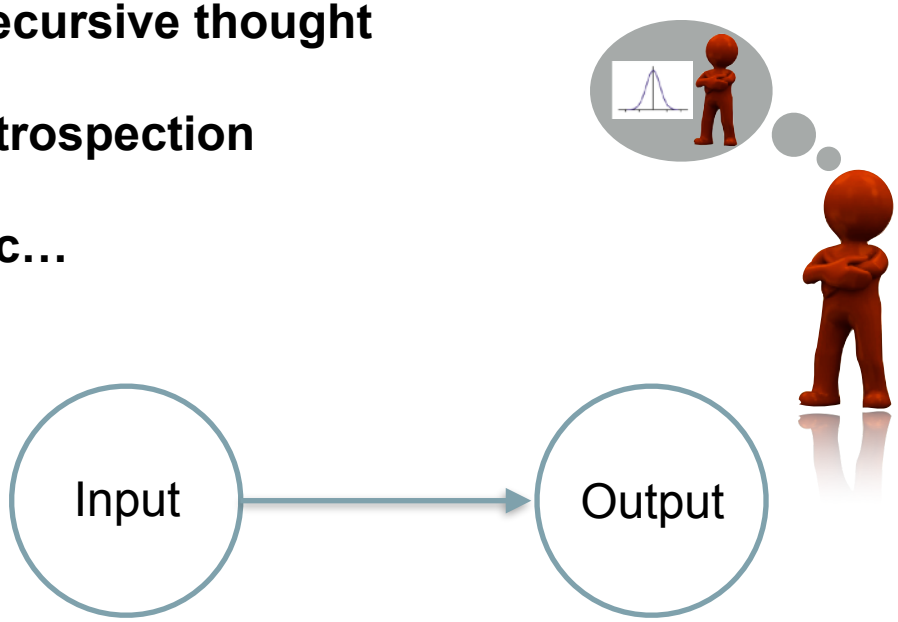
Defining metacognition

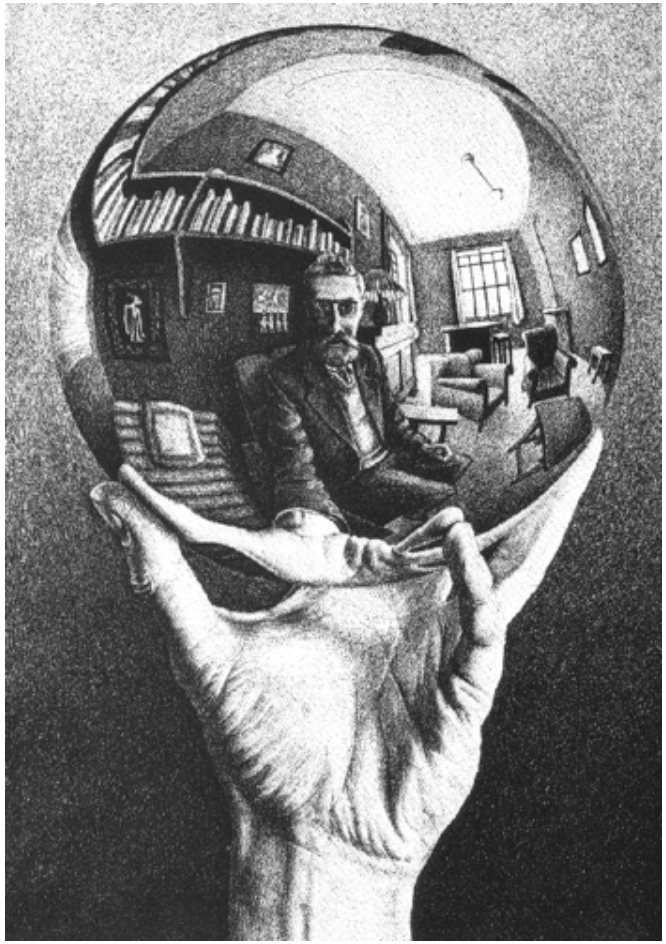
Self-reflection

Recursive thought

Introspection

etc…





Defining metacognition

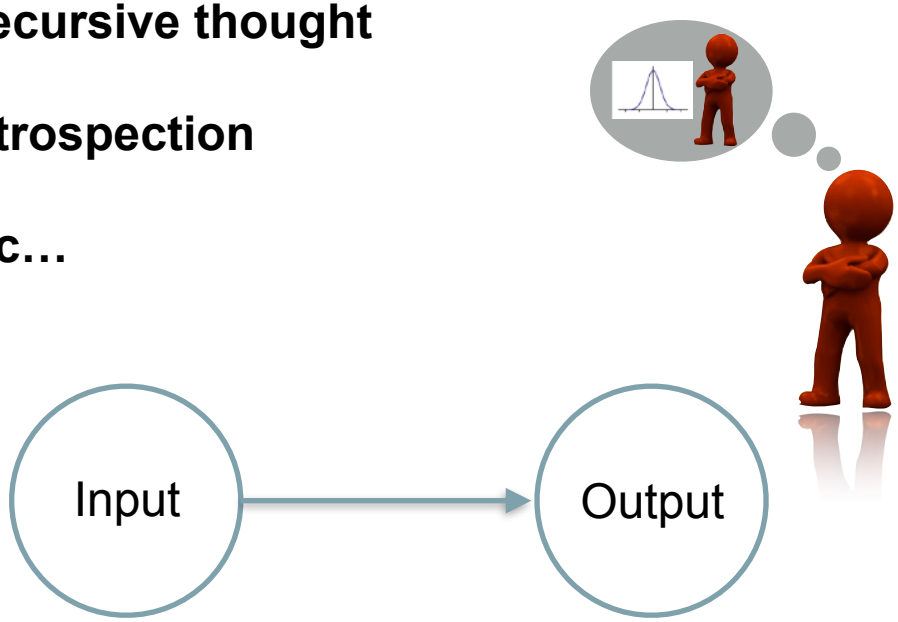
- "cognition about cognitive phenomena..." **(Flavell, 1979)**

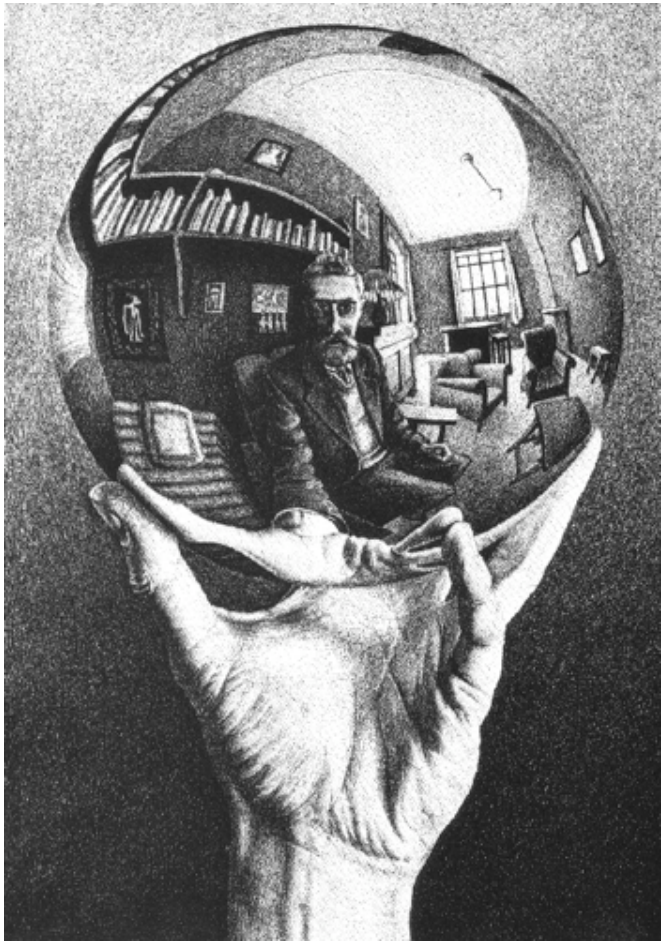
Self-reflection

Recursive thought

Introspection

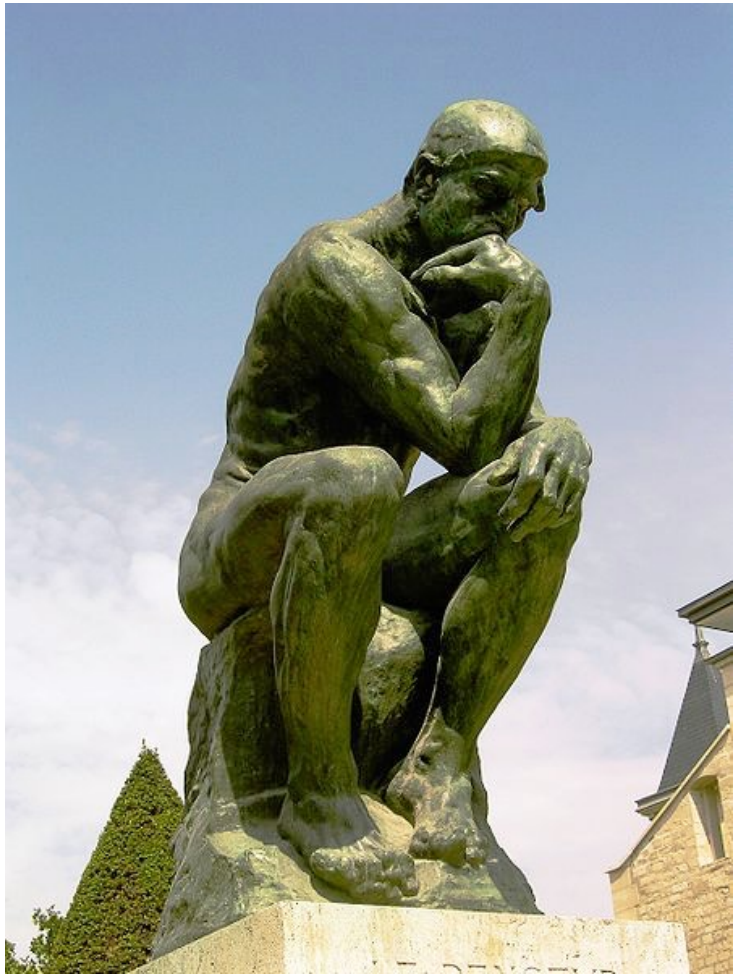
etc…

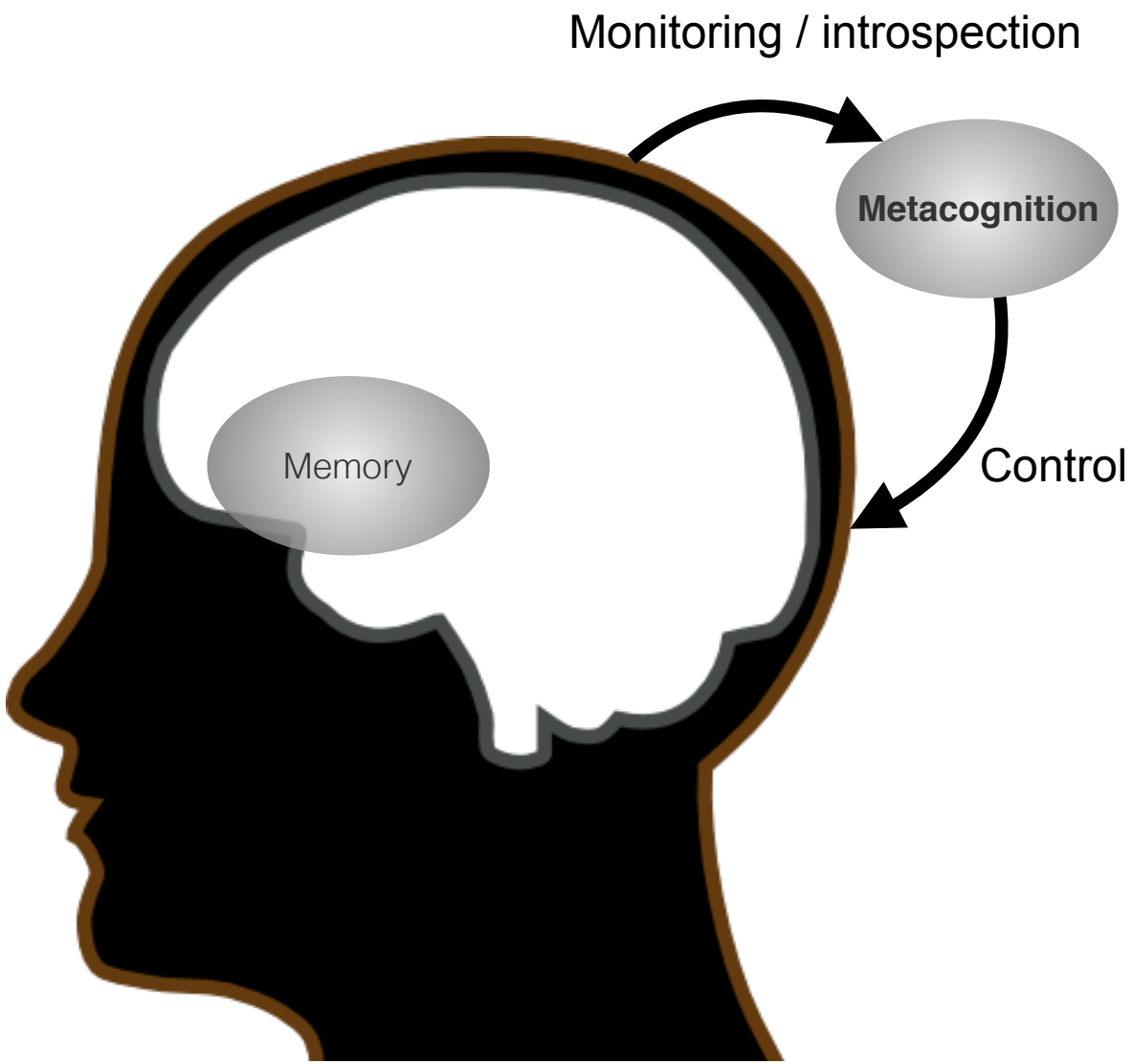




Defining metacognition

- “Metacognition research concerns the processes by which people self-reflect on their own cognitive and memory processes (monitoring) and how they put their metaknowledge to use in regulating their information processing and behaviour (control)” **(Koriat, 2007)**

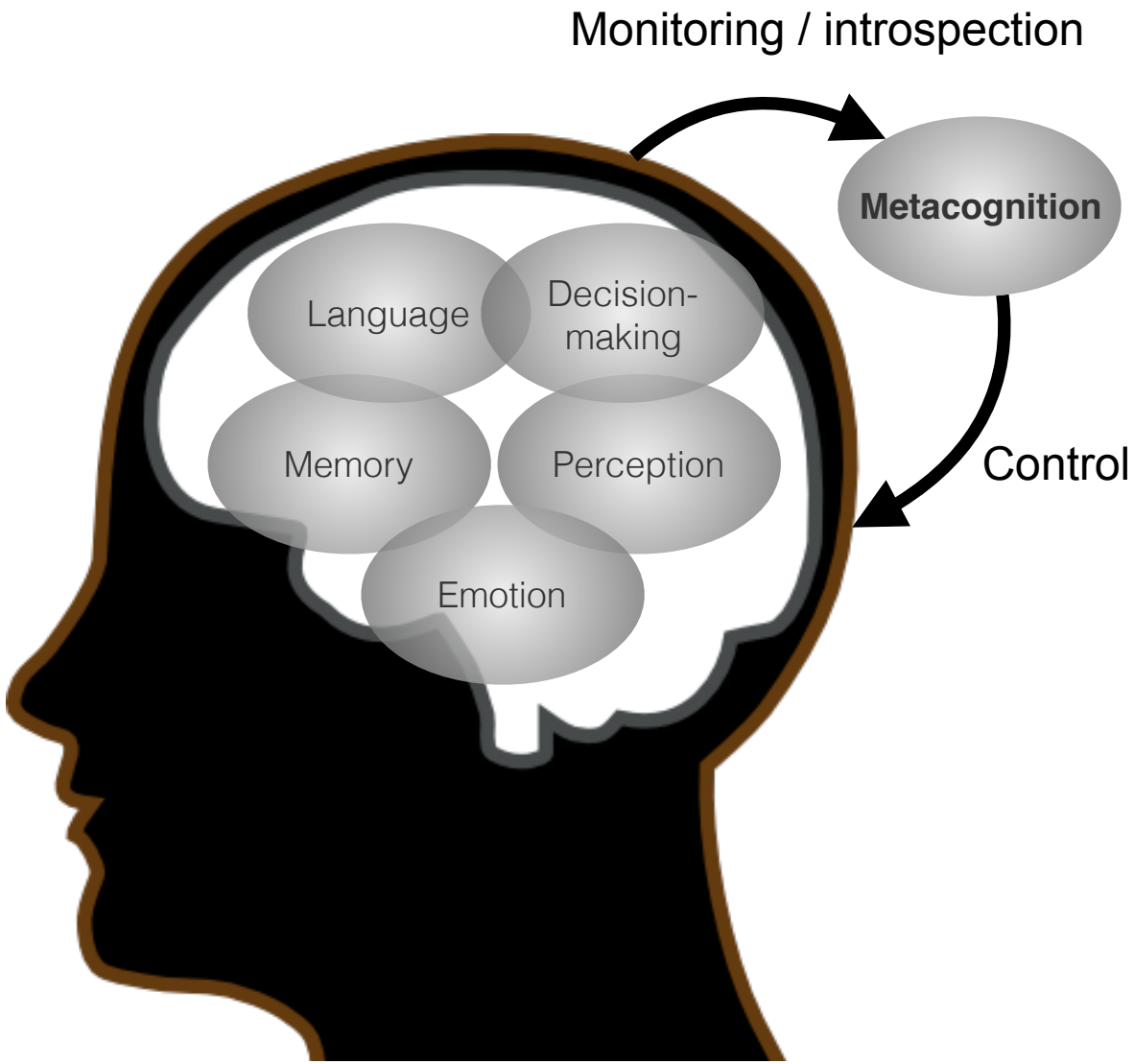




Metacognition

= reflecting on and controlling other cognitive processes

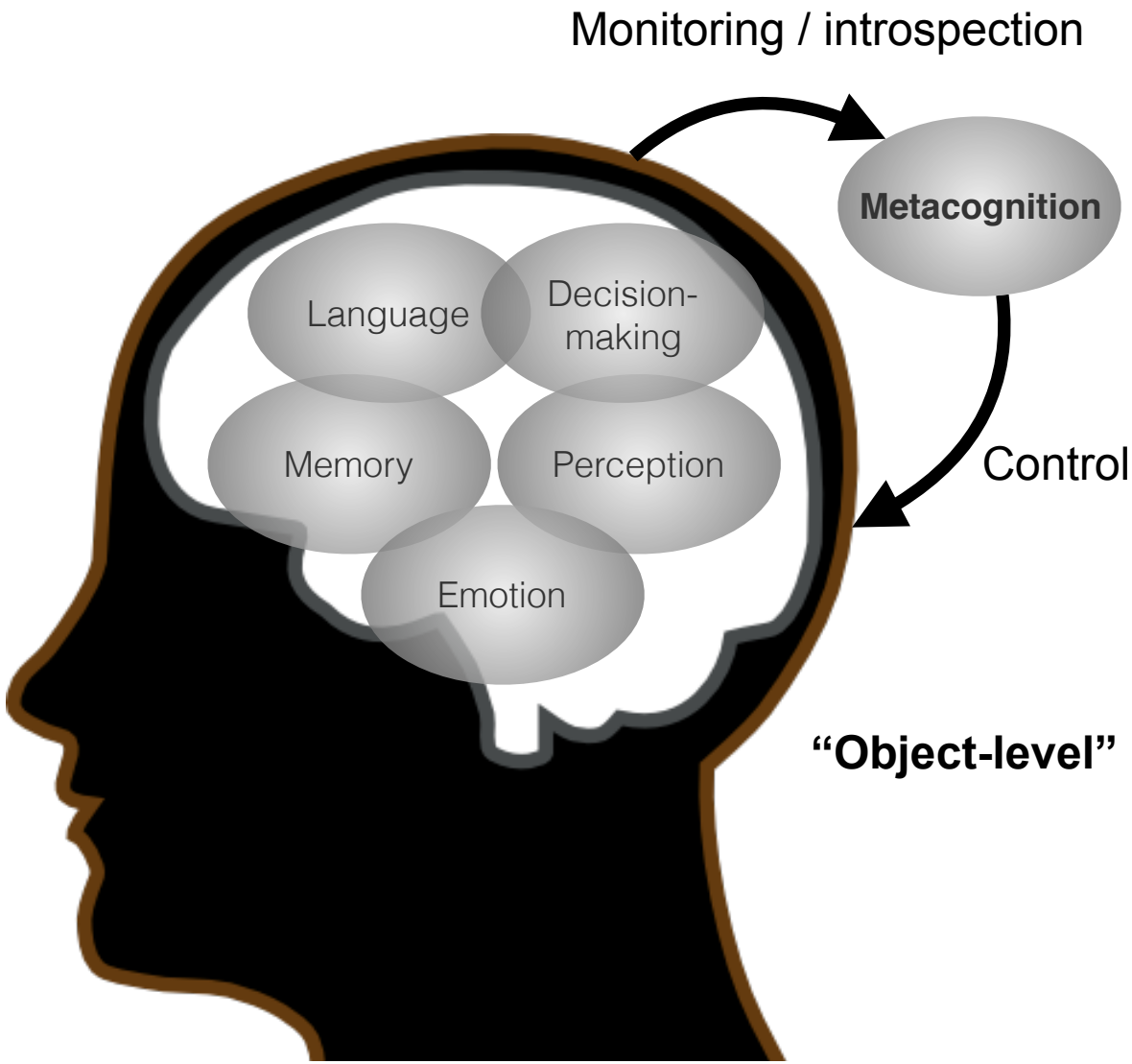
Nelson & Narens (1990)



Metacognition

= reflecting on and controlling other cognitive processes

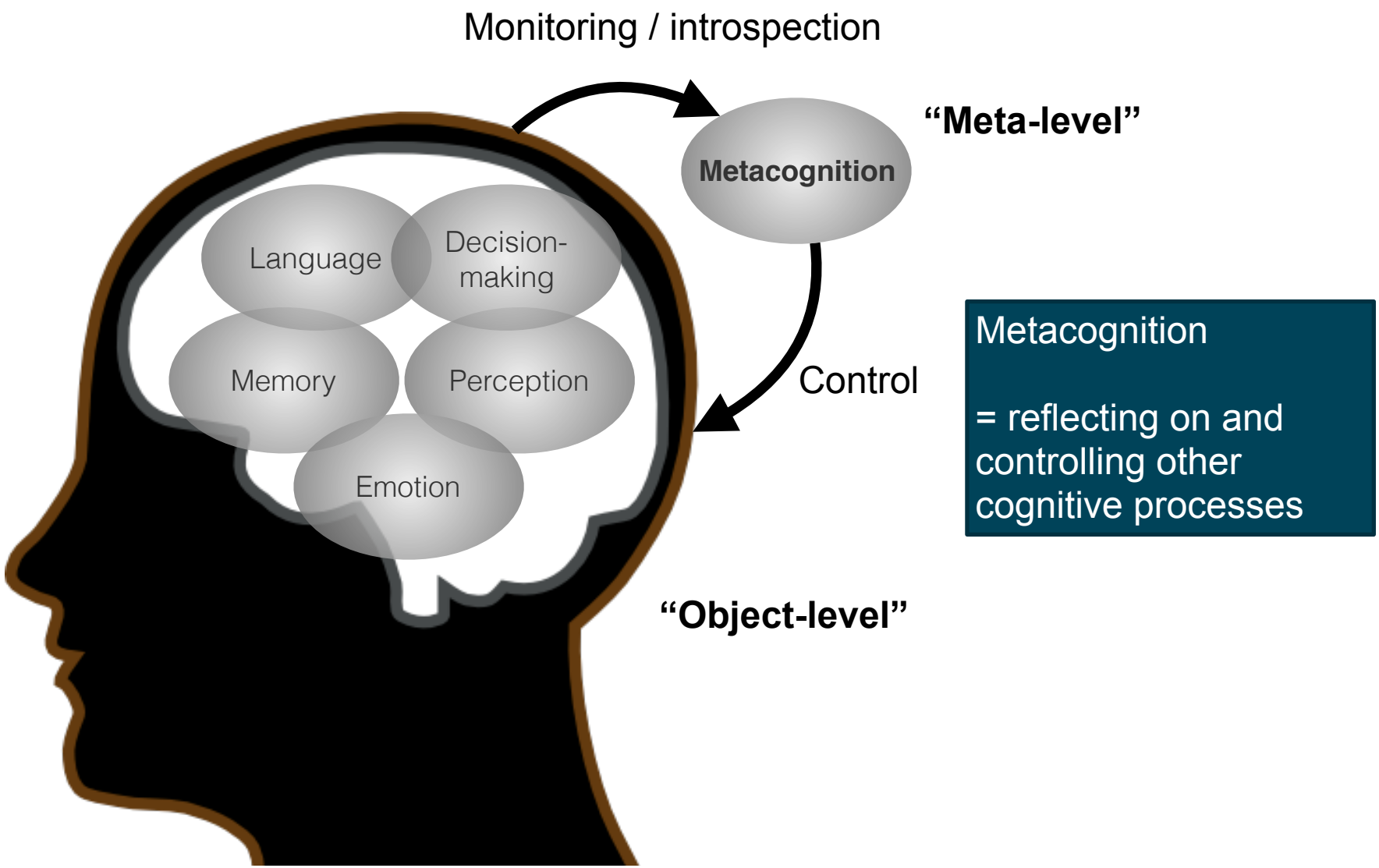
Nelson & Narens (1990)



Metacognition

= reflecting on and controlling other cognitive processes

Nelson & Narens (1990)

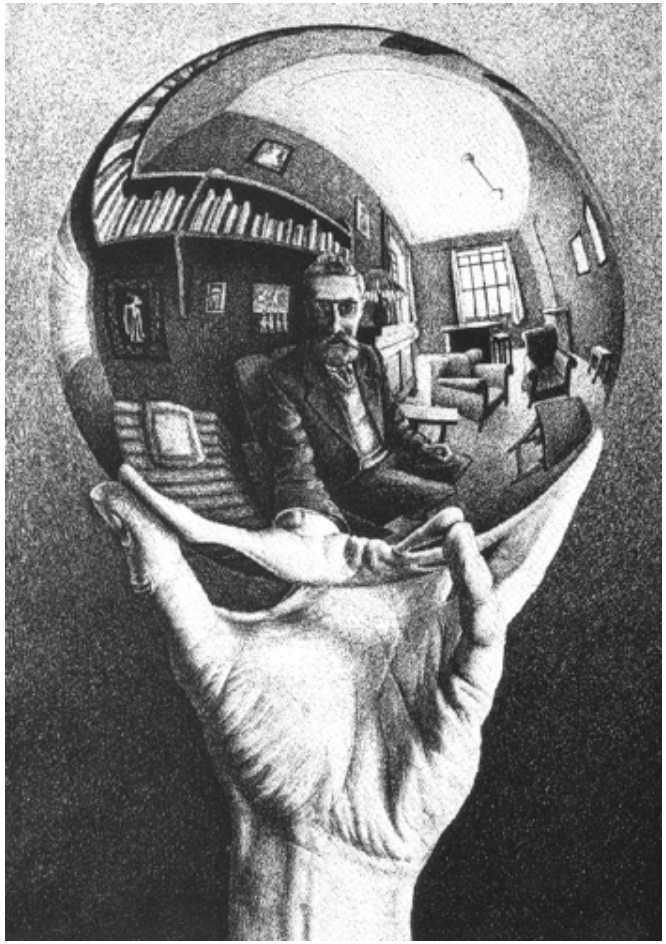


Metacognition

= reflecting on and controlling other cognitive processes

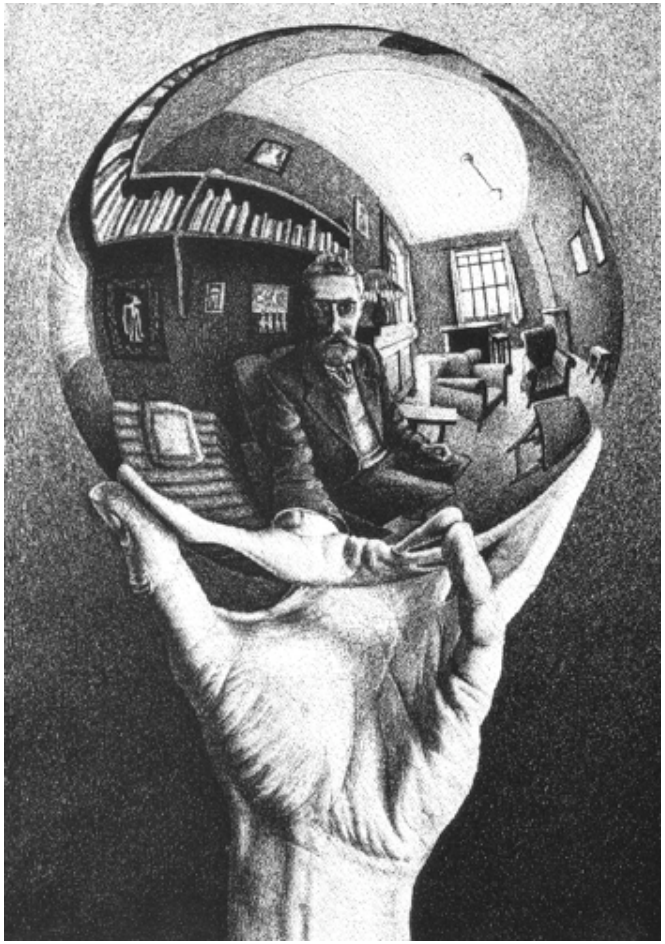
Nelson & Narens (1990)

Questions for today



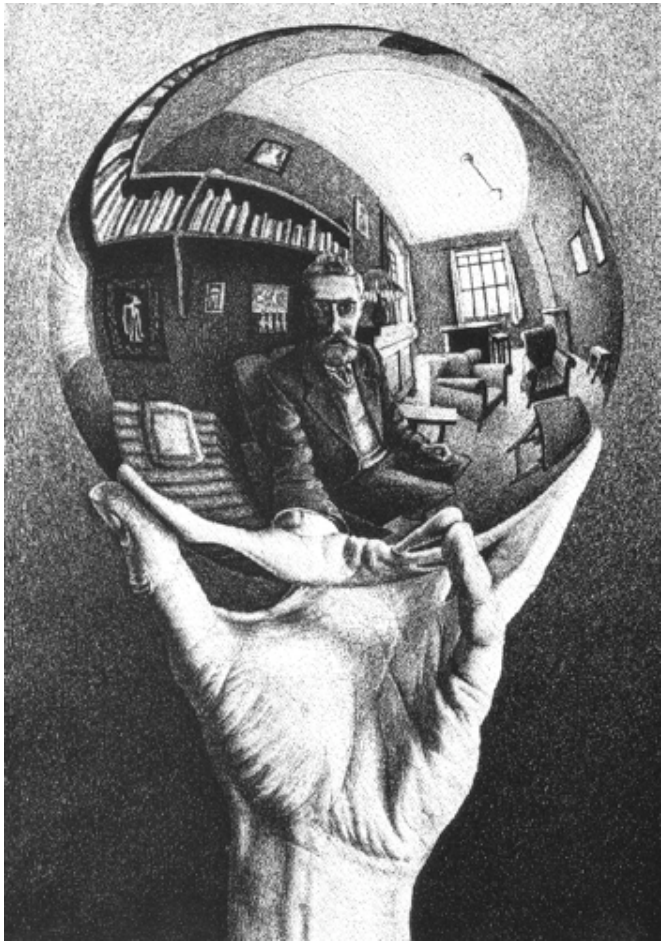
Questions for today

- How can we begin to study / quantify metacognition?



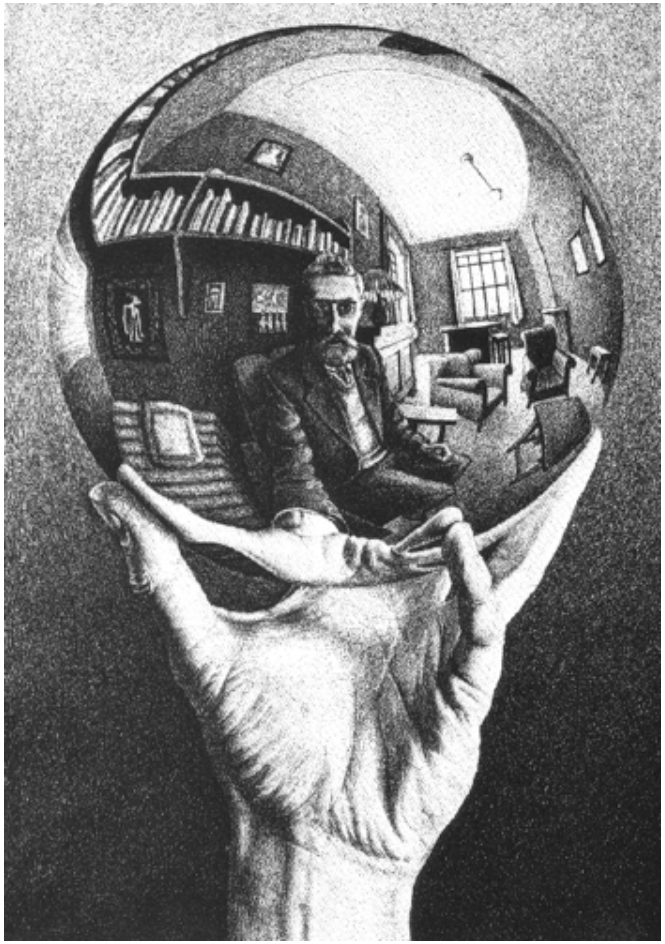
Questions for today

- How can we begin to study / quantify metacognition?
- What neurocognitive architecture supports metacognition?



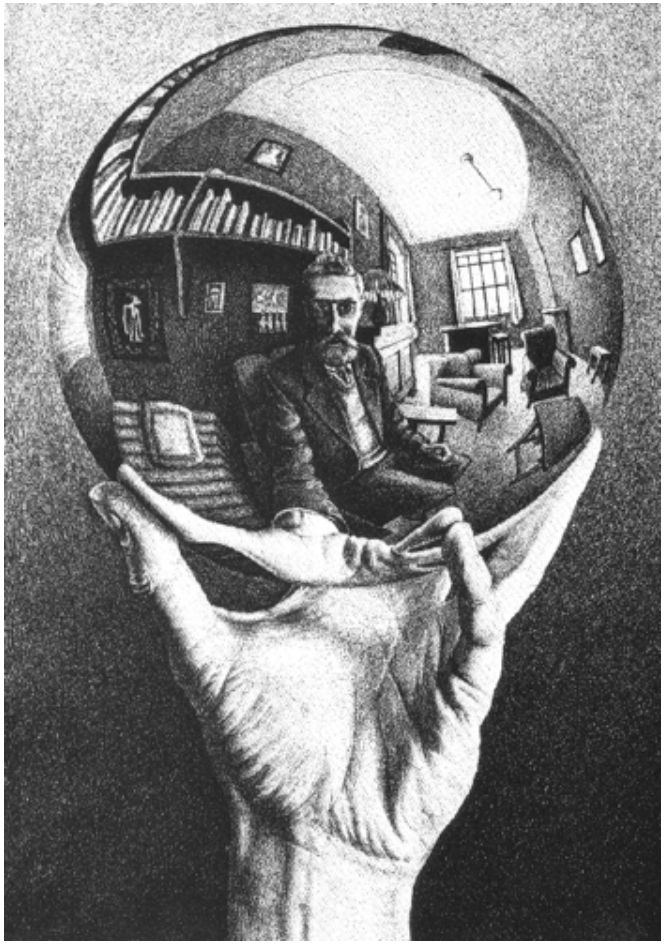
Questions for today

- How can we begin to study / quantify metacognition?
- What neurocognitive architecture supports metacognition?
- Is metacognition related to psychopathology?

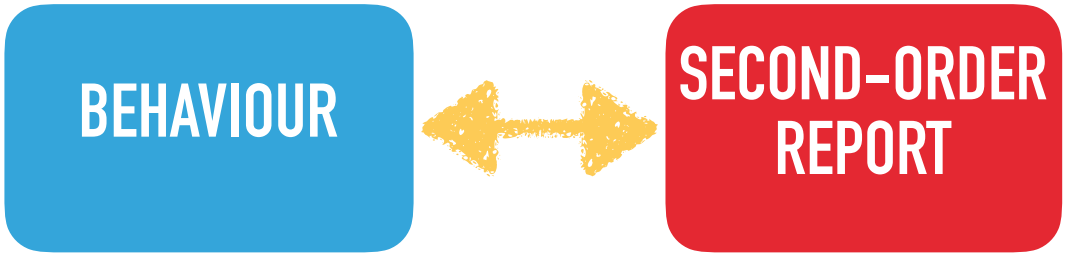


Questions for today

- How can we begin to study / quantify metacognition?
- What neurocognitive architecture supports metacognition?
- Is metacognition related to psychopathology?
- Can we design interventions to modulate (domain-general) metacognition?



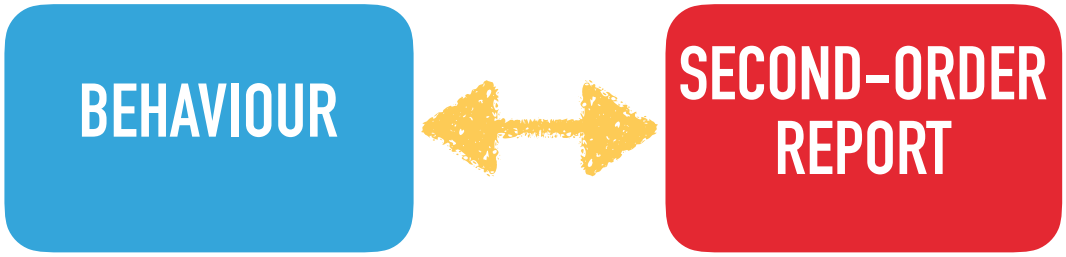
How can we measure metacognition?



E.g. answer to exam question

E.g. **confidence** in getting the answer right

How can we measure metacognition?

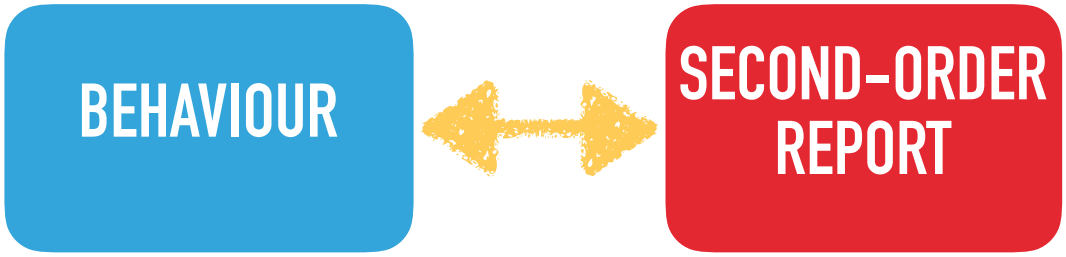


E.g. answer to exam question

E.g. **confidence** in getting the answer right

- **Second-order reports**

How can we measure metacognition?

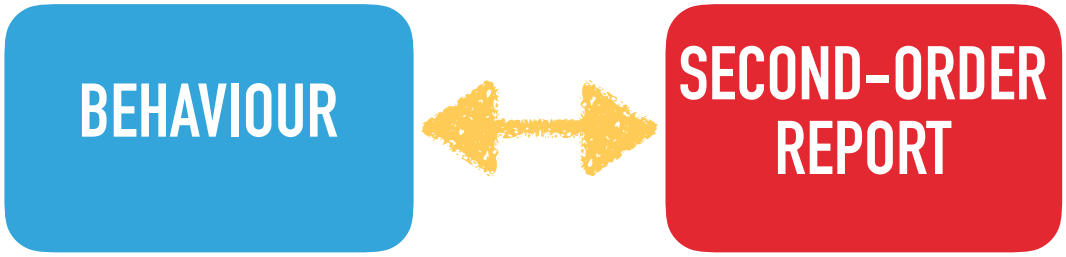


E.g. answer to exam question

E.g. **confidence** in getting the answer right

- **Second-order reports**

How can we measure metacognition?

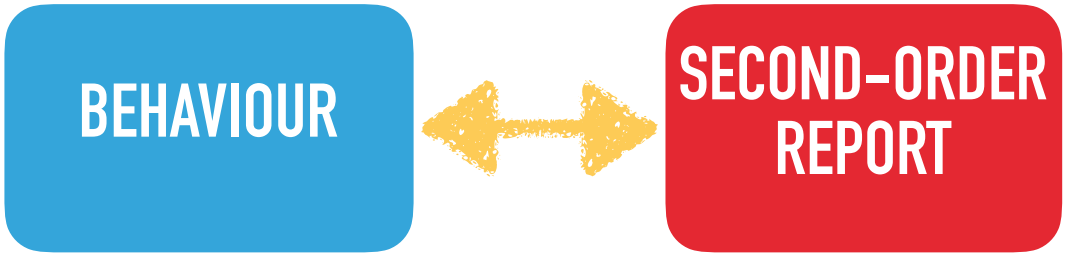


E.g. answer to exam question

E.g. **confidence** in getting the answer right

- **Second-order reports**
  - Judgment or report about self-performance

How can we measure metacognition?

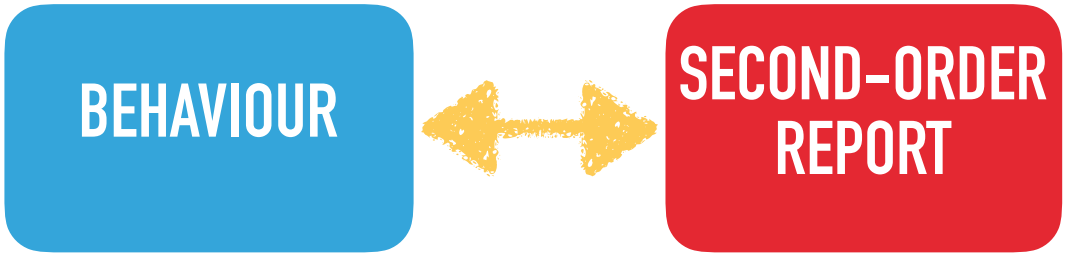


E.g. answer to exam question

E.g. **confidence** in getting the answer right

- **Second-order reports**
  - Judgment or report about self-performance
  - Many different variants, prospective (before the task) or retrospective (after the task)

How can we measure metacognition?



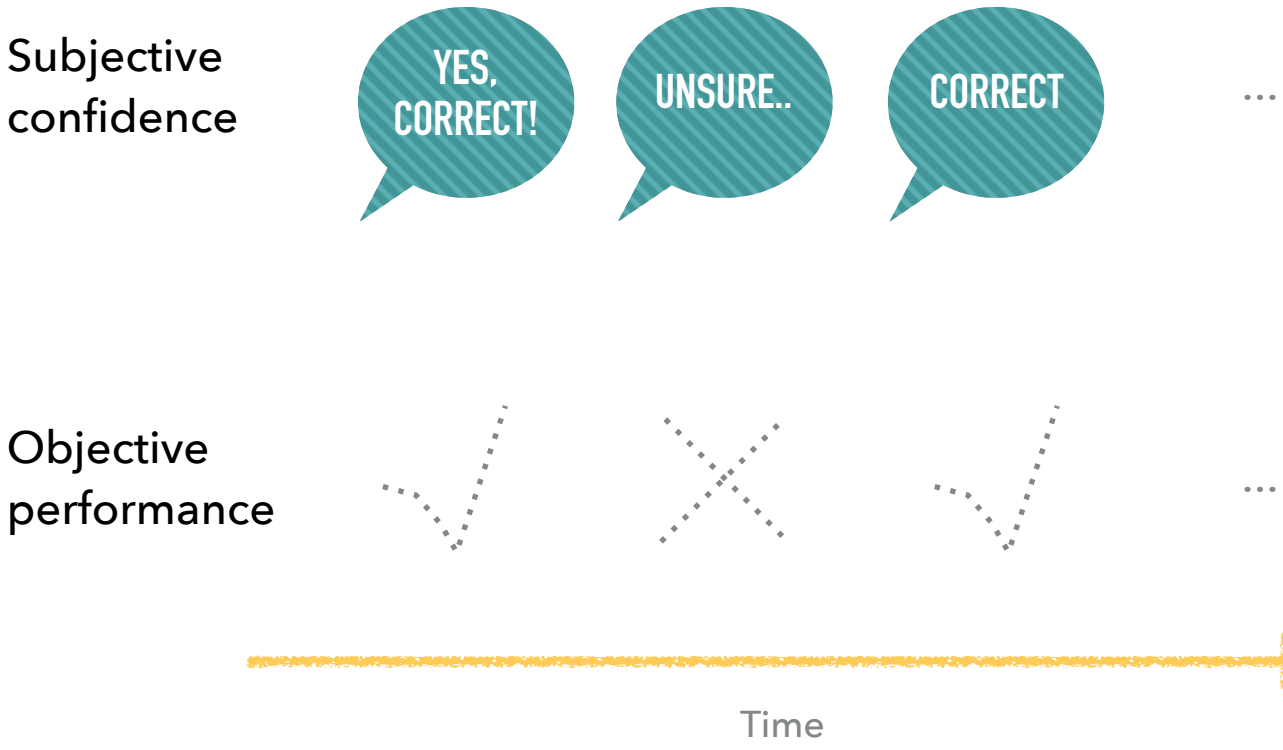
E.g. answer to exam question

E.g. **confidence** in getting the answer right

- **Second-order reports**
  - Judgment or report about self-performance
  - Many different variants, prospective (before the task) or retrospective (after the task)
  - Metacognitive accuracy = relationship between second-order reports and behaviour

How do we study metacognition?

Quantify **statistical association** between behaviour and metacognitive judgments:

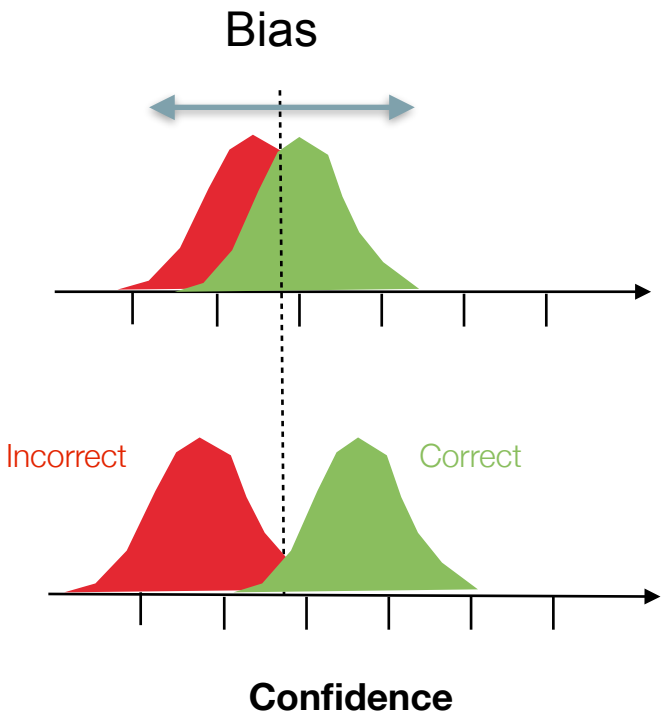


Metacognitive bias and sensitivity

Confidence in behaviour

Metacognitive bias

Metacognitive sensitivity



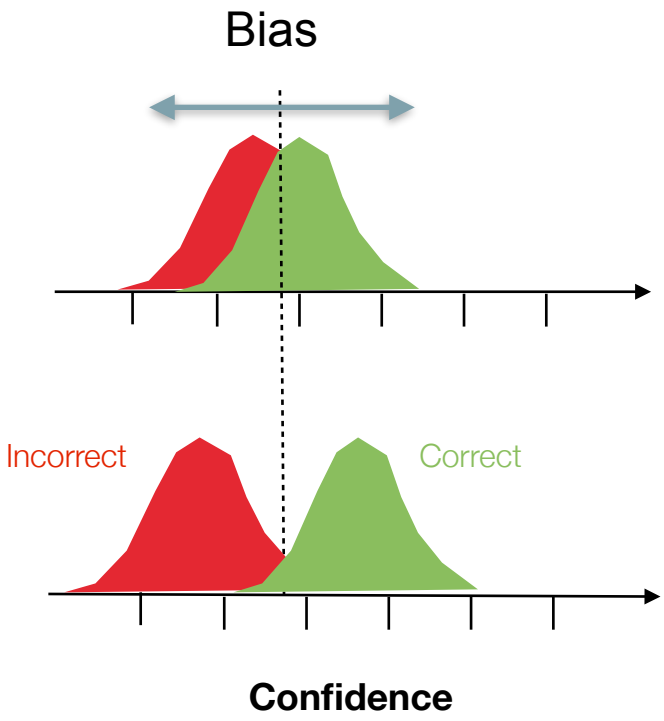
Fleming & Lau (2014) *Frontiers in Neuroscience*

Metacognitive bias and sensitivity

Confidence in behaviour

Metacognitive bias

Metacognitive sensitivity

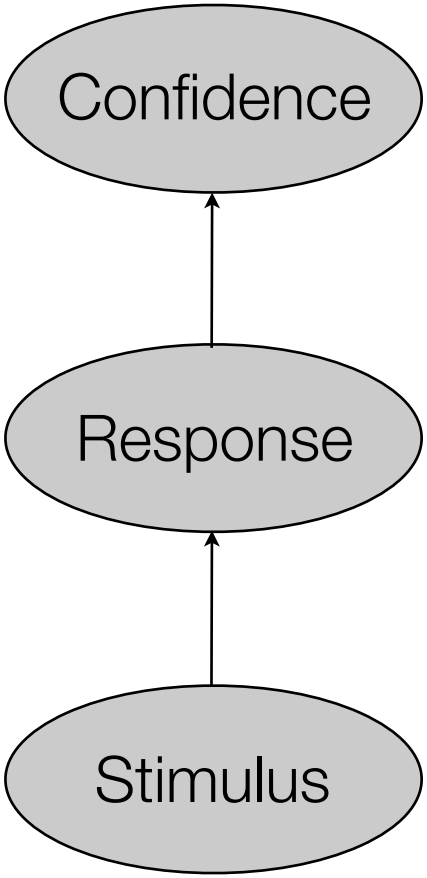


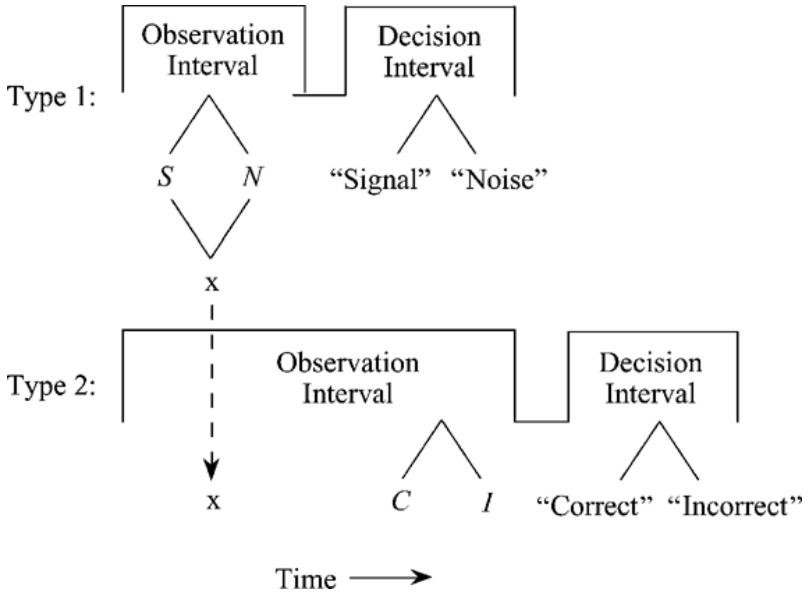
Other terminology in the literature:

Bias: calibration, confidence level, self-perceived ability, self-belief…
Sensitivity: discrimination, resolution, metacognitive awareness, insight…

Fleming & Lau (2014) *Frontiers in Neuroscience*

Quantifying metacognitive sensitivity

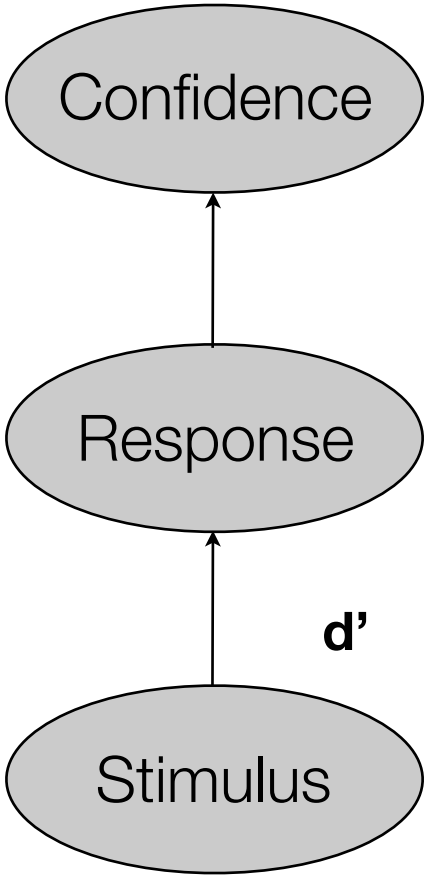


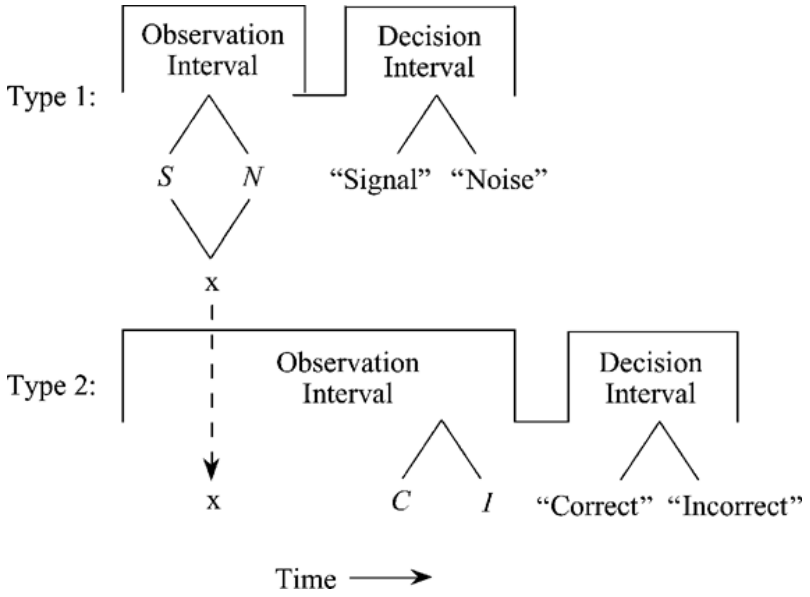


Galvin et al. (2003) *Psych Bull Rev*

Quantifying metacognitive sensitivity

First-order sensitivity



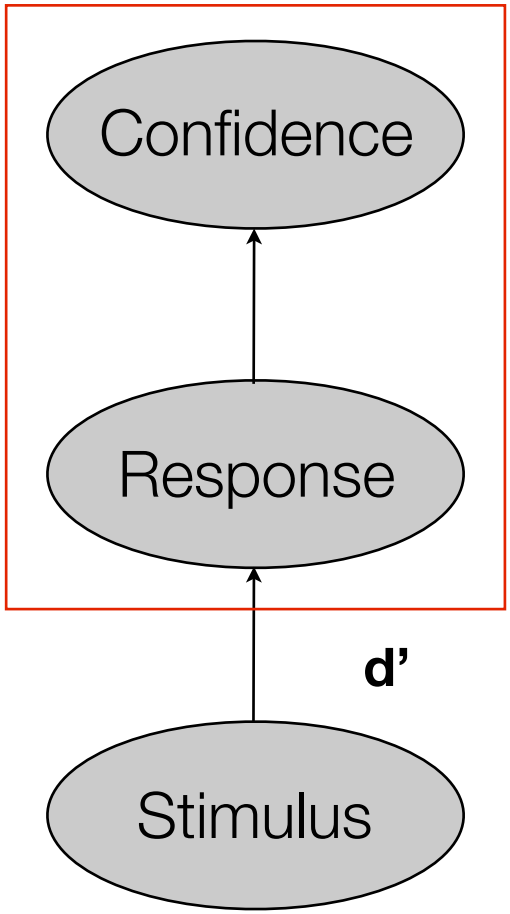


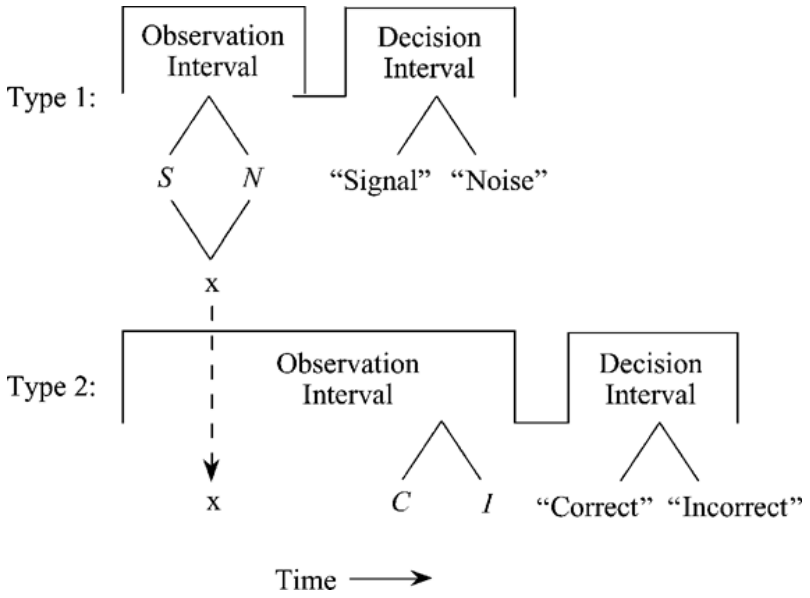
Galvin et al. (2003) *Psych Bull Rev*

Quantifying metacognitive sensitivity

Second-order sensitivity

First-order sensitivity



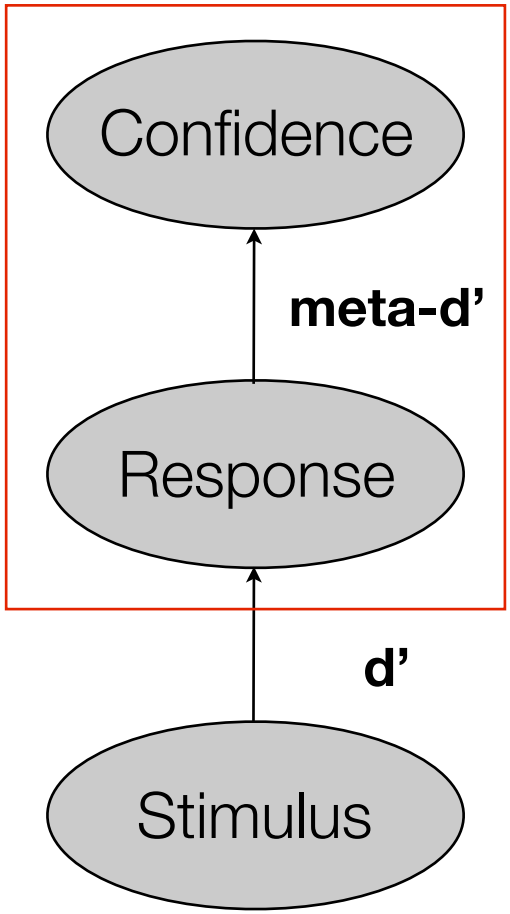


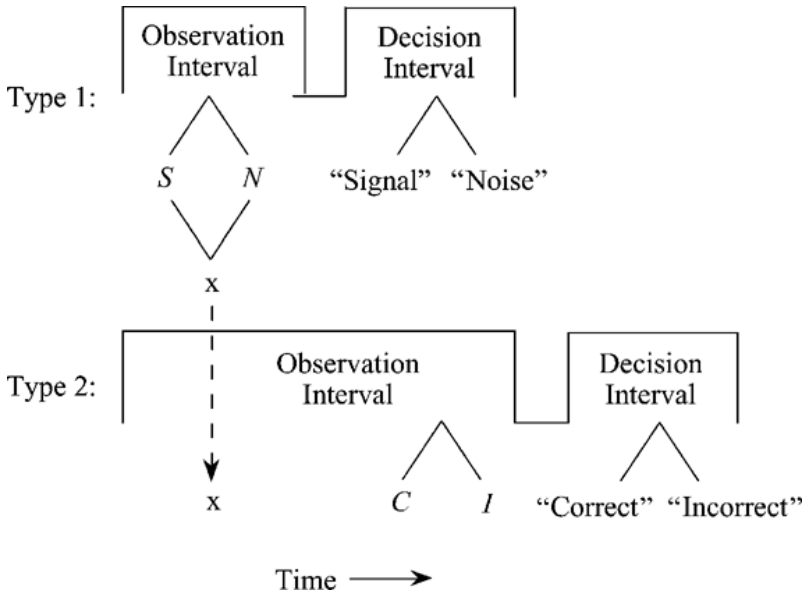
Galvin et al. (2003) *Psych Bull Rev*

Quantifying metacognitive sensitivity

Second-order sensitivity

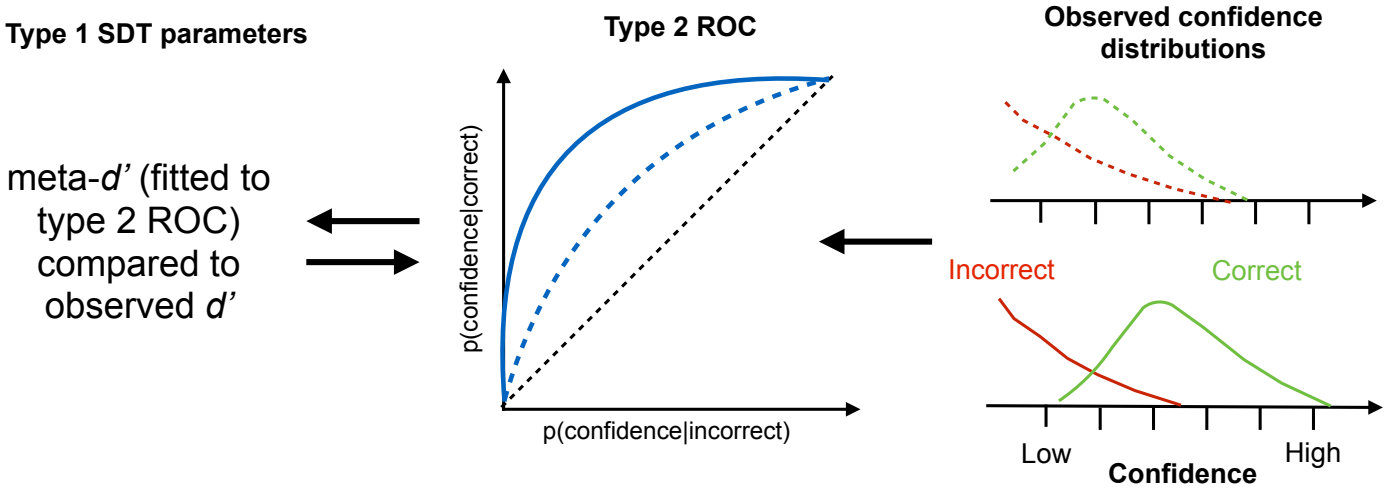
First-order sensitivity

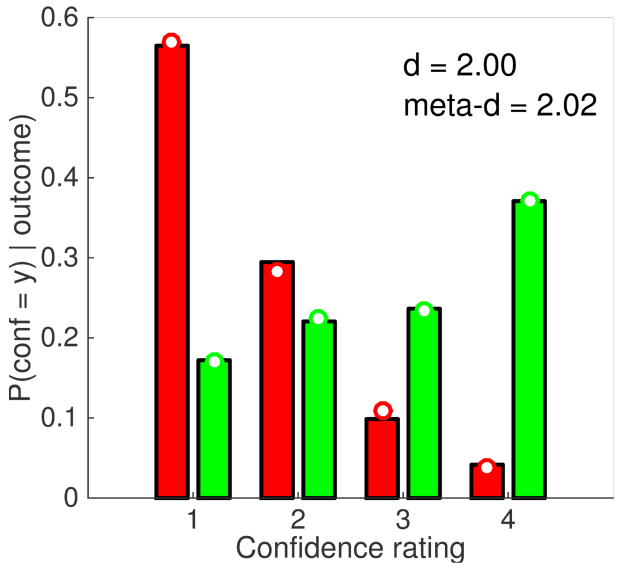


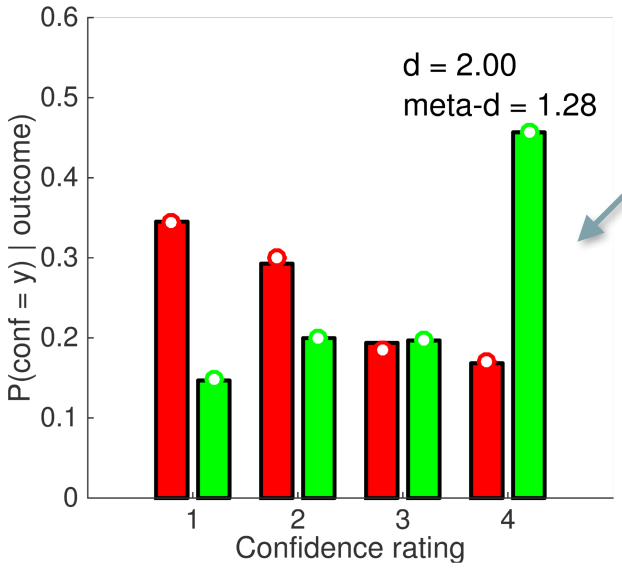


Galvin et al. (2003) *Psych Bull Rev*

ROC analysis / meta-*d'*



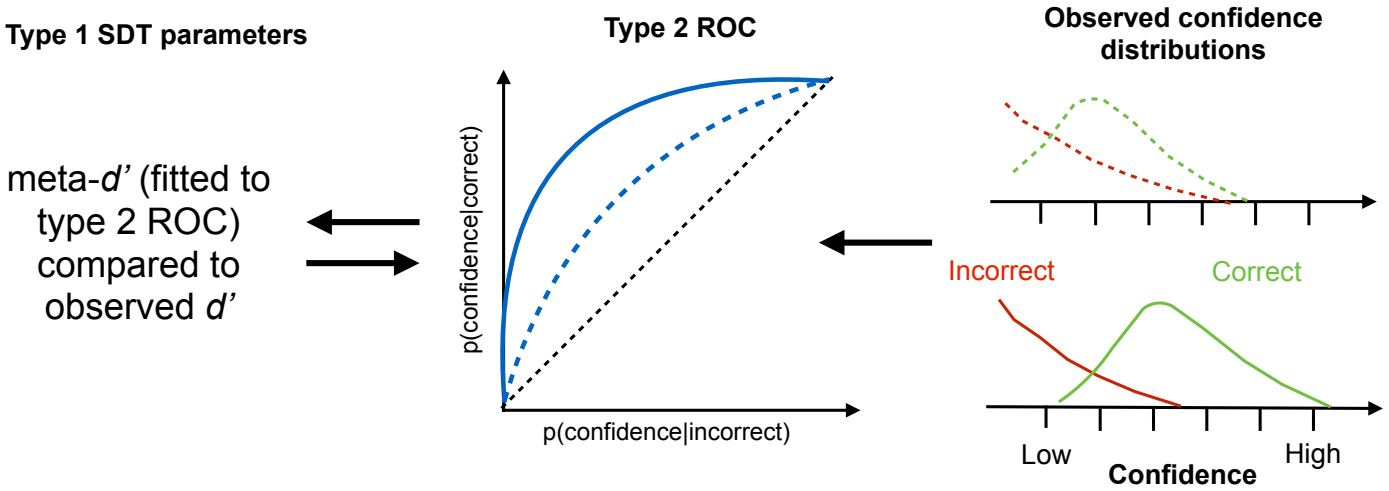


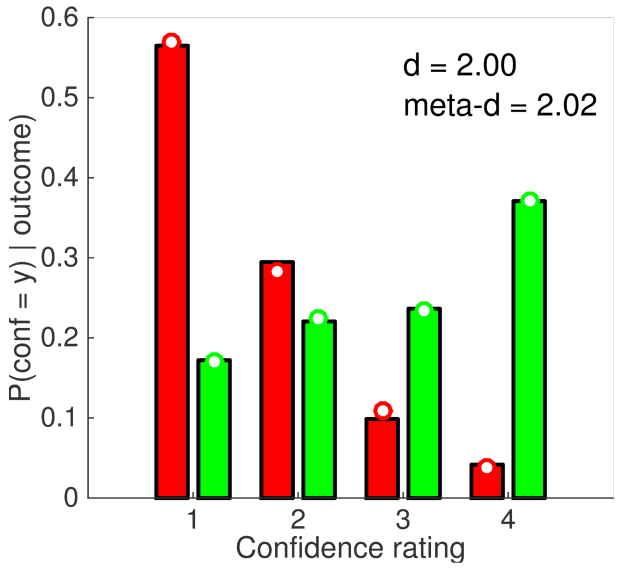


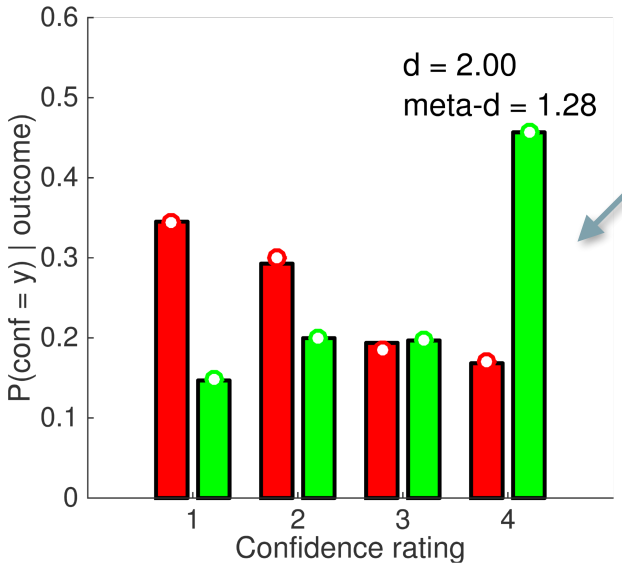
Gaussian noise added to confidence ratings

Maniscalco & Lau (2012) *Consciousness & Cognition*; Fleming (2017) *Neuroscience of Consciousness*

ROC analysis / meta-*d'*





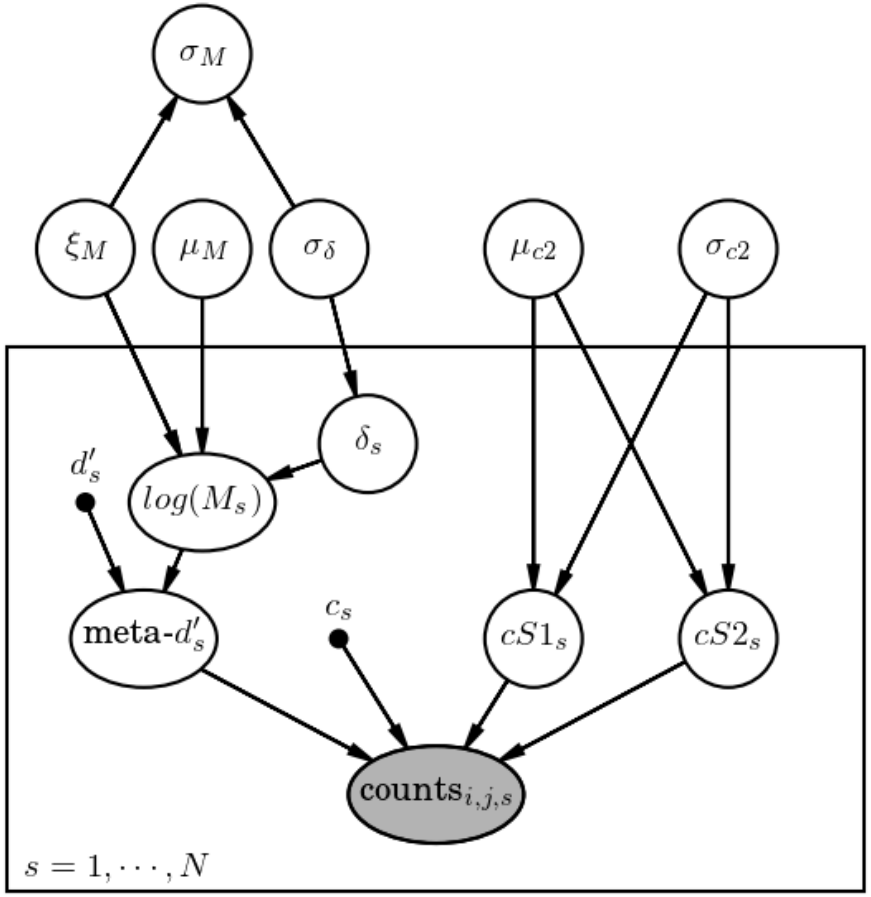


Gaussian noise added to confidence ratings

meta-d'/d' = metacognitive efficiency

Maniscalco & Lau (2012) *Consciousness & Cognition*; Fleming (2017) *Neuroscience of Consciousness*

Bayesian hierarchical model for meta-*d'* (HMeta-d)



$$\mu_{c2} \sim \mathcal{N}(0, 10)$$

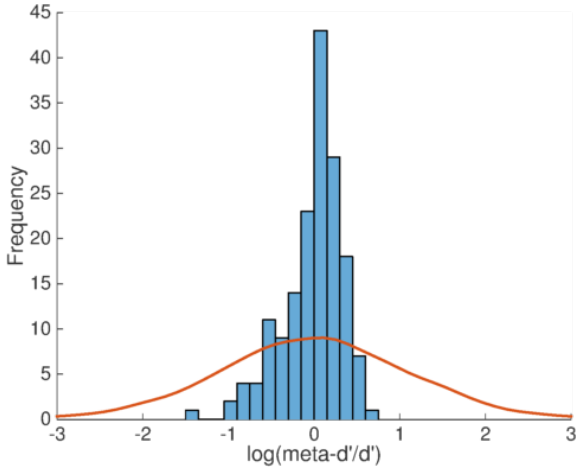
$$\sigma_{c2} \sim \mathcal{HN}(10)$$

$$\mu_M \sim N(0, 1)$$

$$\sigma_M = |\xi_M| \times \delta_s$$

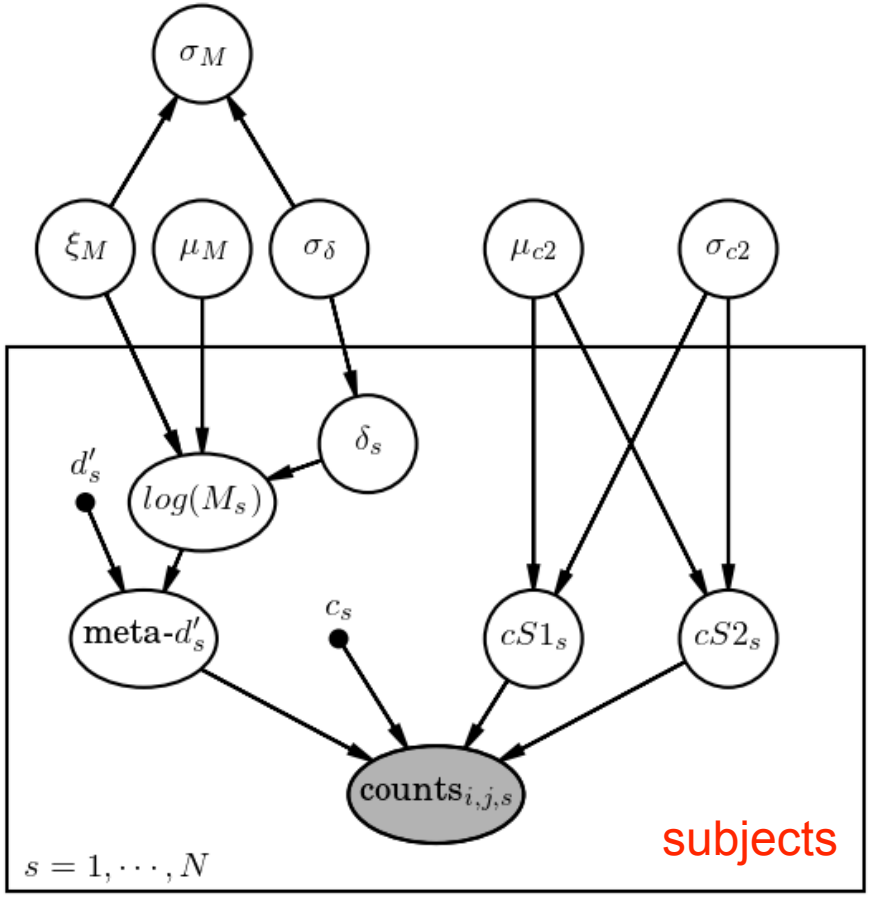
$$\xi_M \sim Beta(1,1)$$

$$\sigma_\delta \sim \mathcal{HN}(1)$$



Fleming (2017) *Neuroscience of Consciousness*

Bayesian hierarchical model for meta-*d'* (HMeta-d)



$$\mu_{c2} \sim \mathcal{N}(0, 10)$$

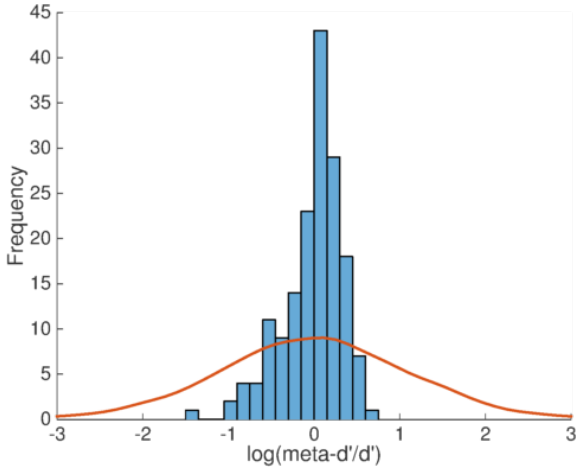
$$\sigma_{c2} \sim \mathcal{HN}(10)$$

$$\mu_M \sim N(0, 1)$$

$$\sigma_M = |\xi_M| \times \delta_s$$

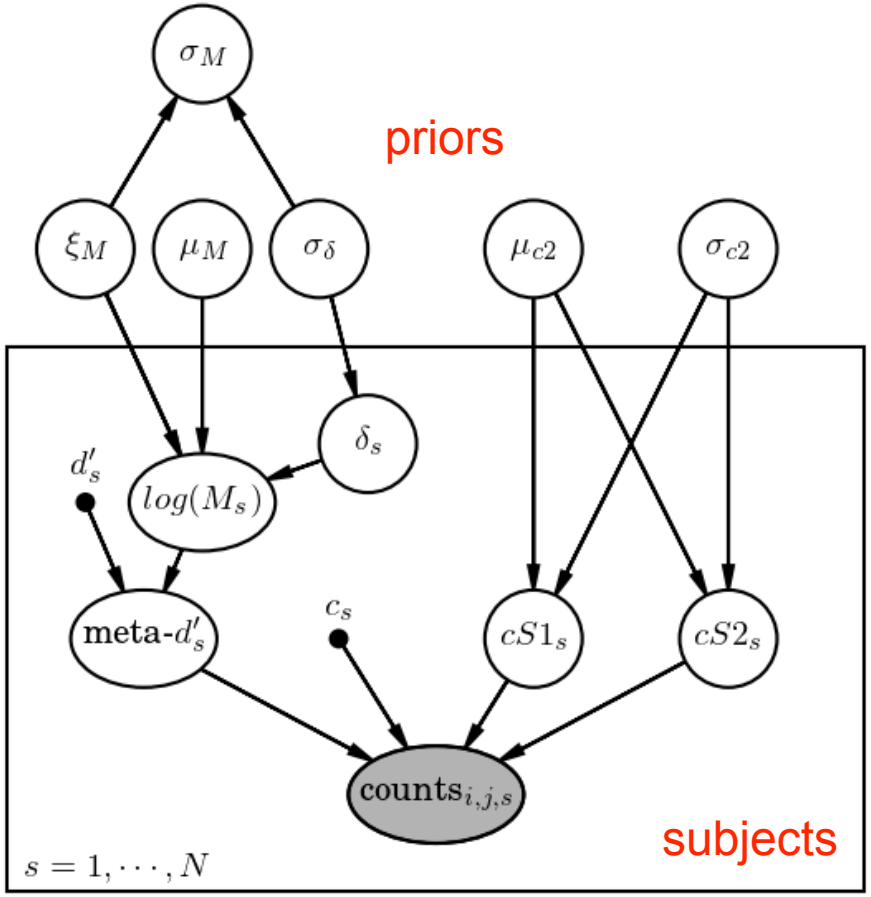
$$\xi_M \sim Beta(1,1)$$

$$\sigma_\delta \sim \mathcal{HN}(1)$$



Fleming (2017) *Neuroscience of Consciousness*

Bayesian hierarchical model for meta-*d'* (HMeta-d)



$$\mu_{c2} \sim \mathcal{N}(0, 10)$$

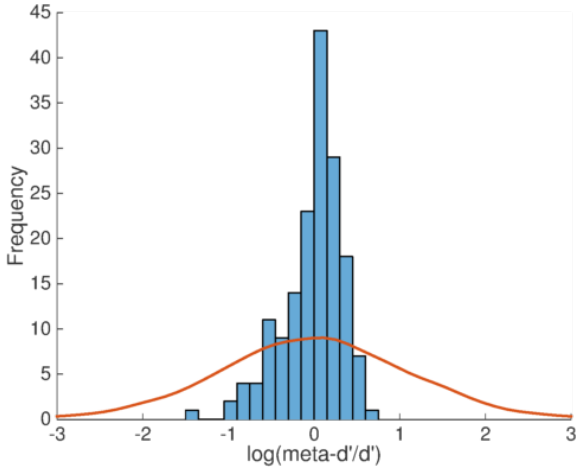
$$\sigma_{c2} \sim \mathcal{HN}(10)$$

$$\mu_M \sim N(0, 1)$$

$$\sigma_M = |\xi_M| \times \delta_s$$

$$\xi_M \sim Beta(1,1)$$

$$\sigma_\delta \sim \mathcal{HN}(1)$$



Fleming (2017) *Neuroscience of Consciousness*

Bayesian hierarchical model for meta-*d'* (HMeta-d)

$$\mu_{c2} \sim \mathcal{N}(0, 10)$$

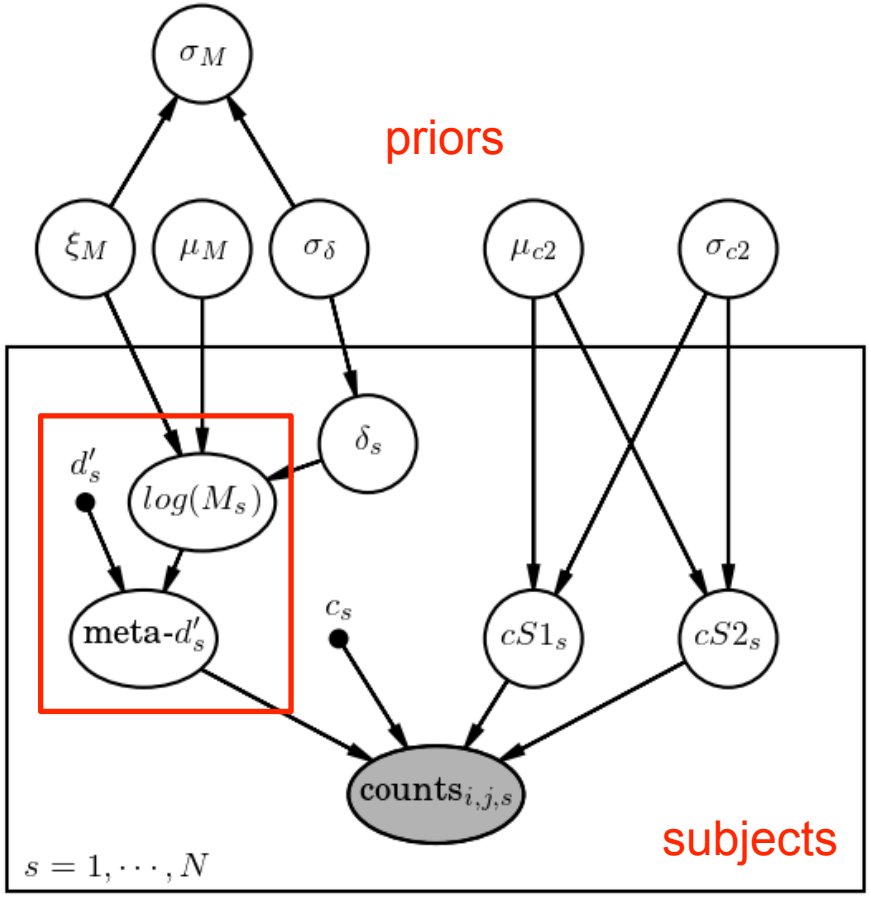
$$\sigma_{c2} \sim \mathcal{HN}(10)$$

$$\mu_M \sim N(0, 1)$$

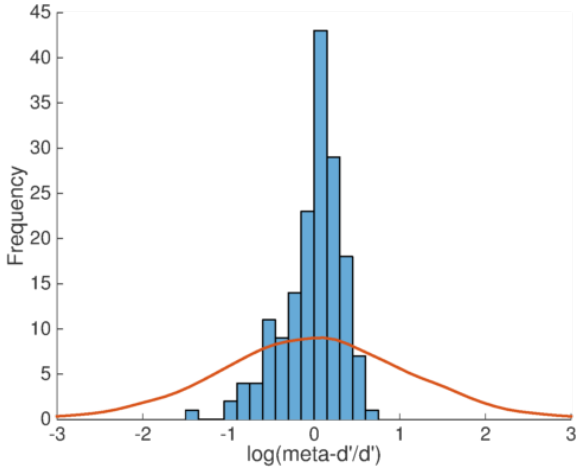
$$\sigma_M = |\xi_M| \times \delta_s$$

$$\xi_M \sim Beta(1,1)$$

$$\sigma_\delta \sim \mathcal{HN}(1)$$



direct estimation of meta-d'/d'

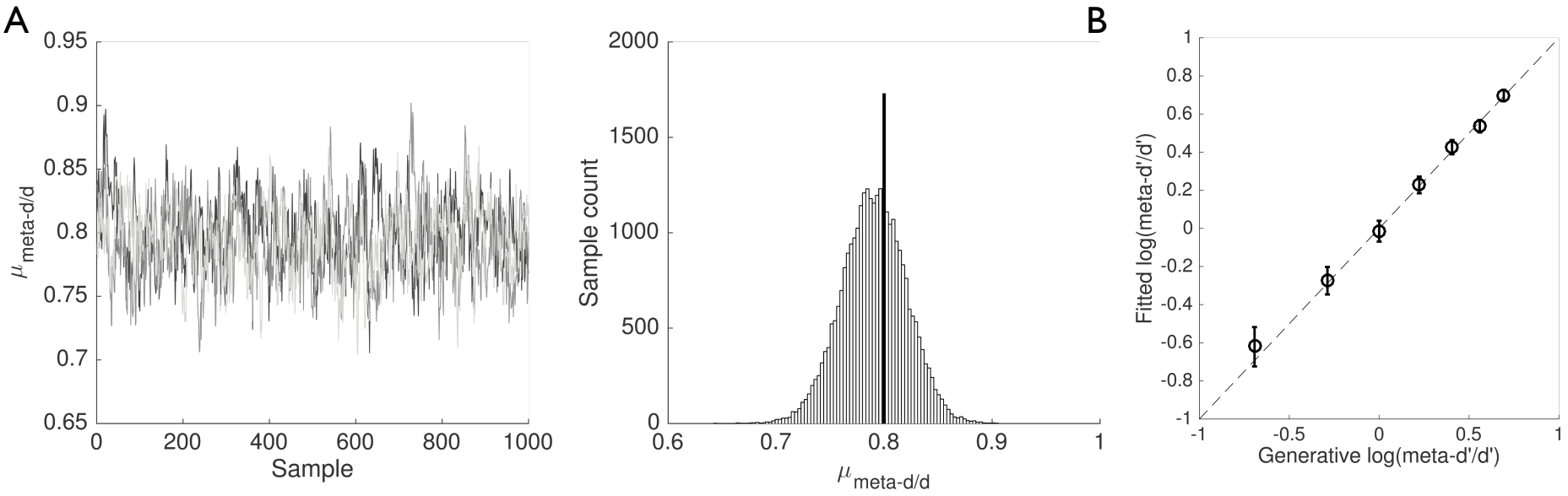


Fleming (2017) *Neuroscience of Consciousness*

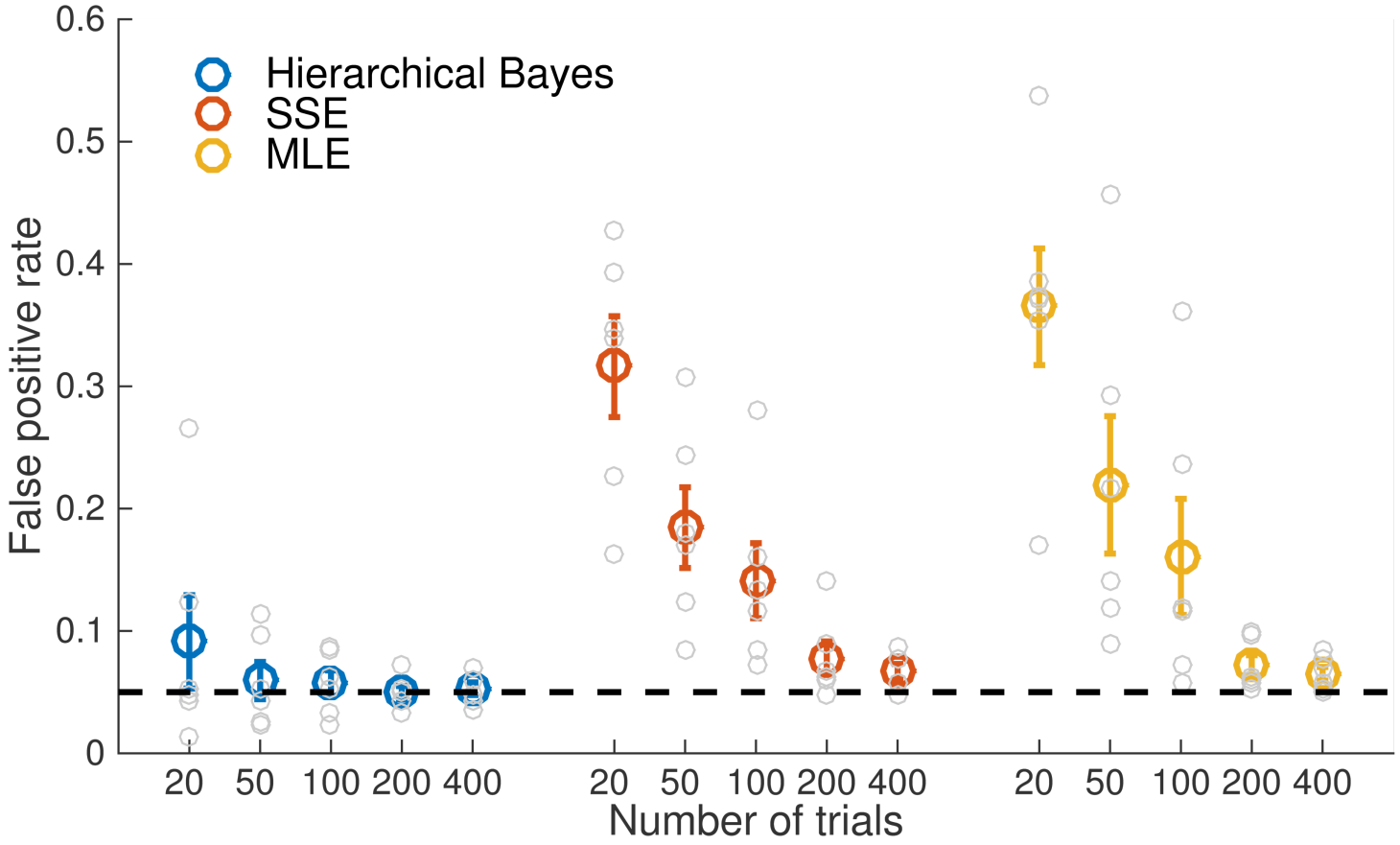
Hierarchical model for meta-*d'* (HMeta-d)

Code and tutorial available at https://github.com/smfleming/HMeta-d

MCMC samples of group-level metacognitive efficiency:

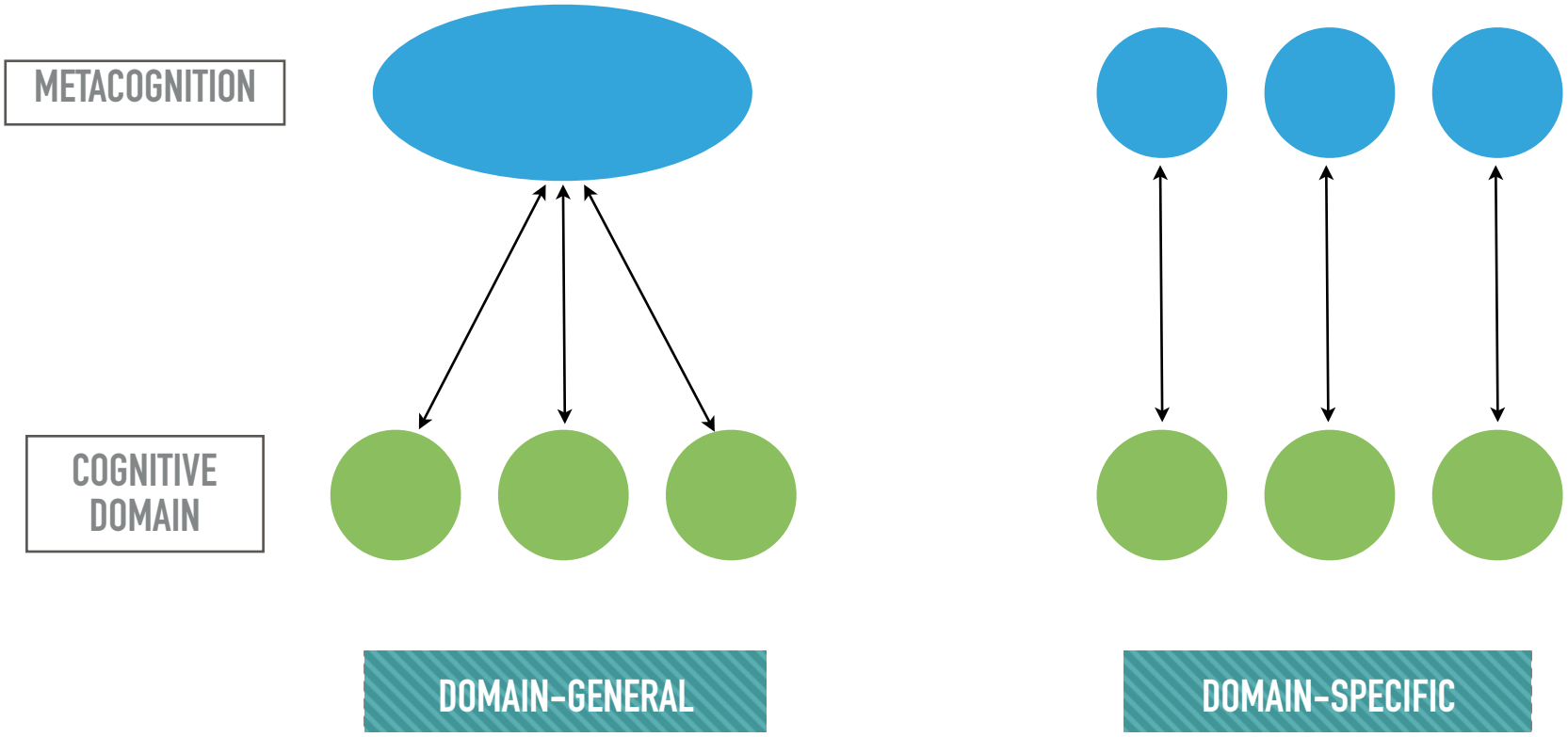


Hierarchical model for meta-*d'* (HMeta-d)



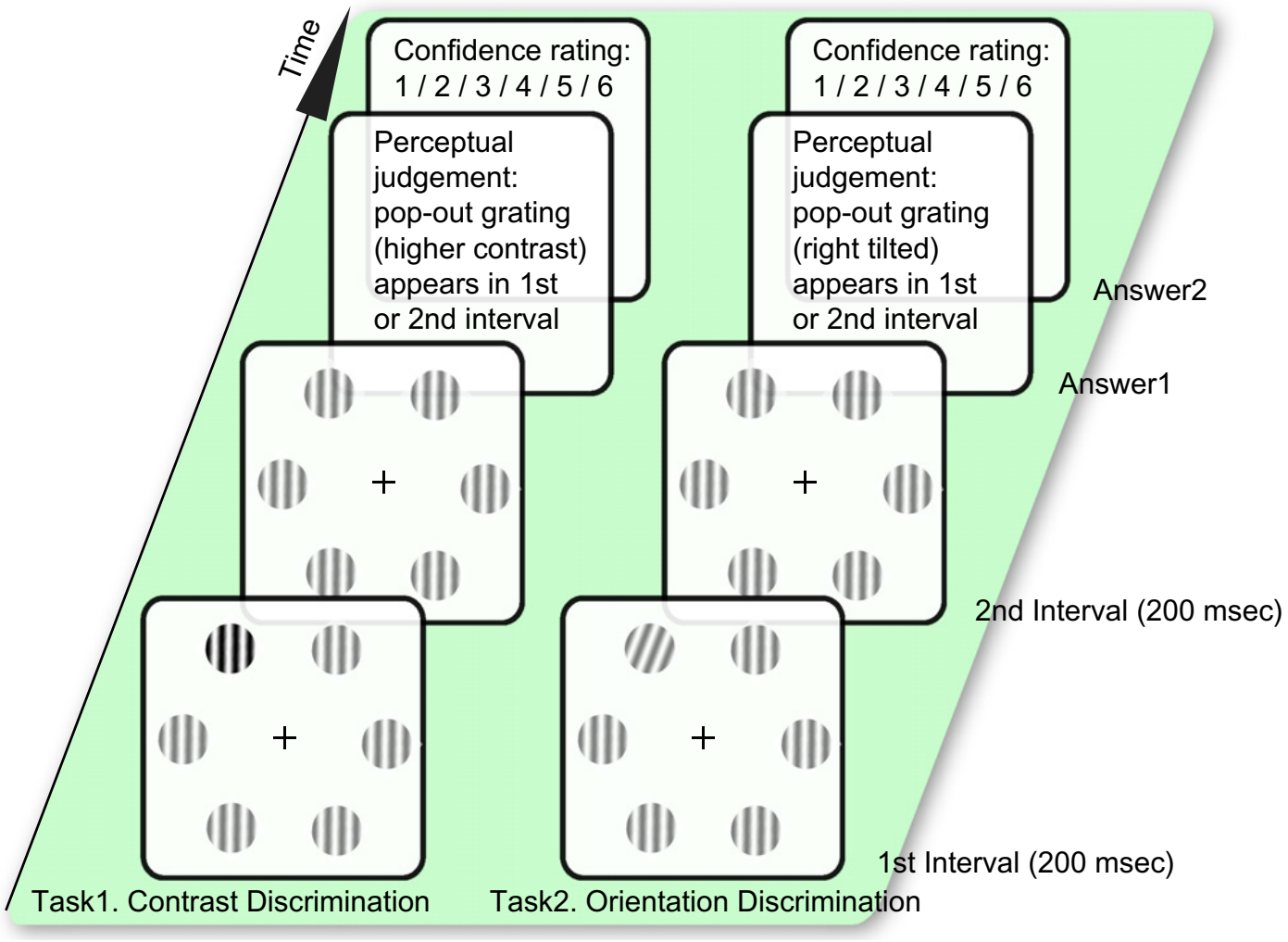
Accurate estimates of **group-level metacognitive efficiency** possible with relatively low trial numbers when using HMeta-d

Domain-general or domain-specific?



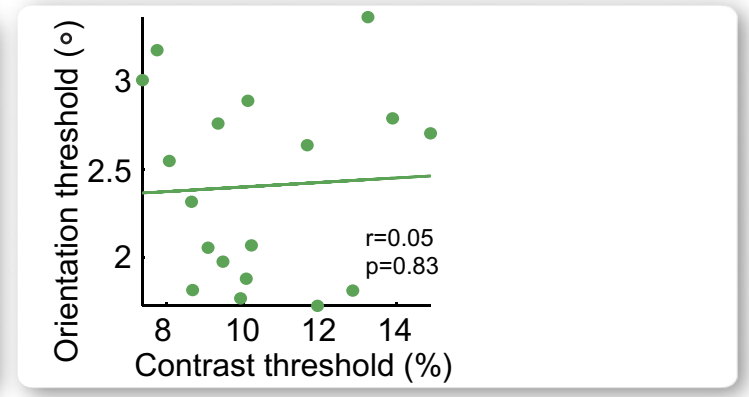
Two broad approaches:

- Analysis of shared variance in individual differences
- Identification of shared/distinct neural resources supporting metacognitive ability



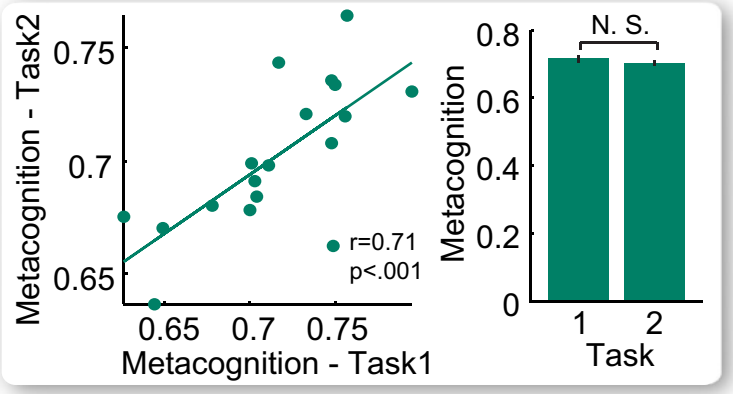
Does having good metacognition on task 1 predict good metacognition on task 2?

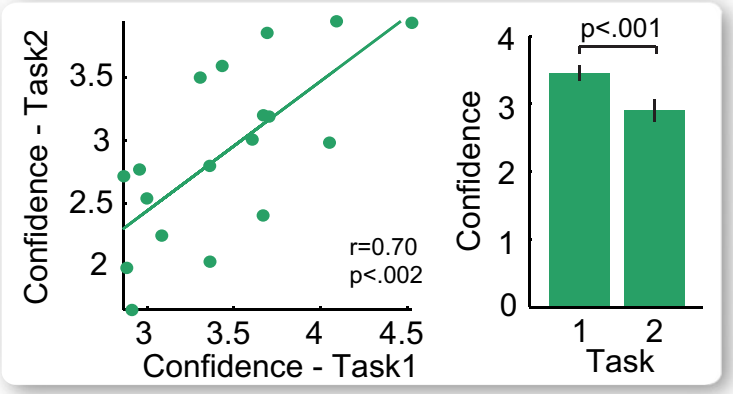
Song, Kanai, Fleming et al. (2011) *Consciousness & Cognition*

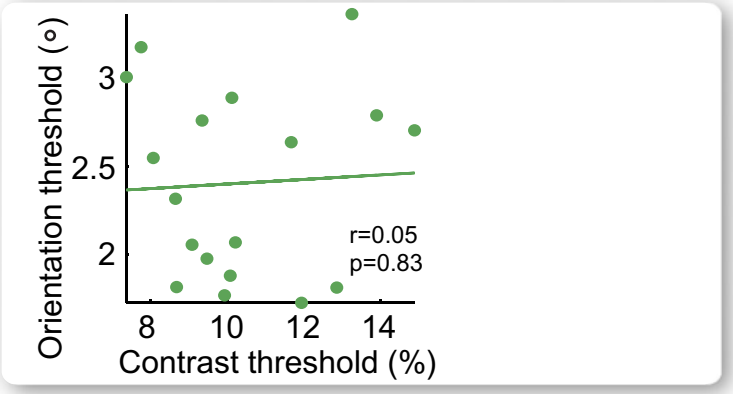


Performance thresholds uncorrelated

Song, Kanai, Fleming et al. (2011) *Consciousness & Cognition*





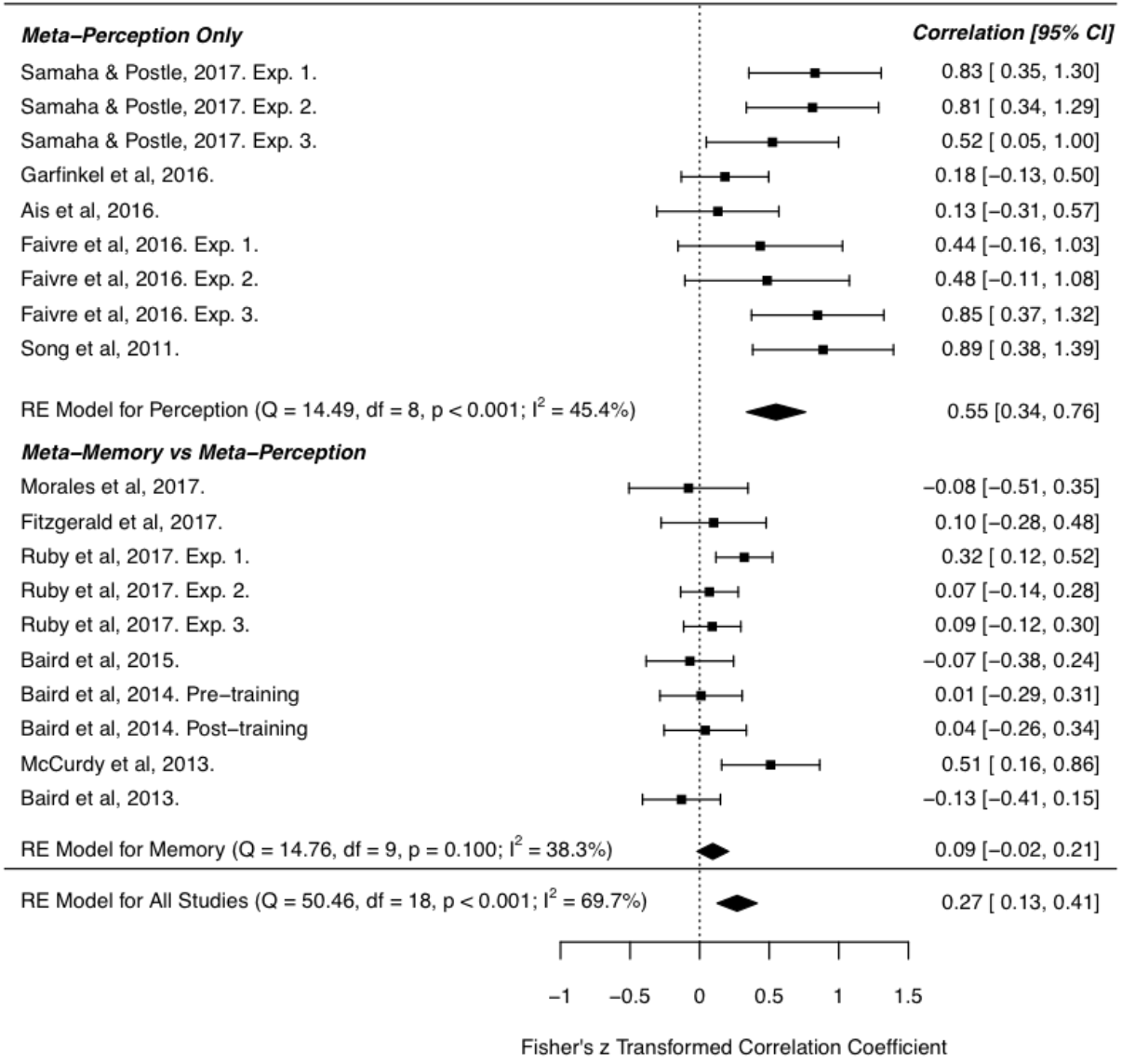


Significant correlations in metacognition (sensitivity and bias) across tasks

Performance thresholds uncorrelated

Song, Kanai, Fleming et al. (2011) *Consciousness & Cognition*

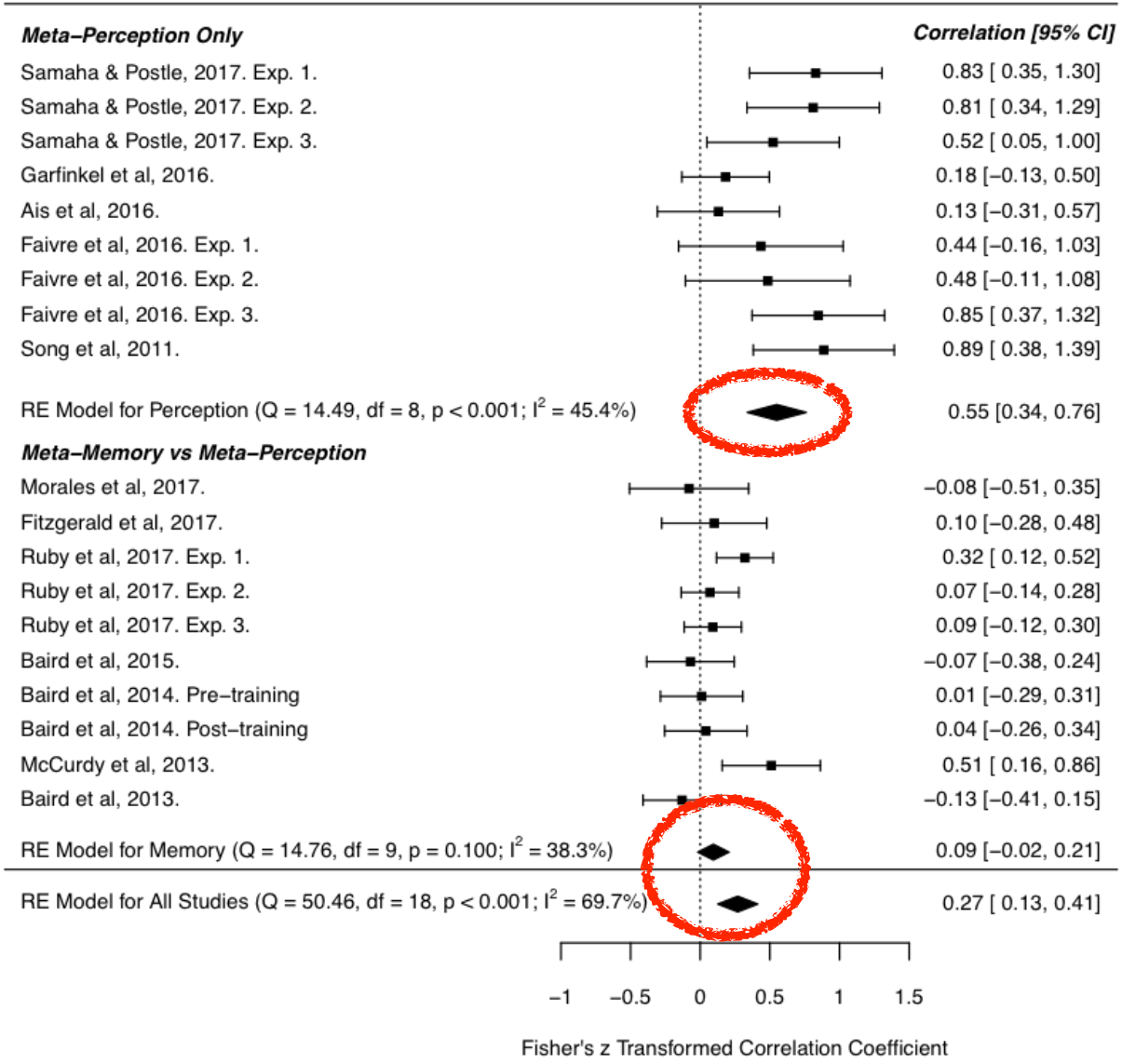
Meta-analysis of efficiency correlations



Rouault, McWilliams, Allen & Fleming (in press) *Personality Neuroscience*

Meta-analysis of efficiency correlations

Some evidence for domain-generality, but lack of consistency across task designs / low power



Rouault, McWilliams, Allen & Fleming (in press) *Personality Neuroscience*

N=181, hierarchical modelling of metacognitive efficiency across 4 2AFC tasks

Mazancieux et al. *in prep*

N=181, hierarchical modelling of metacognitive efficiency across 4 2AFC tasks

$$[\log(M1_s)\,\log(M2_s)\,\log(M3_s)\,\log(M4_s)] \sim N\left(\begin{bmatrix}\mu_{M1}\\ \mu_{M2}\\ \mu_{M3}\\ \mu_{M4}\end{bmatrix}, \begin{bmatrix}{\sigma^2}_{M1} & \rho_{M1M2}\sigma_{M1}\sigma_{M2} & \rho_{M1M3}\sigma_{M1}\sigma_{M3} & \rho_{M1M4}\sigma_{M1}\sigma_{M4}\\ \rho_{M1M2}\sigma_{M1}\sigma_{M2} & {\sigma^2}_{M2} & \rho_{M2M3}\sigma_{M2}\sigma_{M3} & \rho_{M2M4}\sigma_{M2}\sigma_{M4}\\ \rho_{M1M3}\sigma_{M1}\sigma_{M3} & \rho_{M2M3}\sigma_{M2}\sigma_{M3} & {\sigma^2}_{M3} & \rho_{M3M4}\sigma_{M3}\sigma_{M4}\\ \rho_{M1M4}\sigma_{M1}\sigma_{M4} & \rho_{M2M4}\sigma_{M2}\sigma_{M4} & \rho_{M3M4}\sigma_{M3}\sigma_{M4} & {\sigma^2}_{M4}\end{bmatrix}\right)$$

Priors were specified as follows:

$$\mu_{M1}, \mu_{M2}, \mu_{M3}, \mu_{M4} \sim N(0, 1)$$

$$\sigma_{M1}, \sigma_{M2}, \sigma_{M3}, \sigma_{M4} \sim \text{InvSqrtGamma}(0.001, 0.001)$$

$$\rho_{M1M2}, \rho_{M1M3}, \rho_{M1M4}, \rho_{M2M3}, \rho_{M2M4}, \rho_{M3M4} \sim \text{Uniform}(-1, 1)$$

Mazancieux et al. *in prep*

N=181, hierarchical modelling of metacognitive efficiency across 4 2AFC tasks

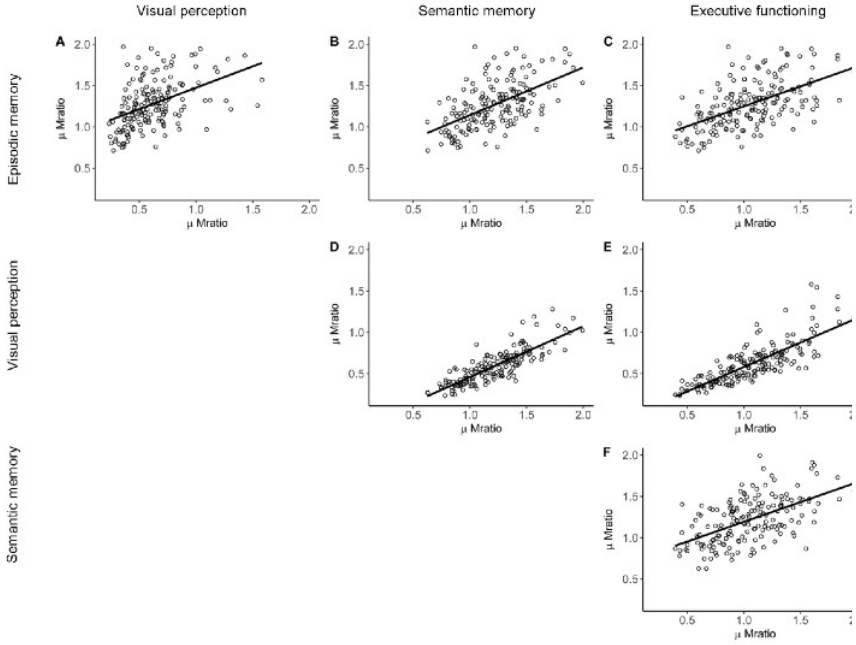
$$[\log(M1_s)\,\log(M2_s)\,\log(M3_s)\,\log(M4_s)] \sim N\left(\begin{bmatrix}\mu_{M1}\\ \mu_{M2}\\ \mu_{M3}\\ \mu_{M4}\end{bmatrix}, \begin{bmatrix}\sigma^2{}_{M1} & \rho_{M1M2}\sigma_{M1}\sigma_{M2} & \rho_{M1M3}\sigma_{M1}\sigma_{M3} & \rho_{M1M4}\sigma_{M1}\sigma_{M4}\\ \rho_{M1M2}\sigma_{M1}\sigma_{M2} & \sigma^2{}_{M2} & \rho_{M2M3}\sigma_{M2}\sigma_{M3} & \rho_{M2M4}\sigma_{M2}\sigma_{M4}\\ \rho_{M1M3}\sigma_{M1}\sigma_{M3} & \rho_{M2M3}\sigma_{M2}\sigma_{M3} & \sigma^2{}_{M3} & \rho_{M3M4}\sigma_{M3}\sigma_{M4}\\ \rho_{M1M4}\sigma_{M1}\sigma_{M4} & \rho_{M2M4}\sigma_{M2}\sigma_{M4} & \rho_{M3M4}\sigma_{M3}\sigma_{M4} & \sigma^2{}_{M4}\end{bmatrix}\right)$$

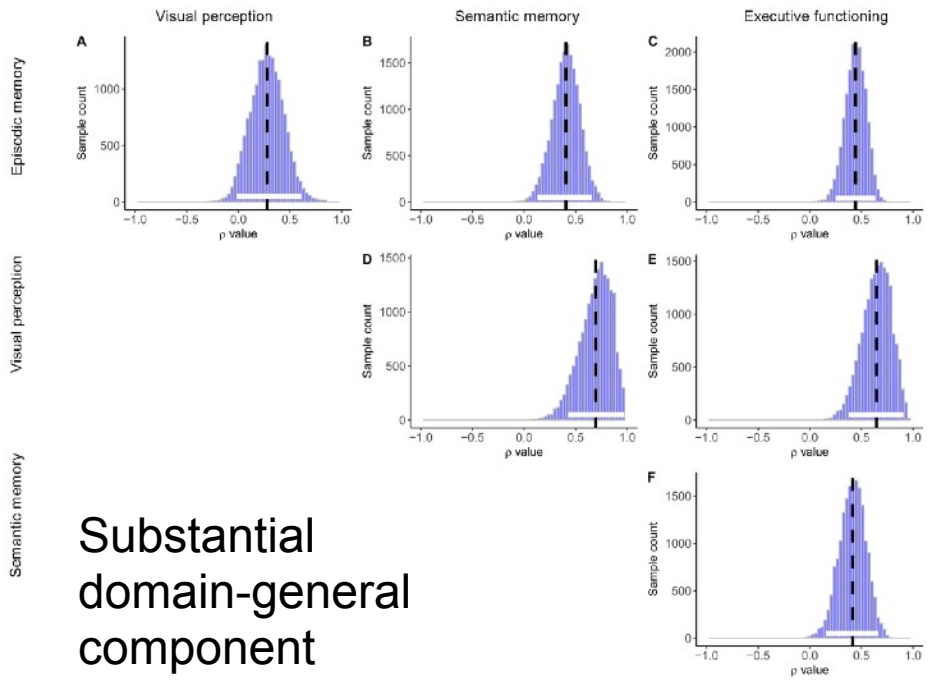
Priors were specified as follows:

$$\mu_{M1}, \mu_{M2}, \mu_{M3}, \mu_{M4} \sim N(0, 1)$$

$$\sigma_{M1}, \sigma_{M2}, \sigma_{M3}, \sigma_{M4} \sim \text{InvSqrtGamma}(0.001, 0.001)$$

$$\rho_{M1M2}, \rho_{M1M3}, \rho_{M1M4}, \rho_{M2M3}, \rho_{M2M4}, \rho_{M3M4} \sim \text{Uniform}(-1, 1)$$





Substantial domain-general component

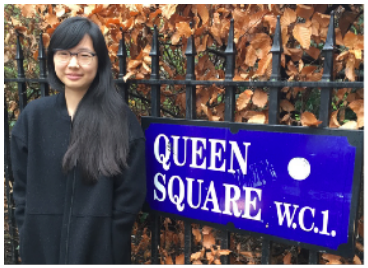
Mazancieux et al. *in prep*

Is metacognition related to psychopathology?

Experiment 1 - N=498 participants
Experiment 2 - N=497 participants

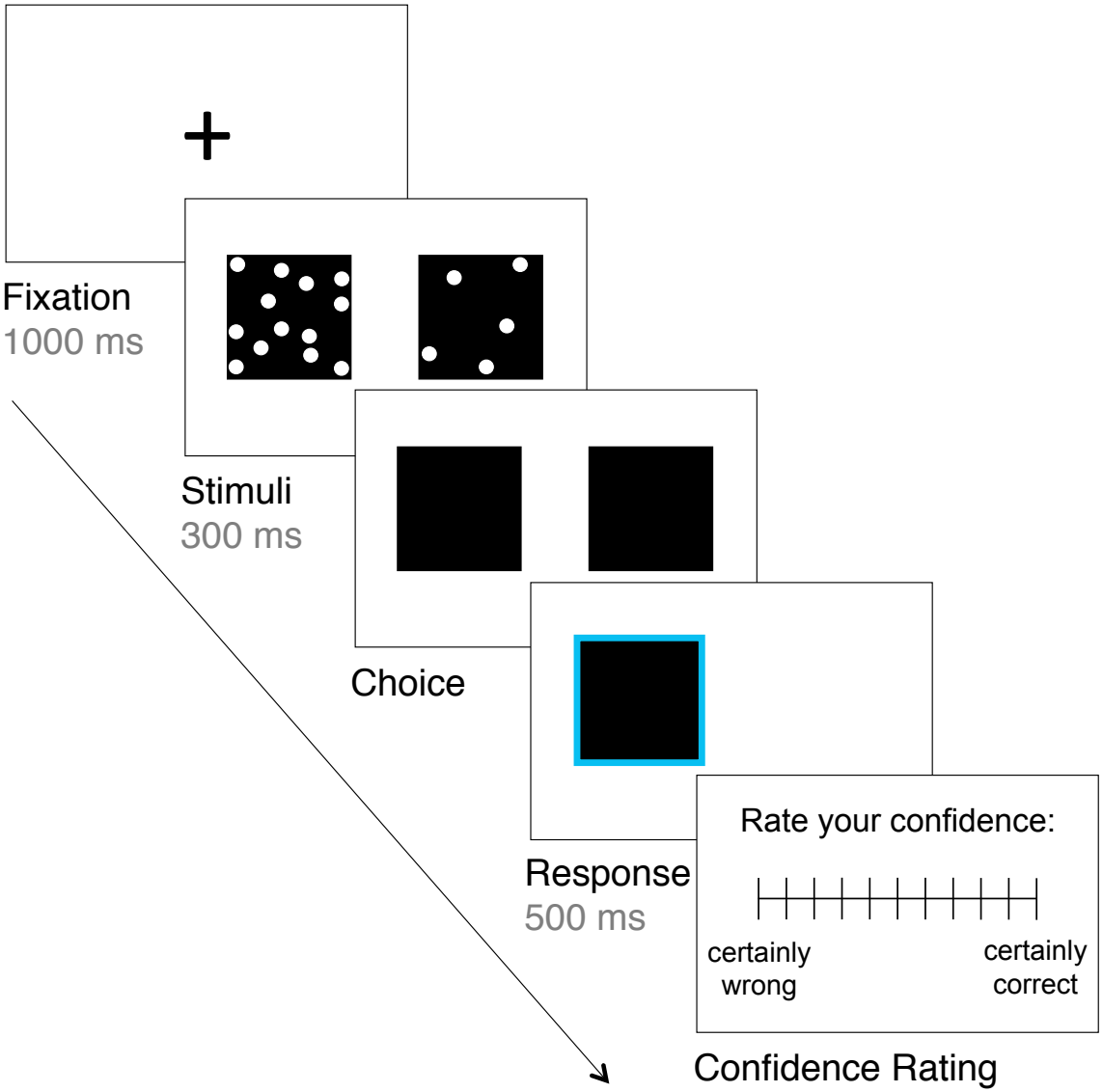
Perceptual decision-making task

Self-reported symptom questionnaires



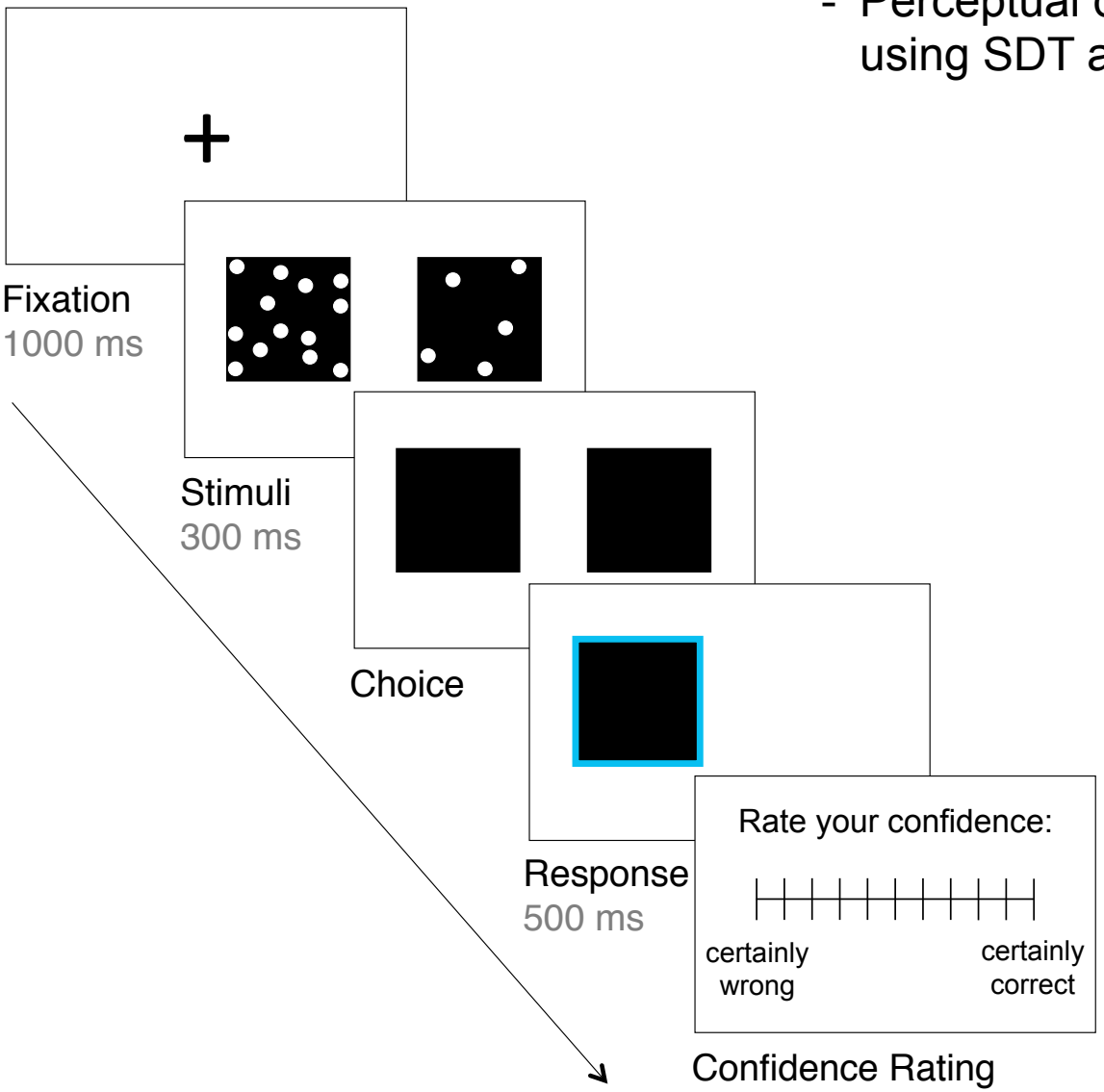
Rouault, Seow, Gillan & Fleming (2018) *Biological Psychiatry*

Decision-making + confidence task



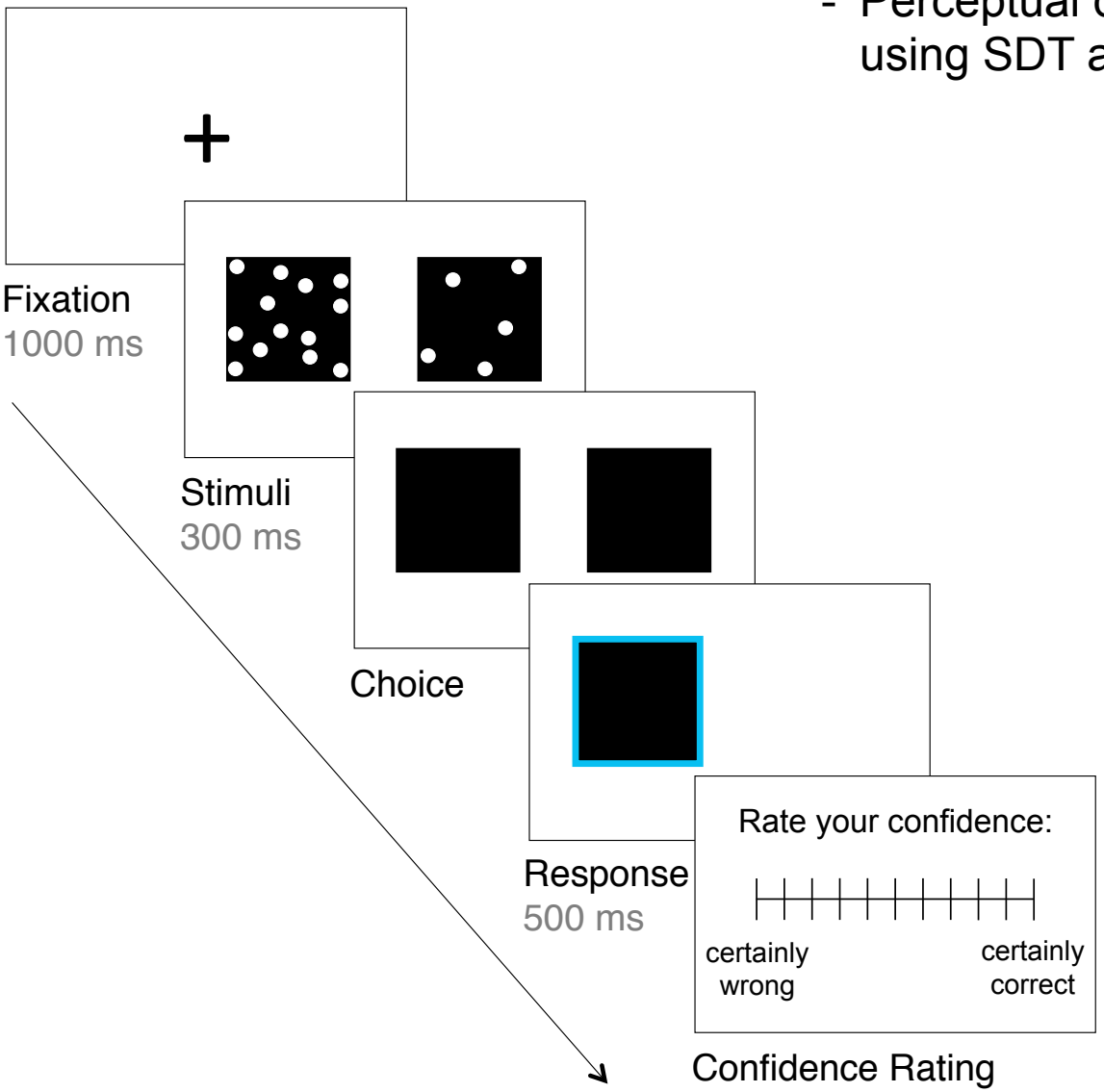
Decision-making + confidence task

- Perceptual decision-making quantified using SDT and drift-diffusion modelling

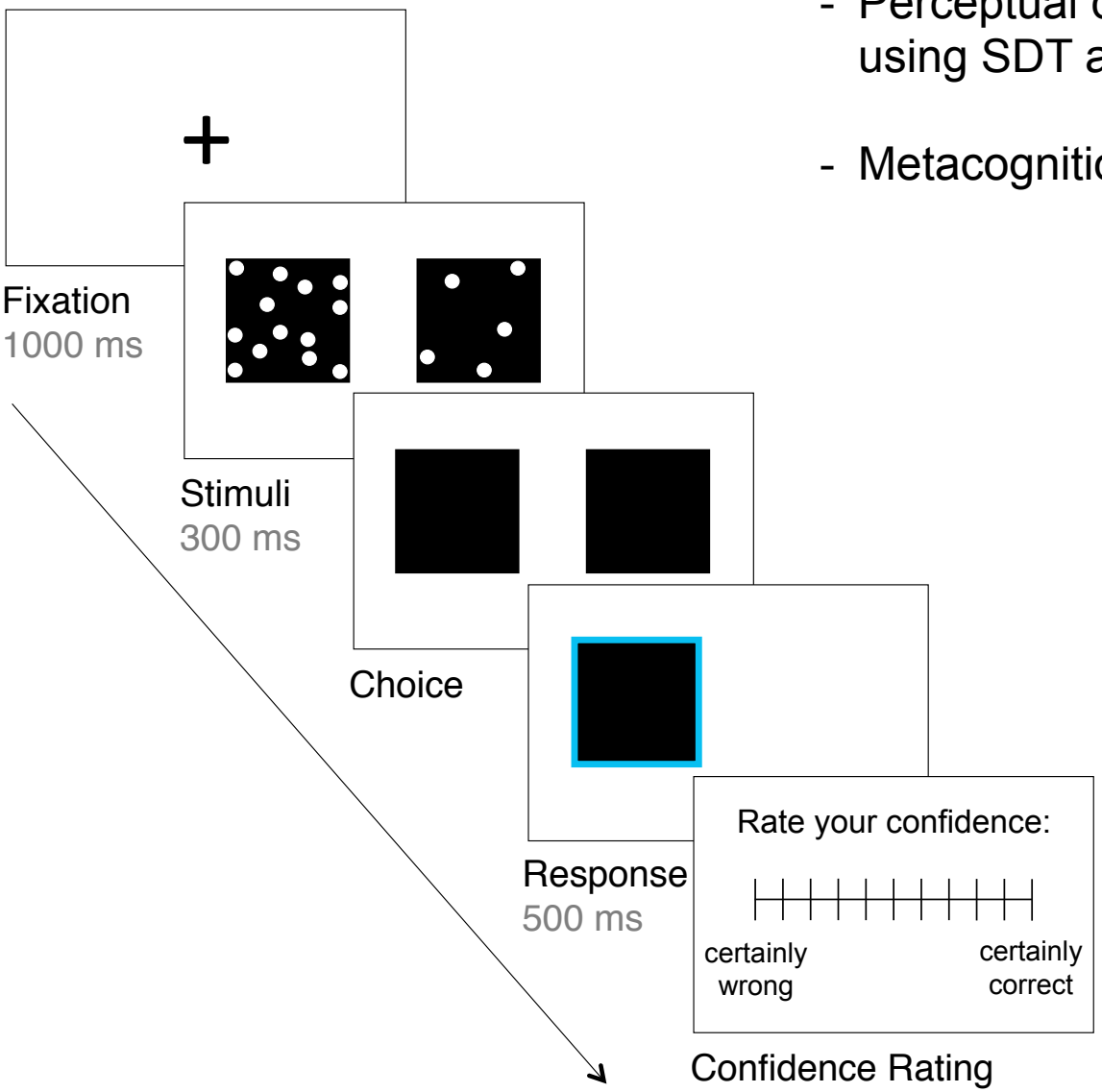


Decision-making + confidence task

- Perceptual decision-making quantified using SDT and drift-diffusion modelling

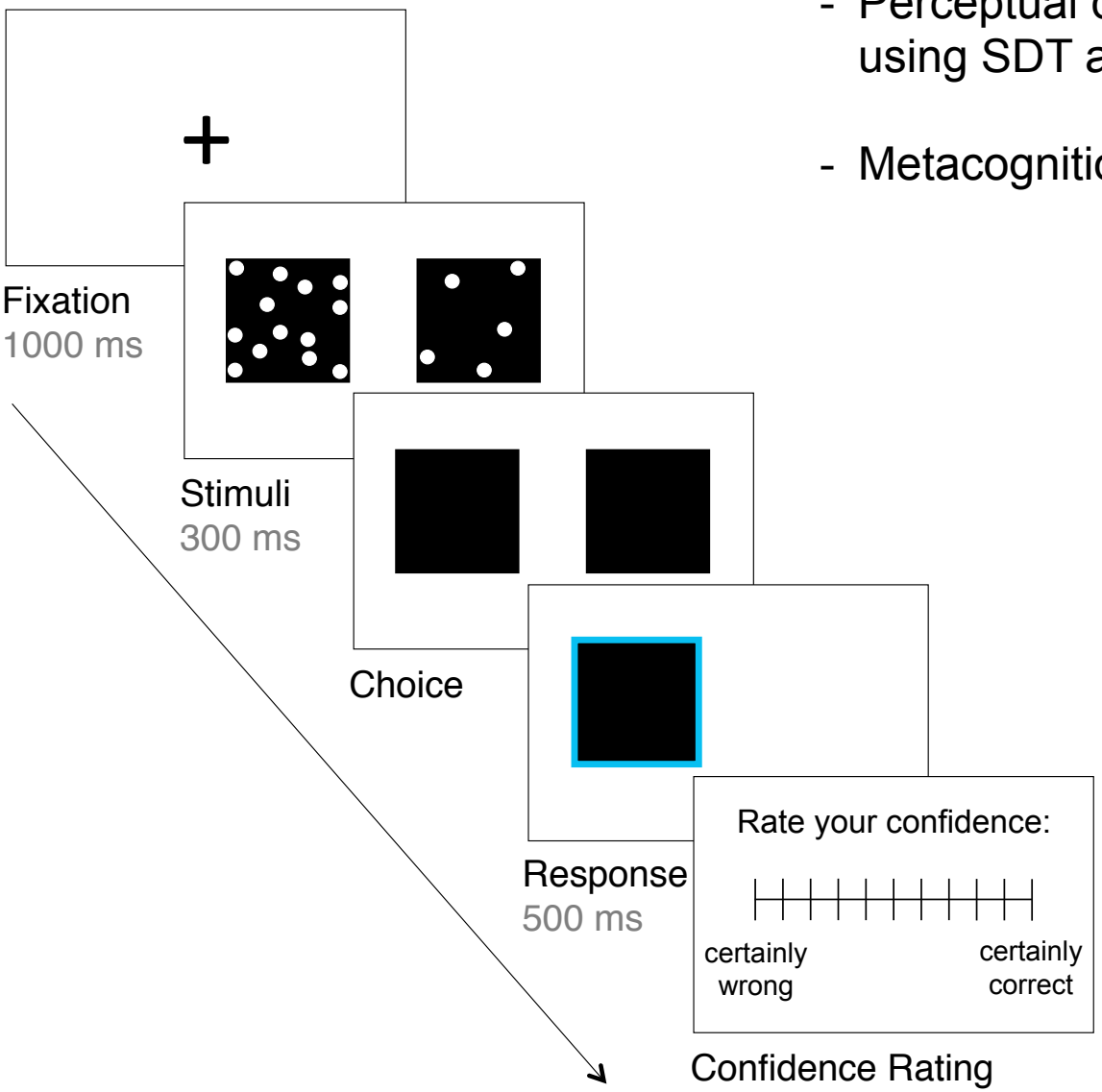


Decision-making + confidence task



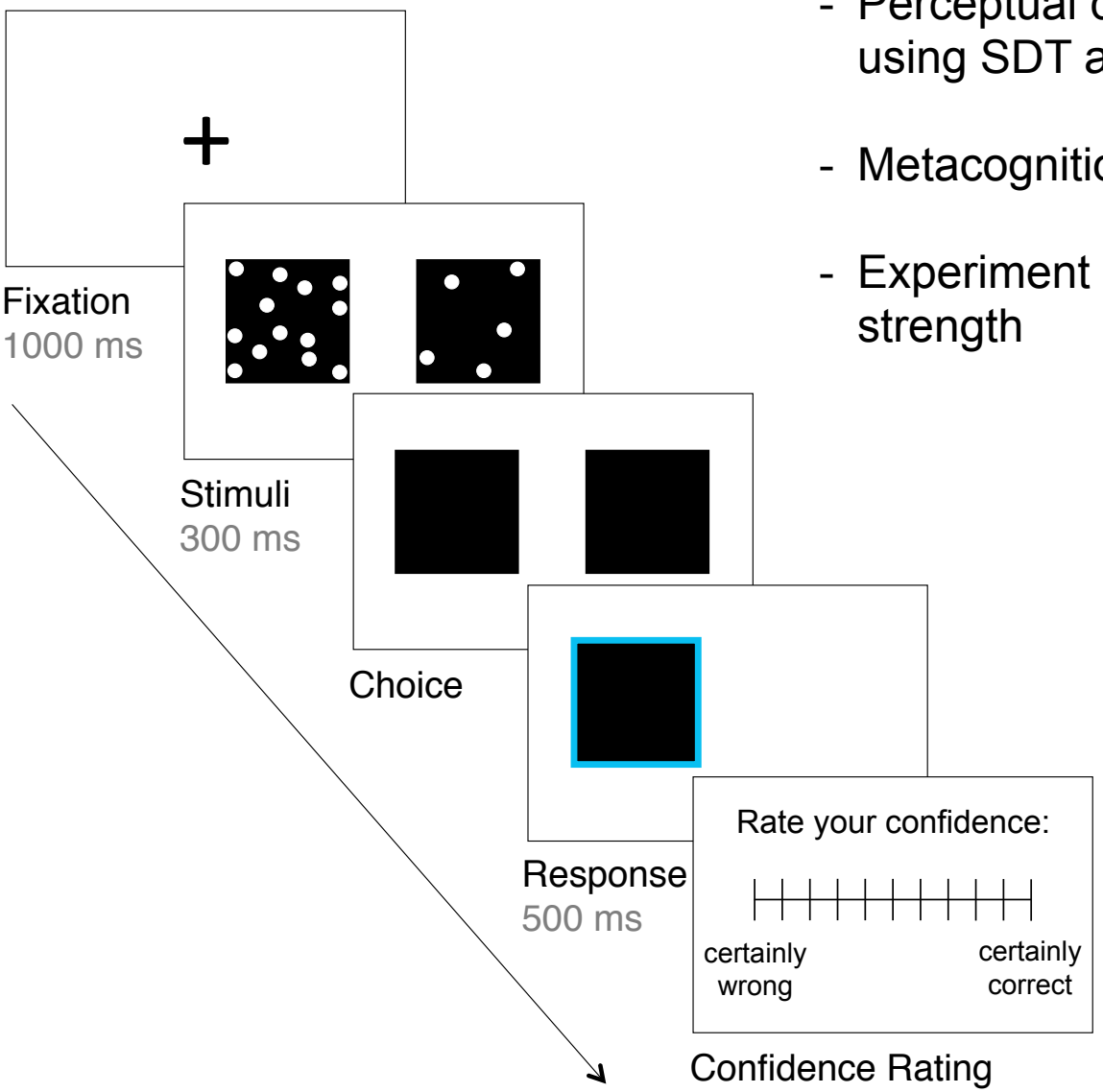
- Perceptual decision-making quantified using SDT and drift-diffusion modelling
- Metacognition quantified using meta-d'

Decision-making + confidence task



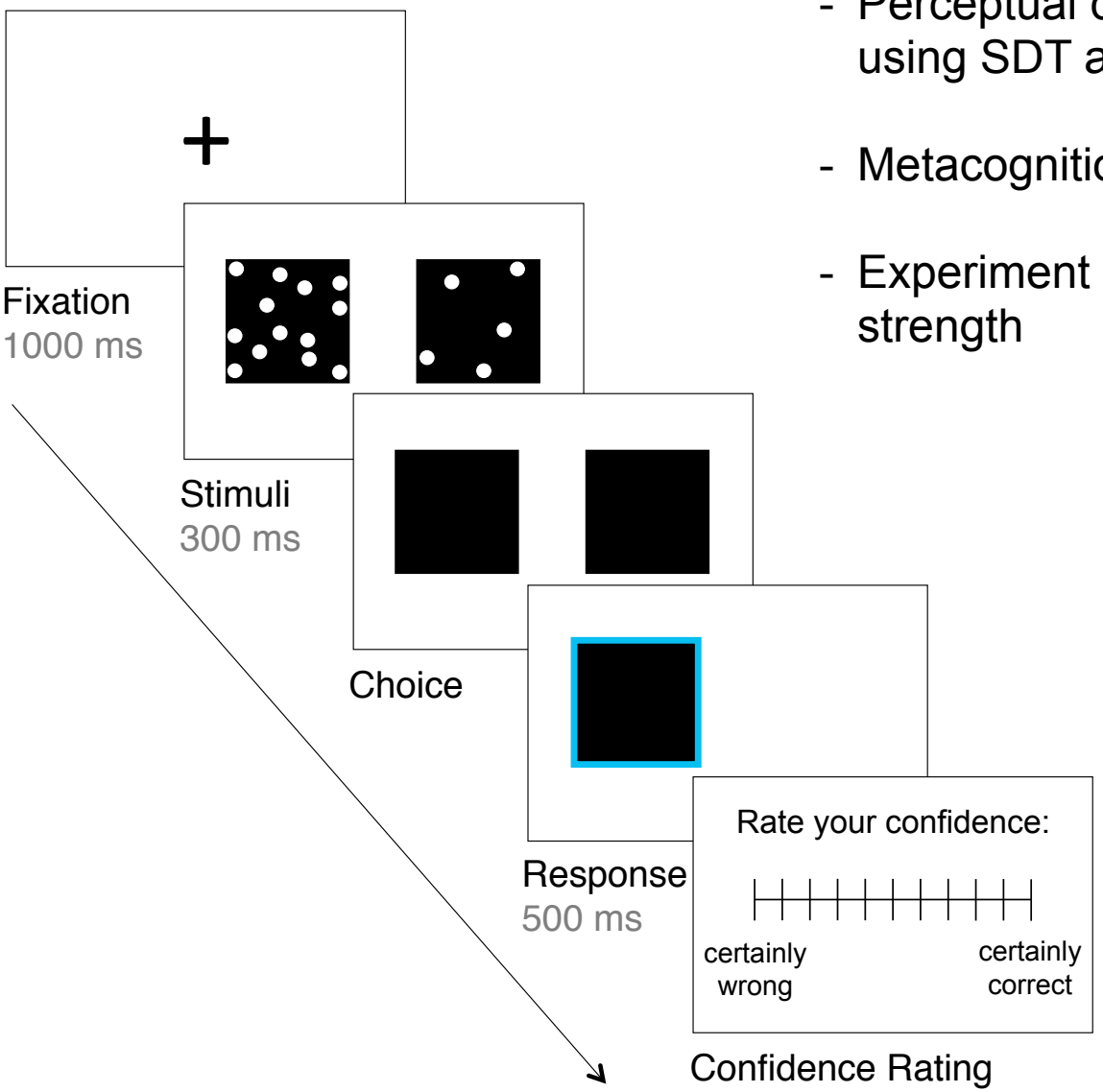
- Perceptual decision-making quantified using SDT and drift-diffusion modelling
- Metacognition quantified using meta-d'

Decision-making + confidence task



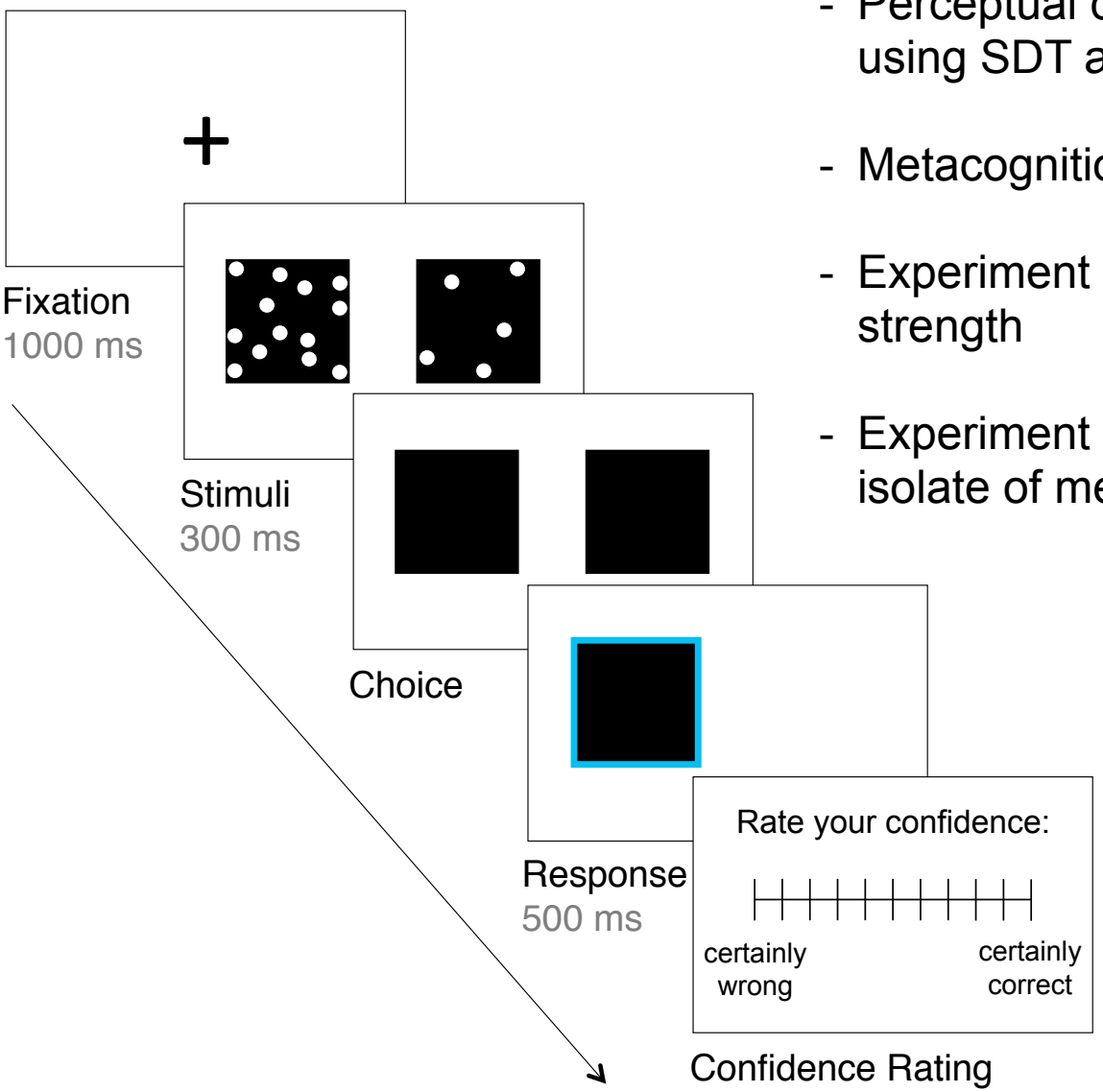
- Perceptual decision-making quantified using SDT and drift-diffusion modelling
- Metacognition quantified using meta-d'
- Experiment 1 = variable stimulus strength

Decision-making + confidence task



- Perceptual decision-making quantified using SDT and drift-diffusion modelling
- Metacognition quantified using meta-d'
- Experiment 1 = variable stimulus strength

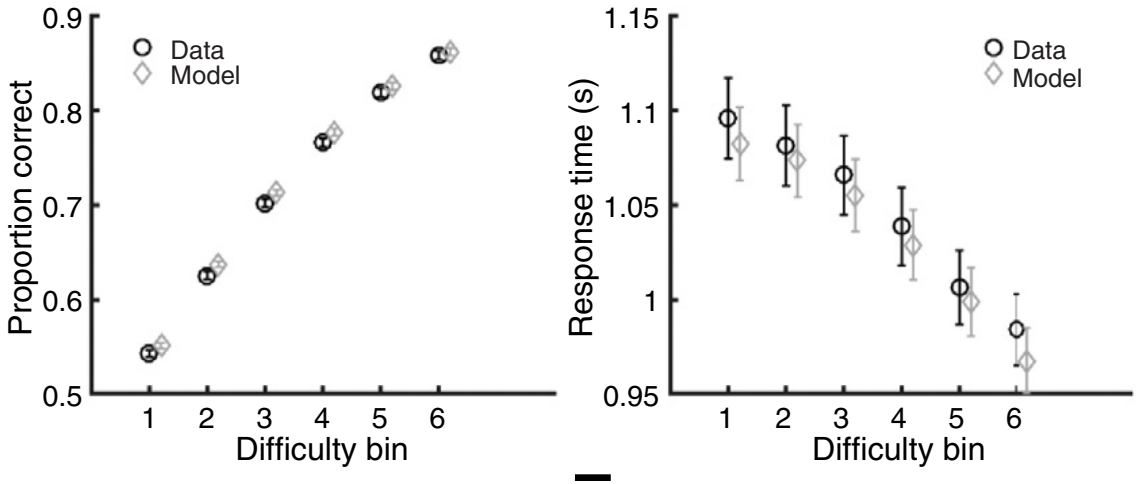
Decision-making + confidence task



- Perceptual decision-making quantified using SDT and drift-diffusion modelling
- Metacognition quantified using meta-d'
- Experiment 1 = variable stimulus strength
- Experiment 2 = staircase used to isolate of metacognitive variability

Decision-making + confidence task

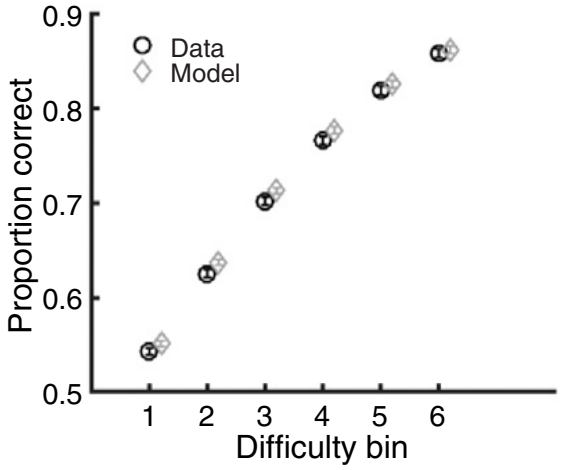
Perceptual decision performance

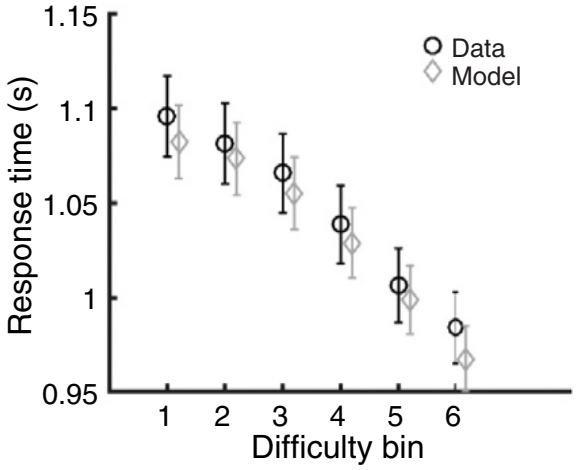


Experiment 1, N=498

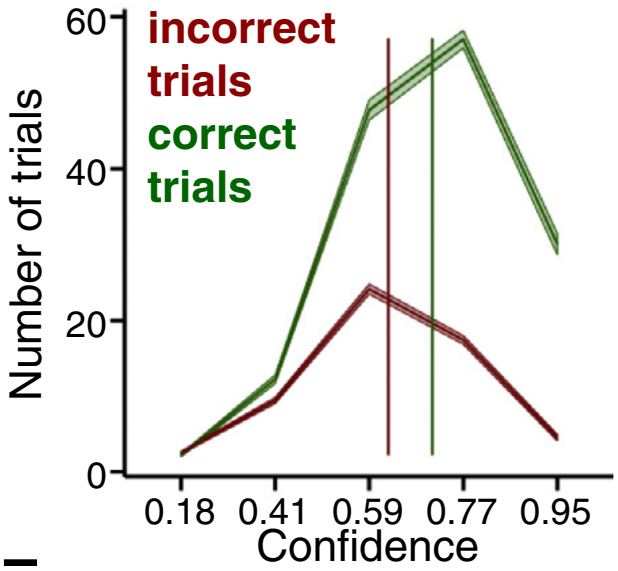
Decision-making + confidence task

Perceptual decision performance



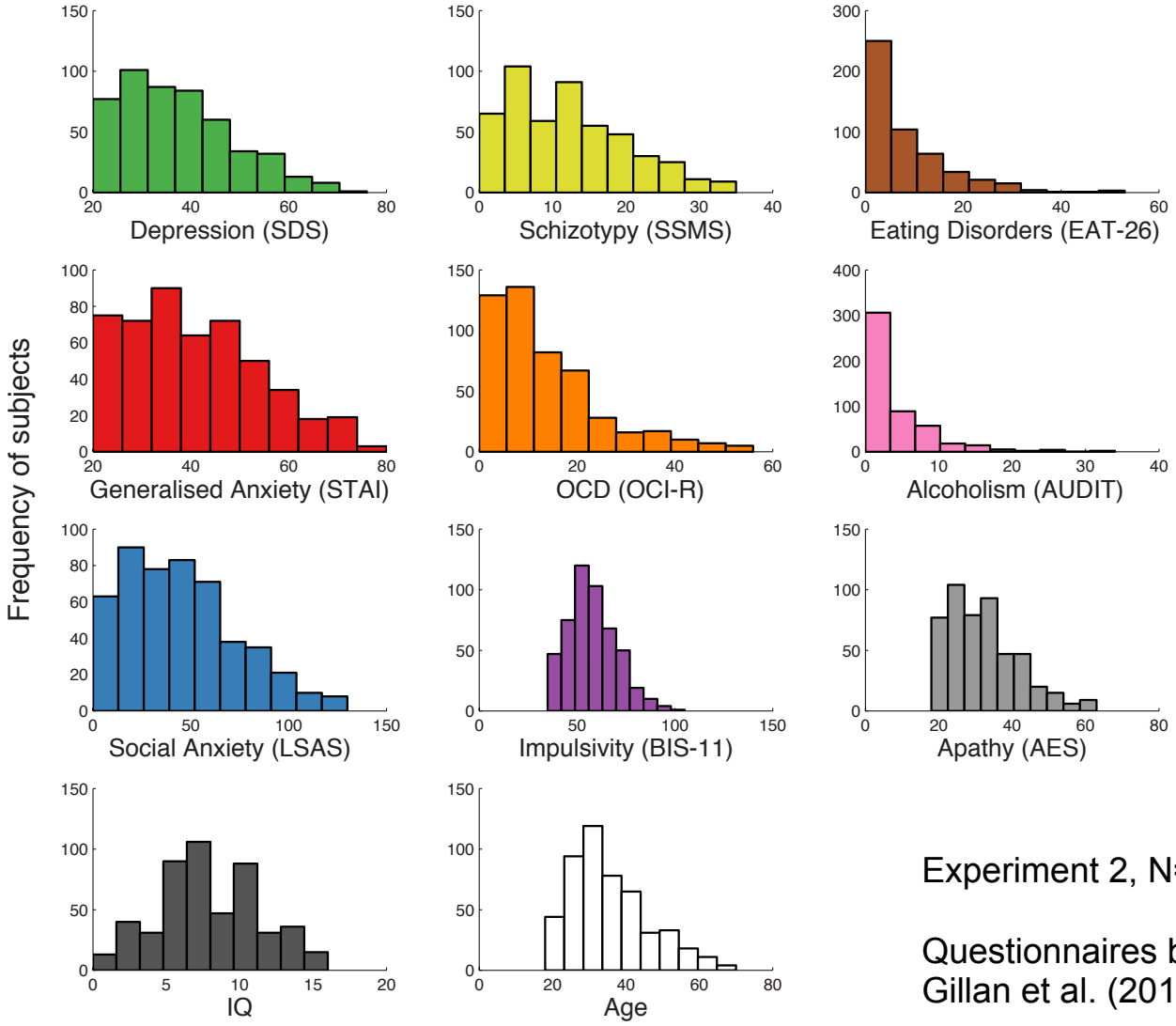


Confidence ratings



Experiment 1, N=498

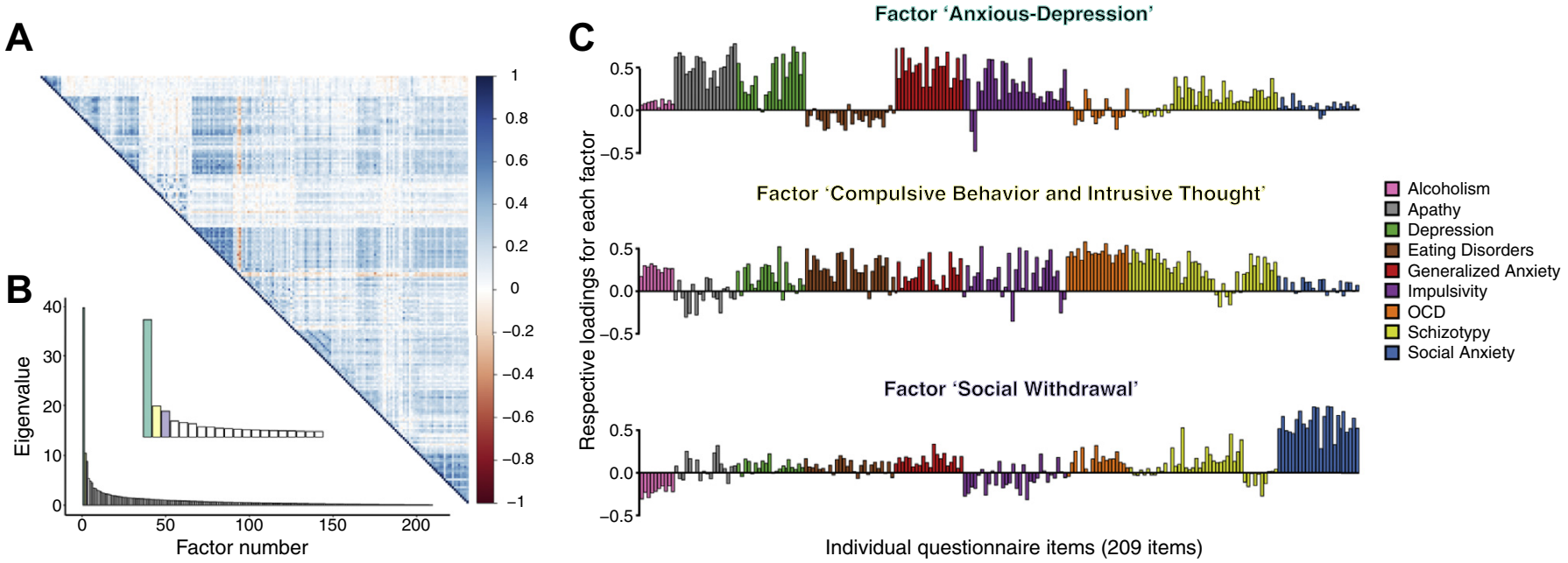
Self-reported symptom questionnaires



Experiment 2, N=497

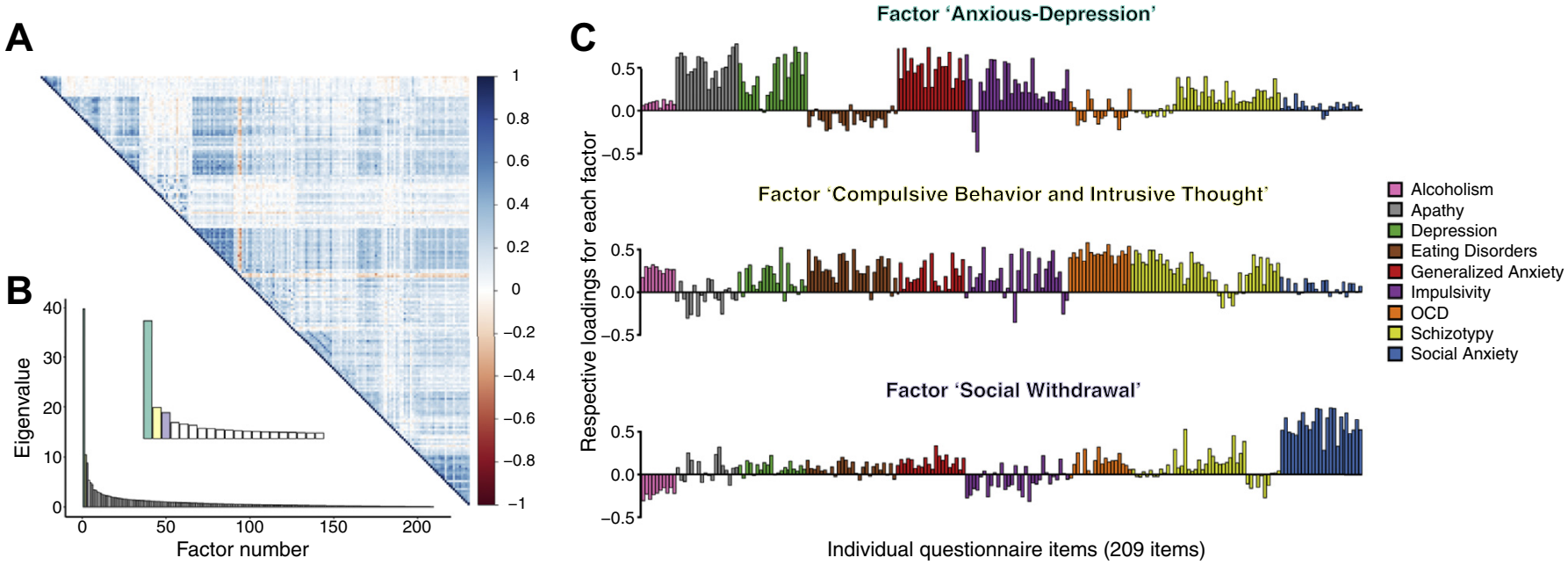
Questionnaires based on Gillan et al. (2016) eLife

Identifying latent transdiagnostic dimensions



See also Gillan et al. (2016) eLife

Identifying latent transdiagnostic dimensions



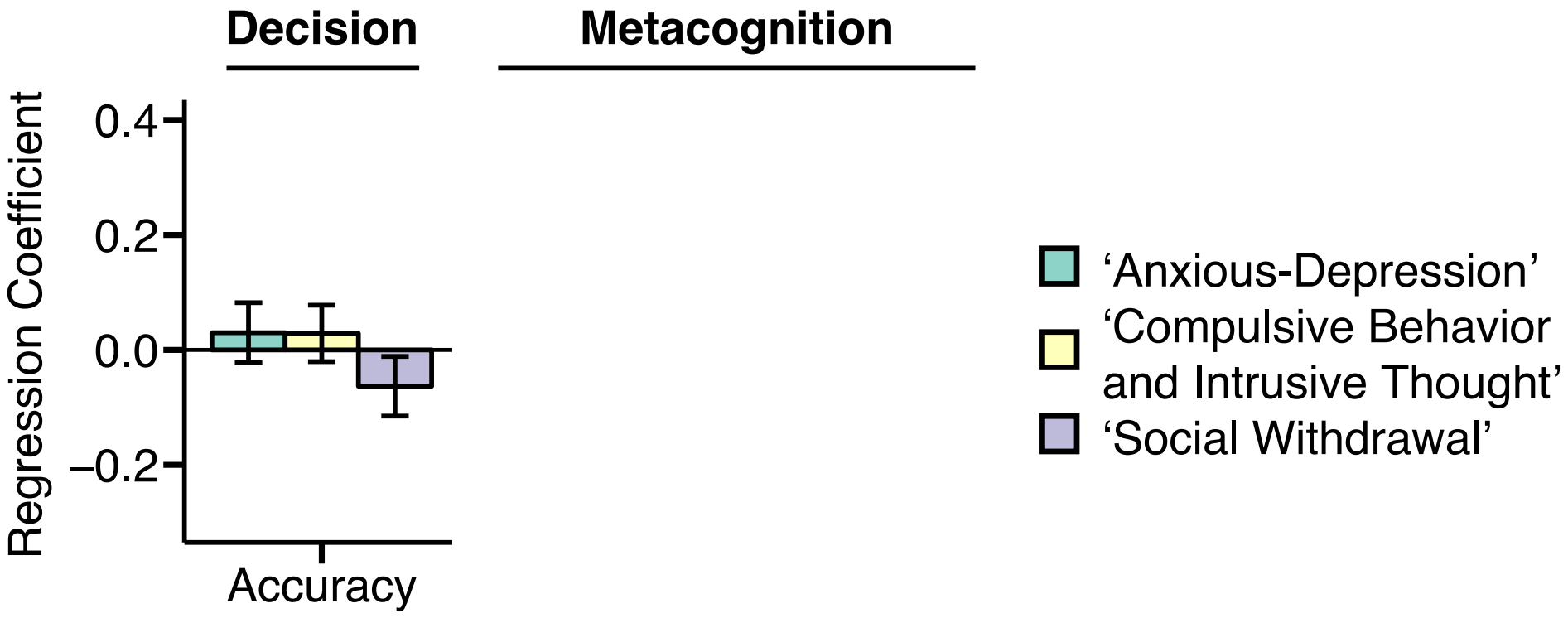
See also Gillan et al. (2016) eLife

Anxious/ Depression

Compulsive Behavior and Intrusive Thought

Social Withdrawal

Metacognition (but not decision performance) is associated with latent symptom dimensions

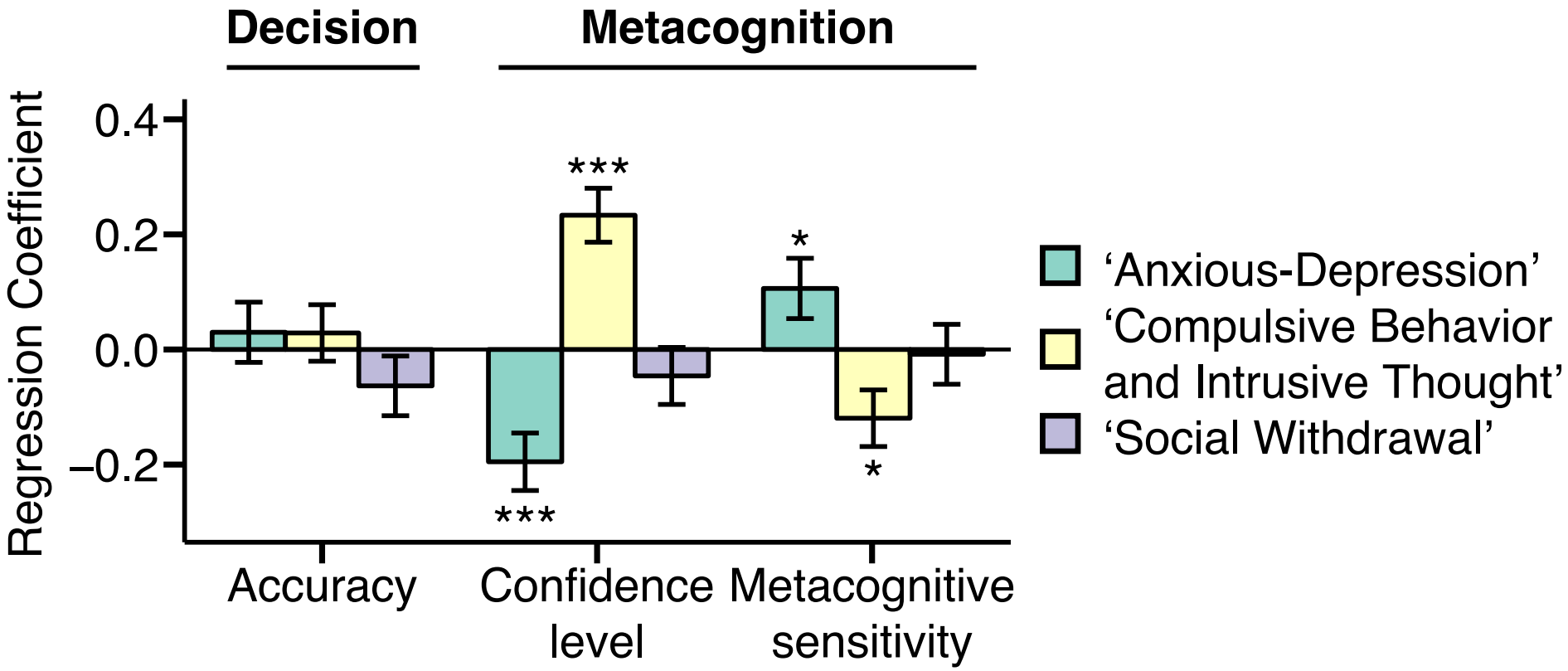


Experiment 2, N=497

Controlled for age, IQ, gender

*p<.05 uncorr, ***p<.001, corrected for multiple comparisons over number of dependent variables

Metacognition (but not decision performance) is associated with latent symptom dimensions

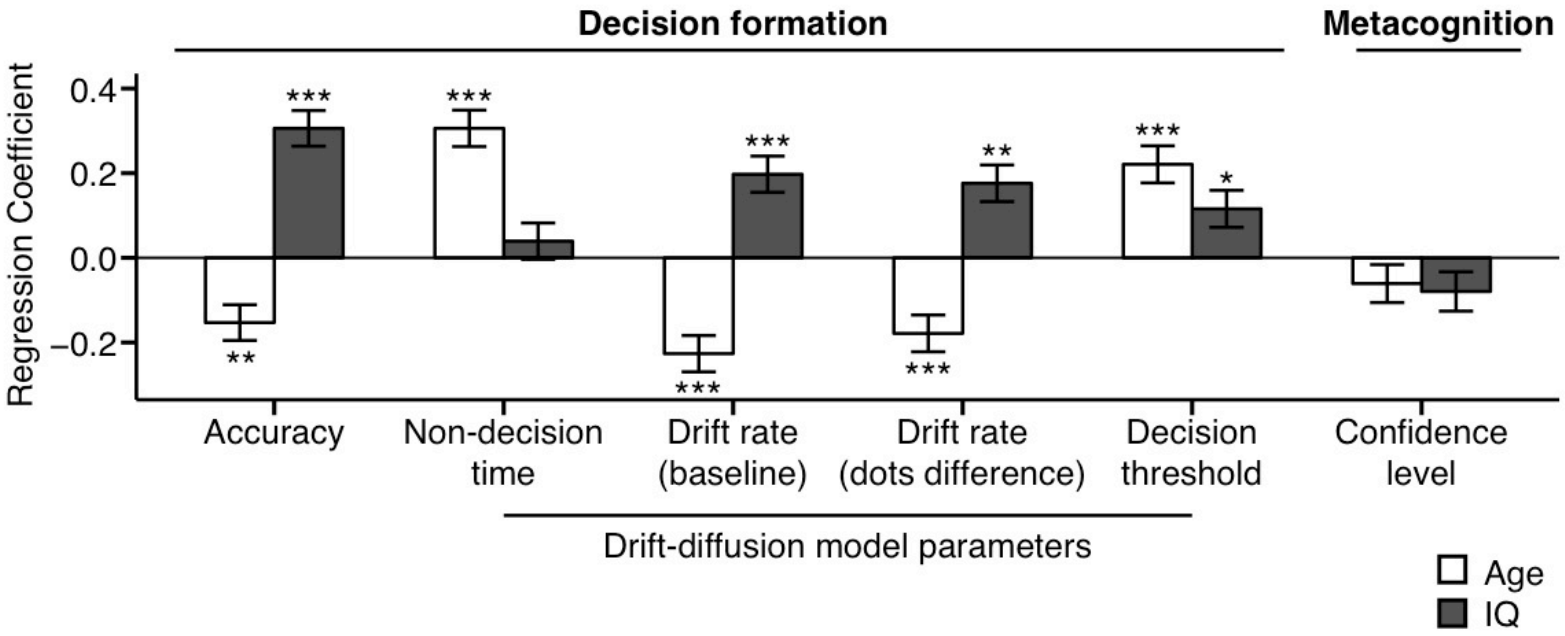


Experiment 2, N=497

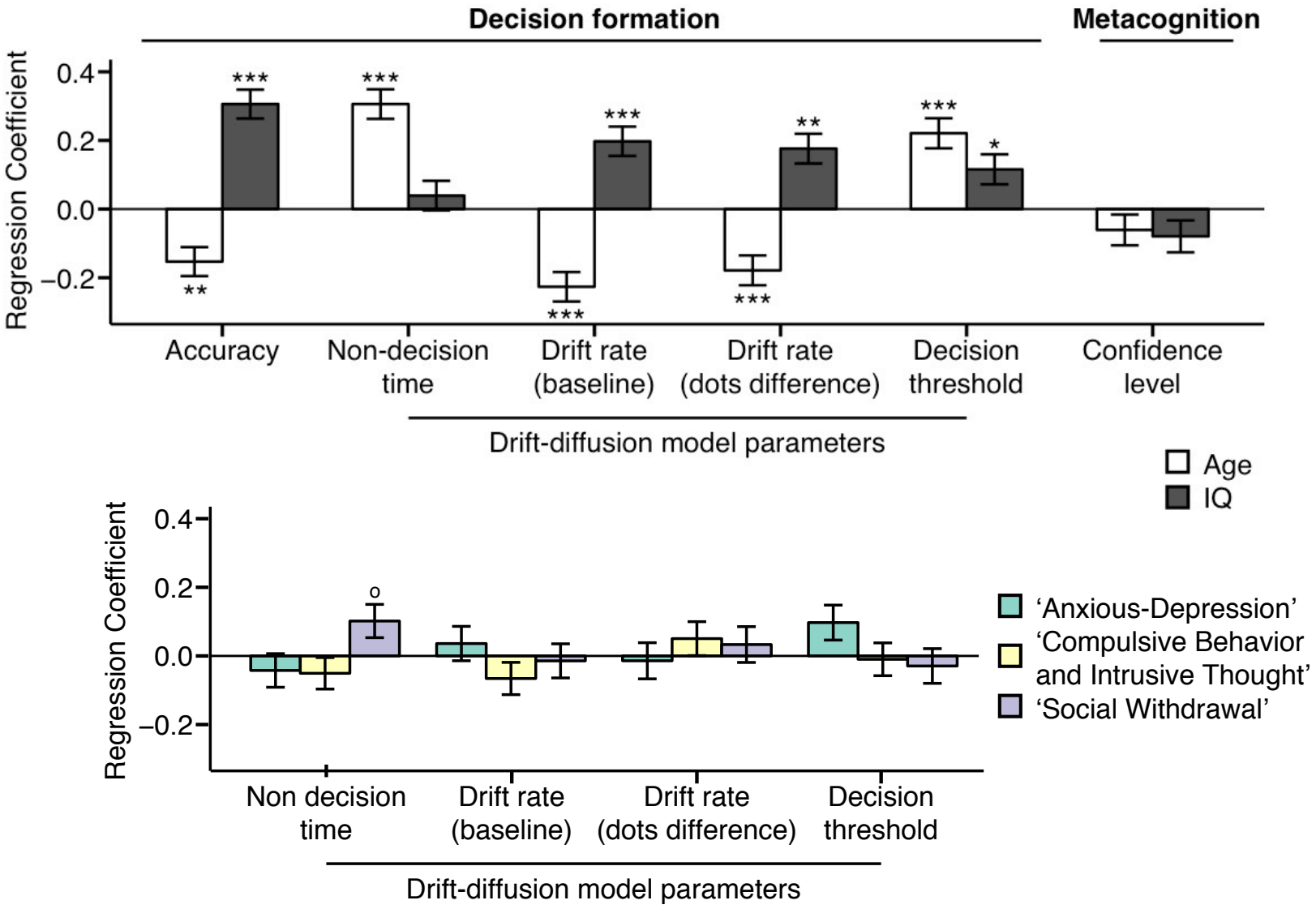
Controlled for age, IQ, gender

*p<.05 uncorr, ***p<.001, corrected for multiple comparisons over number of dependent variables

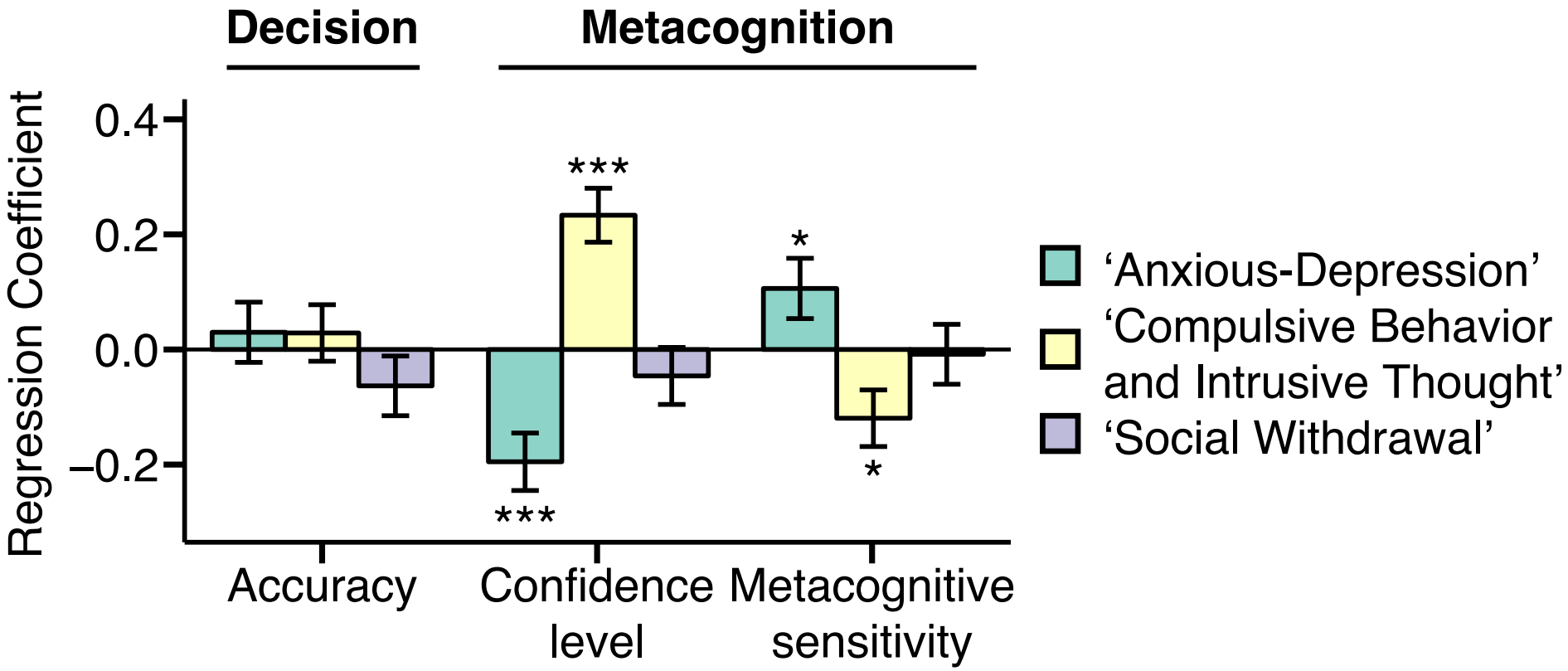
Dissociating metacognition and decision performance



Dissociating metacognition and decision performance



Metacognition (but not decision performance) is associated with latent symptom dimensions



Experiment 2, N=497

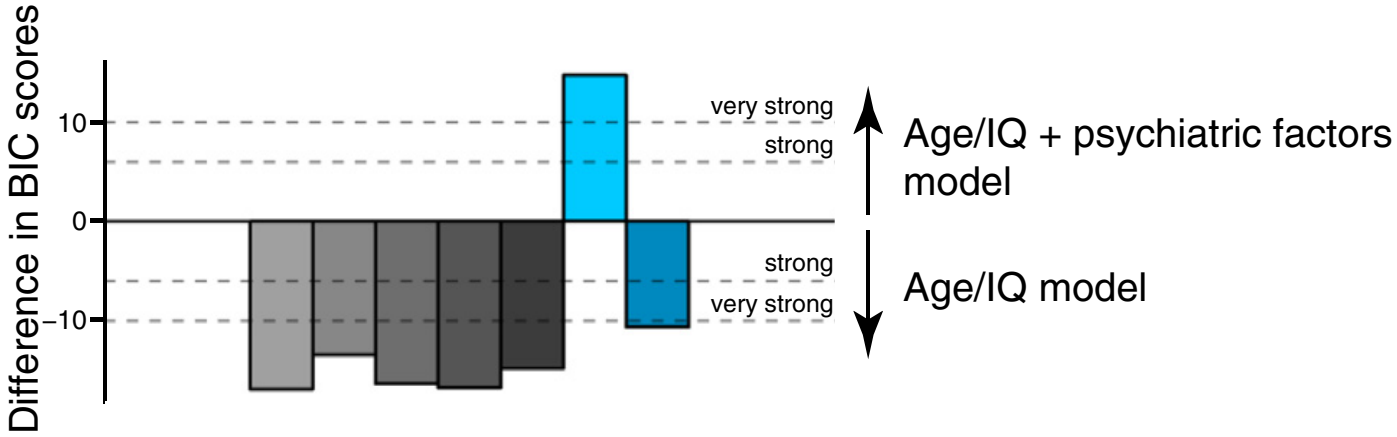
Controlled for age, IQ, gender

*p<.05 uncorr, ***p<.001, corrected for multiple comparisons over number of dependent variables

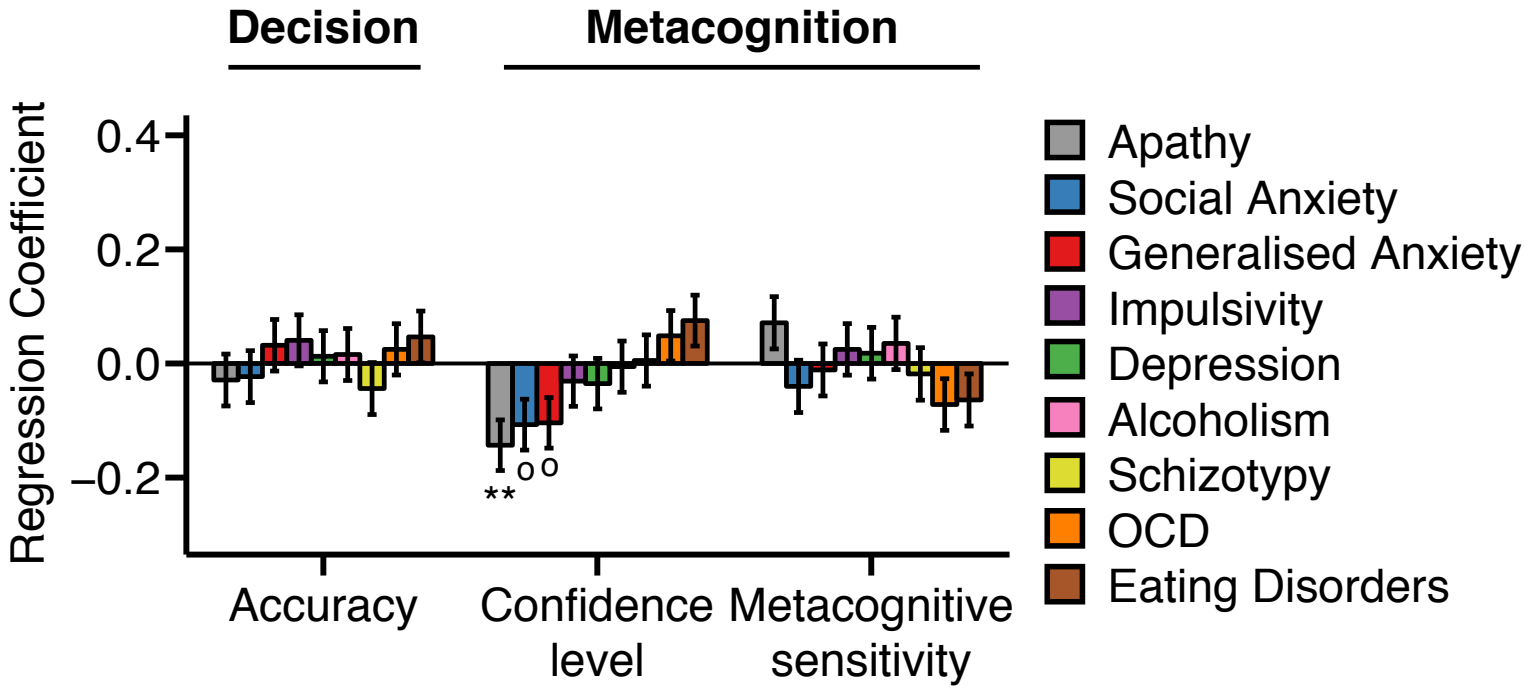
Metacognition (but not decision performance) is associated with latent symptom dimensions

Variables list:

Accuracy
Non-decision time
Drift rate (baseline)
Drift rate (dots difference)
Decision threshold
Confidence level
Metacognitive efficiency



Latent symptom dimensions are stronger predictors than individual scores



Controlled for age, IQ, gender

$^{o}p<.05$ uncorr, $^{**}p<.01$, corrected for multiple comparisons over number of dependent variables

Interim summary

Interim summary

- Behavioural evidence indicates a domain-general resource supporting metacognition in simple tasks

Interim summary

- Behavioural evidence indicates a domain-general resource supporting metacognition in simple tasks

Interim summary

- Behavioural evidence indicates a domain-general resource supporting metacognition in simple tasks
- Psychiatric symptom dimensions are associated with distinct aspects of metacognitive ability, despite generally unaffected decision-making (at least in this task)

Interim summary

- Behavioural evidence indicates a domain-general resource supporting metacognition in simple tasks
- Psychiatric symptom dimensions are associated with distinct aspects of metacognitive ability, despite generally unaffected decision-making (at least in this task)

Interim summary

- Behavioural evidence indicates a domain-general resource supporting metacognition in simple tasks
- Psychiatric symptom dimensions are associated with distinct aspects of metacognitive ability, despite generally unaffected decision-making (at least in this task)
- What **brain systems** might support domain-general metacognition?

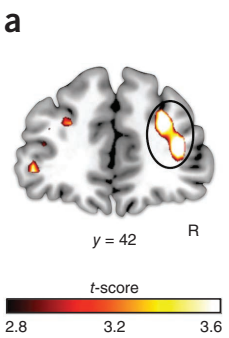
Interim summary

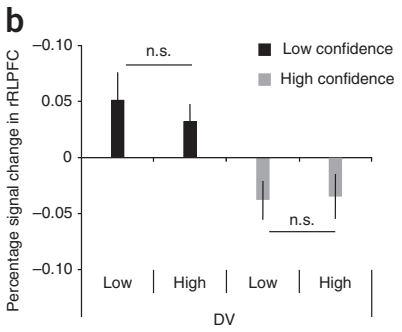
- Behavioural evidence indicates a domain-general resource supporting metacognition in simple tasks
- Psychiatric symptom dimensions are associated with distinct aspects of metacognitive ability, despite generally unaffected decision-making (at least in this task)
- What **brain systems** might support domain-general metacognition?

Interim summary

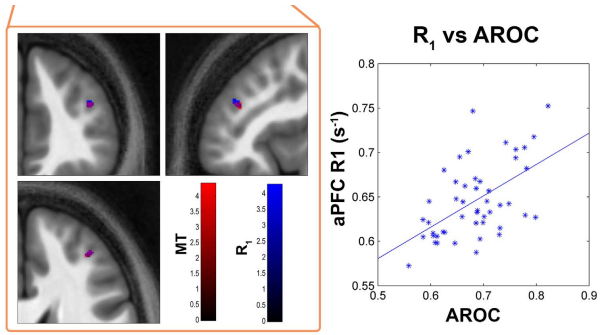
- Behavioural evidence indicates a domain-general resource supporting metacognition in simple tasks
- Psychiatric symptom dimensions are associated with distinct aspects of metacognitive ability, despite generally unaffected decision-making (at least in this task)
- What **brain systems** might support domain-general metacognition?
- Can we develop **neural/behavioural interventions** for modulating metacognition?

Metacognitive evaluation and aPFC



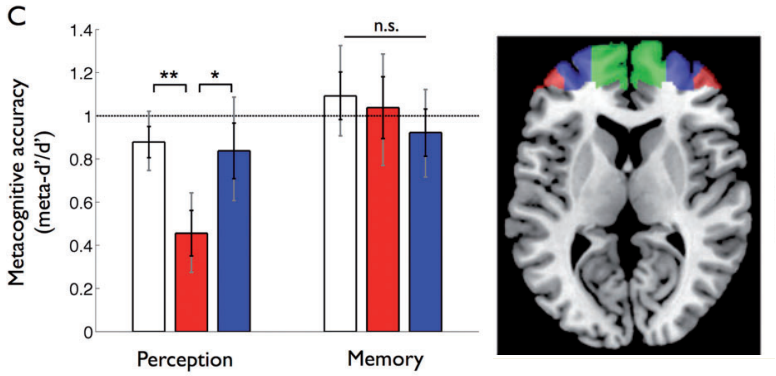


De Martino, Fleming et al. 2013 *Nat Neuro*

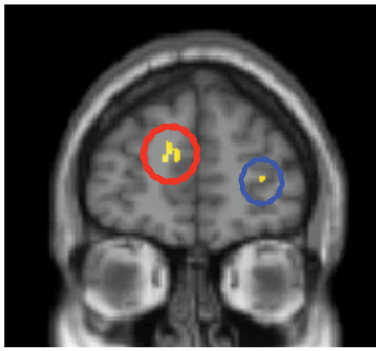


Allen et al. 2017 *Neuroimage*

anterior prefrontal cortex (aPFC)

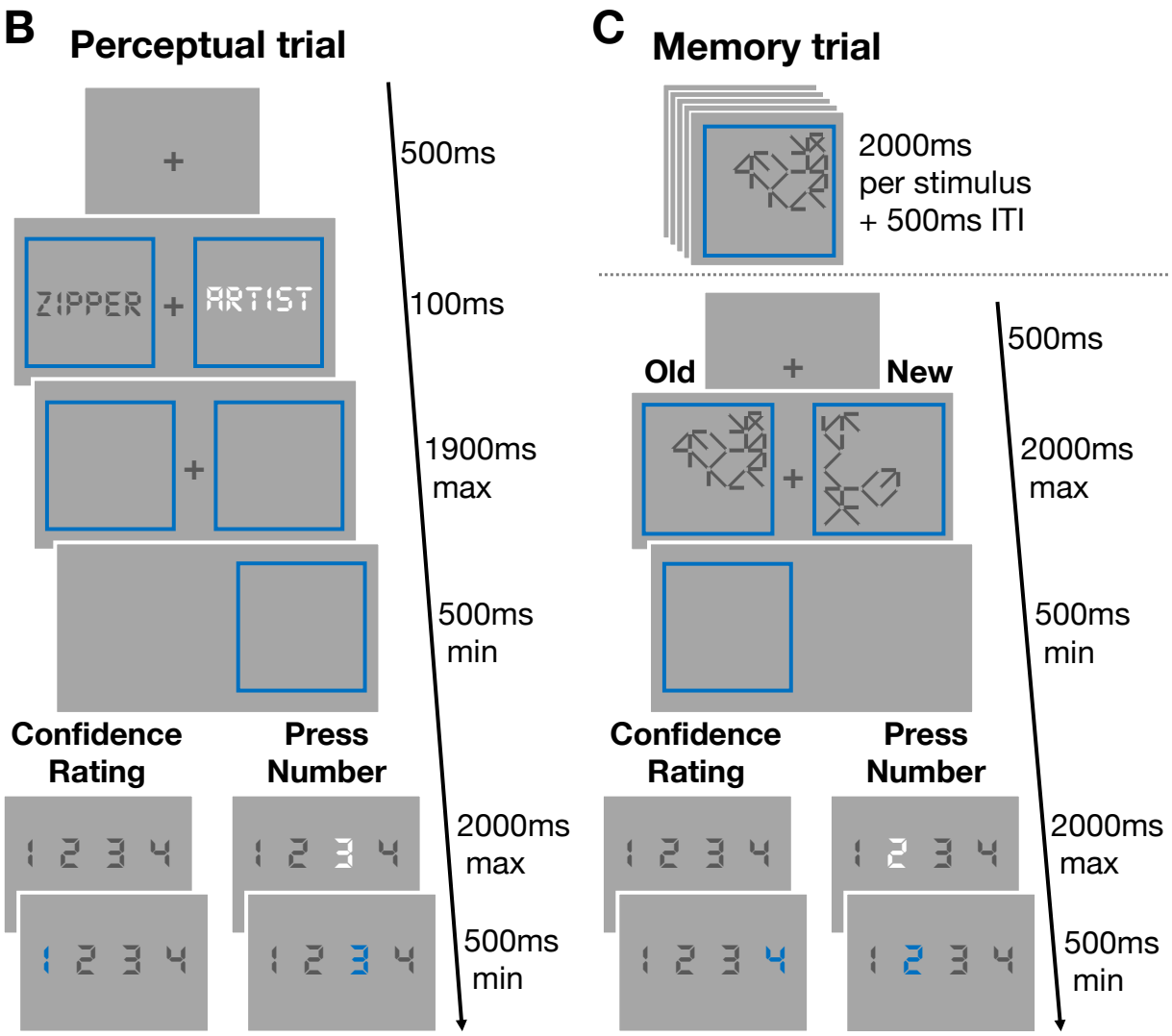


Fleming et al. 2014 *Brain*



McCurdy et al. 2013 *J Neuro;*
Fleming et al. 2010 *Science*

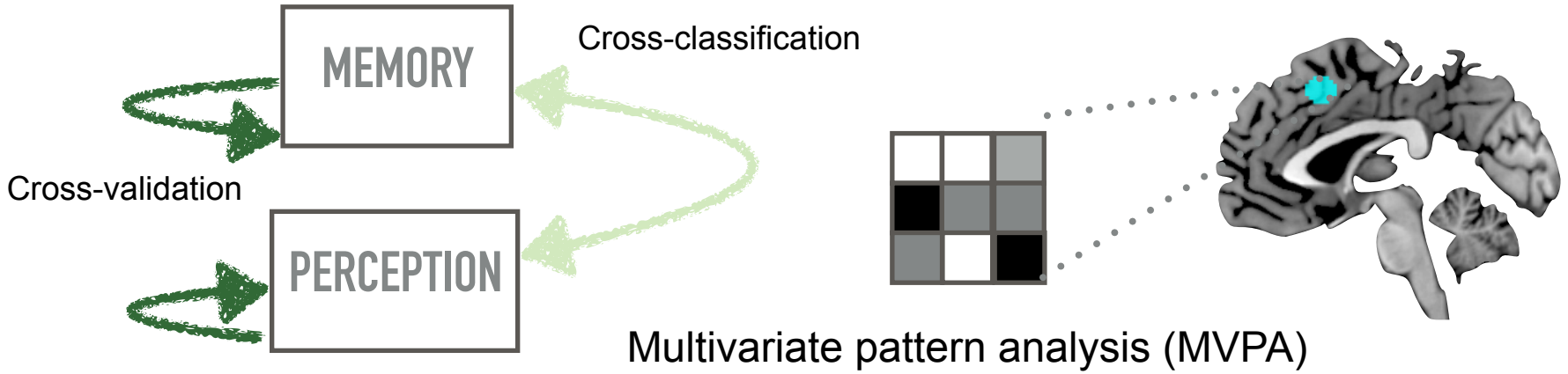
Shared signals for confidence across tasks?



2 (stimulus) x
2 (domain)
block design

Morales, Lau & Fleming (2018) *J Neuro*

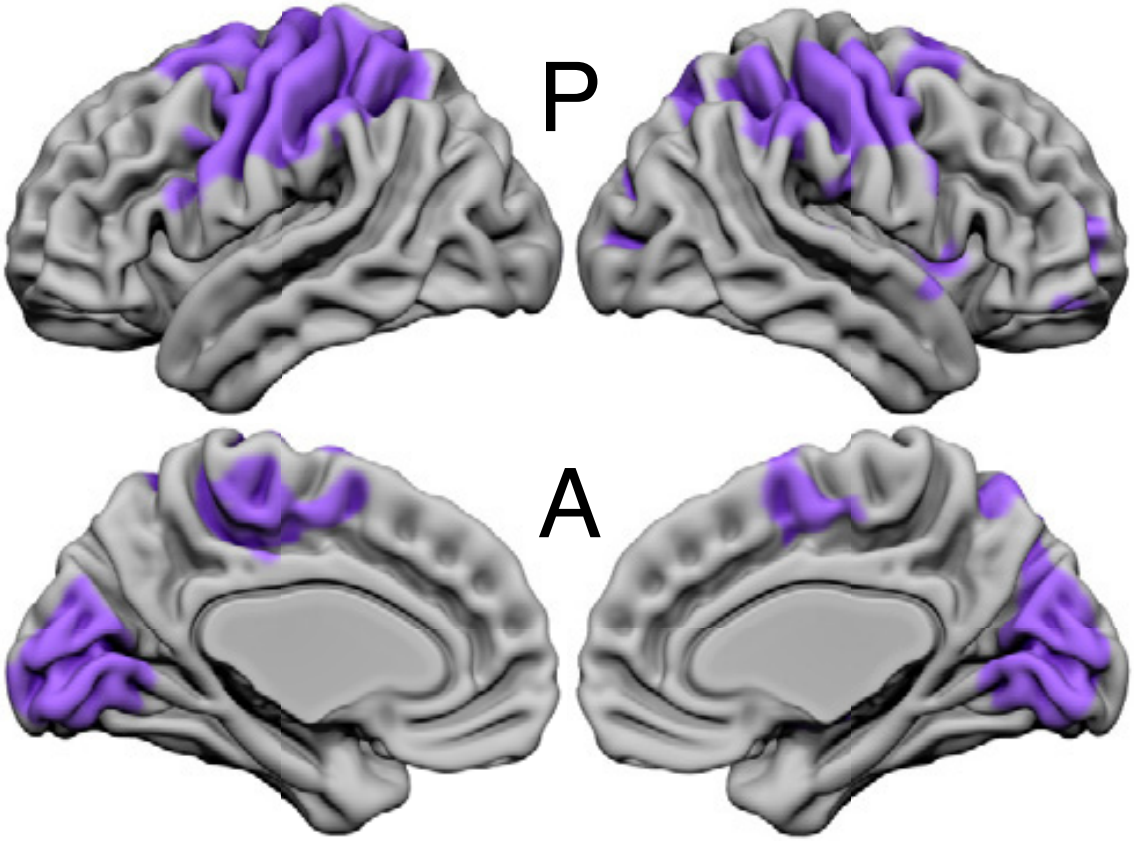
Shared signals for confidence across tasks?

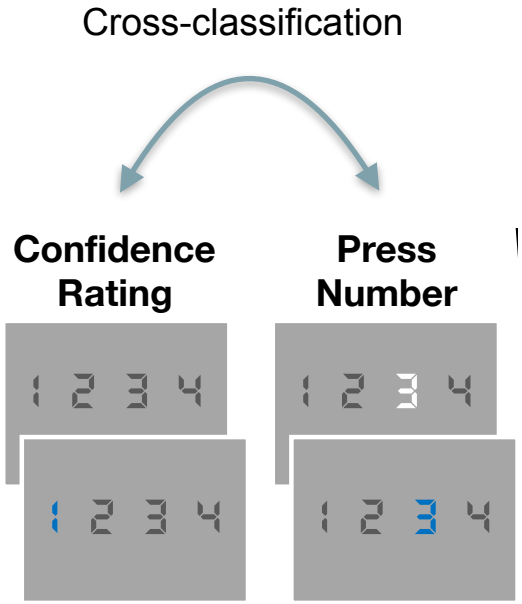


Multivariate pattern analysis (MVPA)

Morales, Lau & Fleming (2018) *J Neuro*

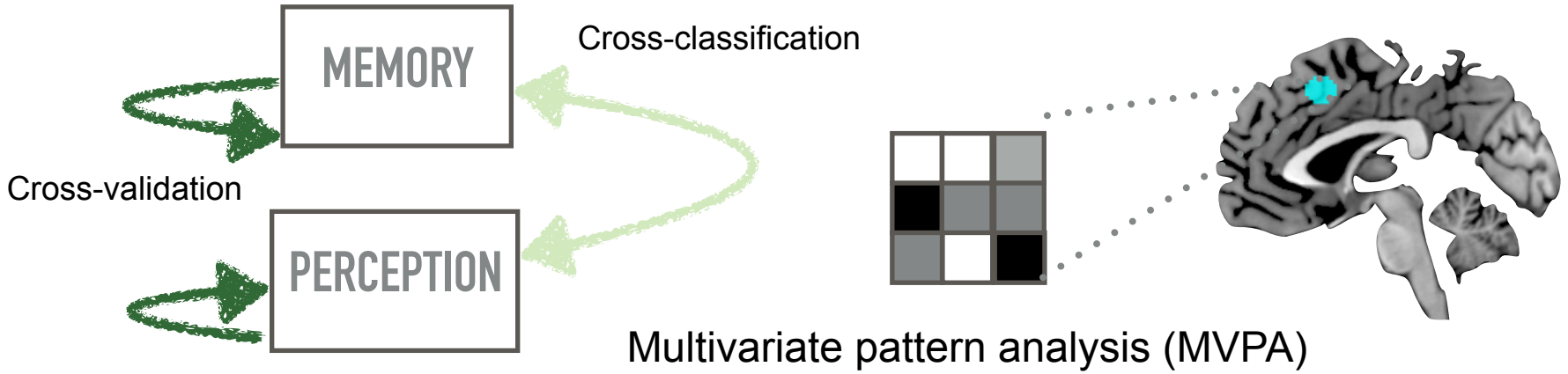
Excluding button-press related activity patterns





Morales, Lau & Fleming (2018) *J Neuro*

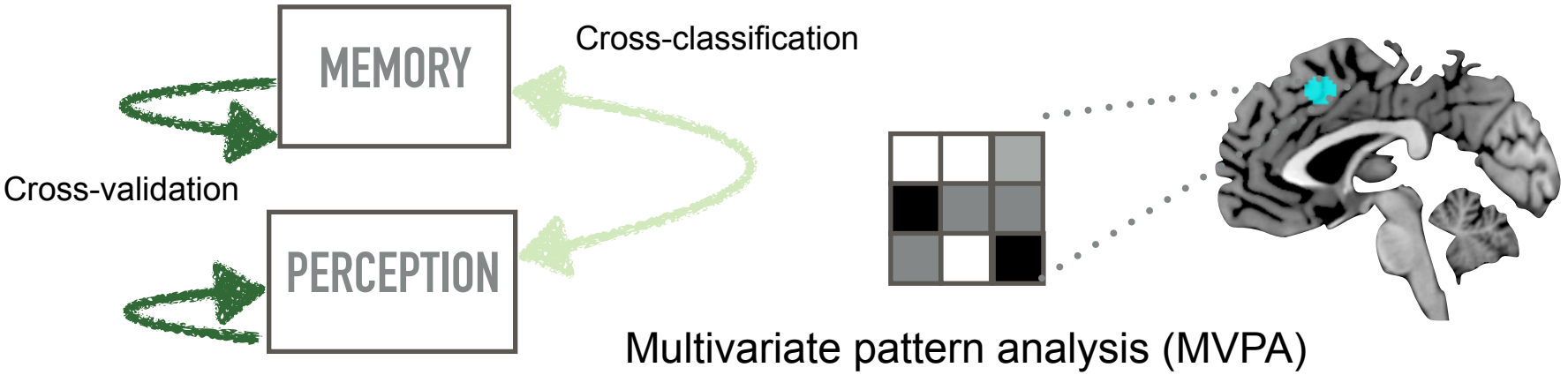
Shared signals for confidence across tasks?



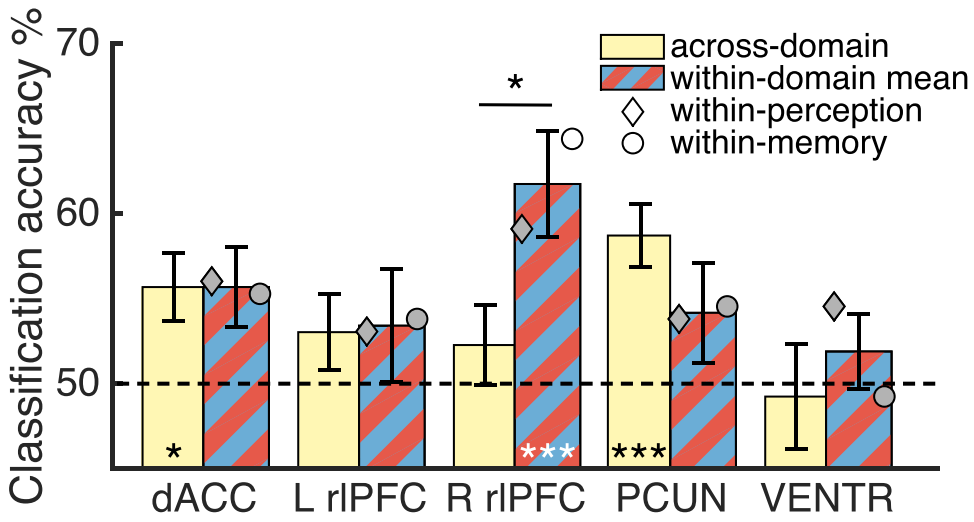
Multivariate pattern analysis (MVPA)

Morales, Lau & Fleming (2018) *J Neuro*

Shared signals for confidence across tasks?

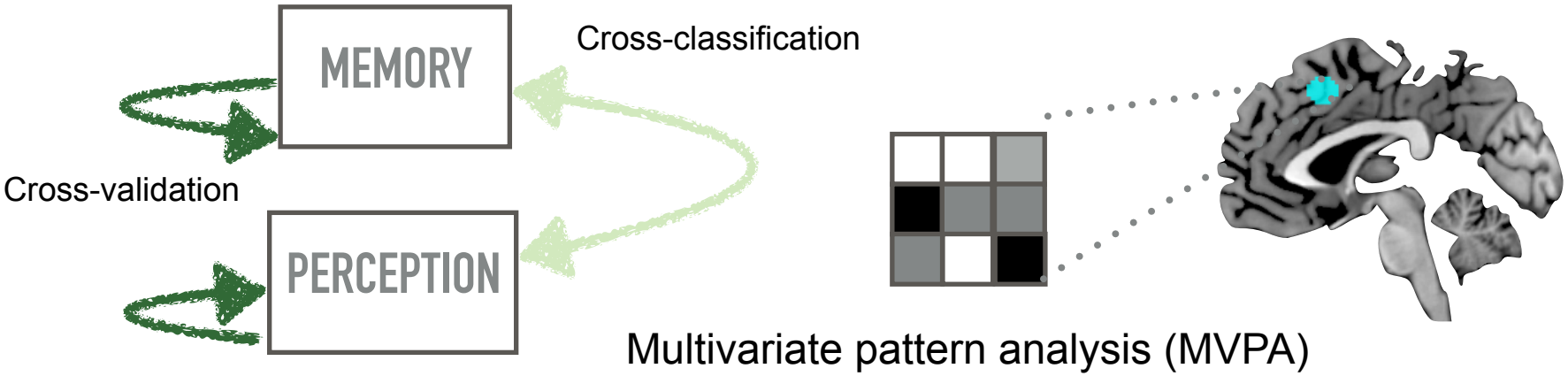


Confidence-related activity patterns

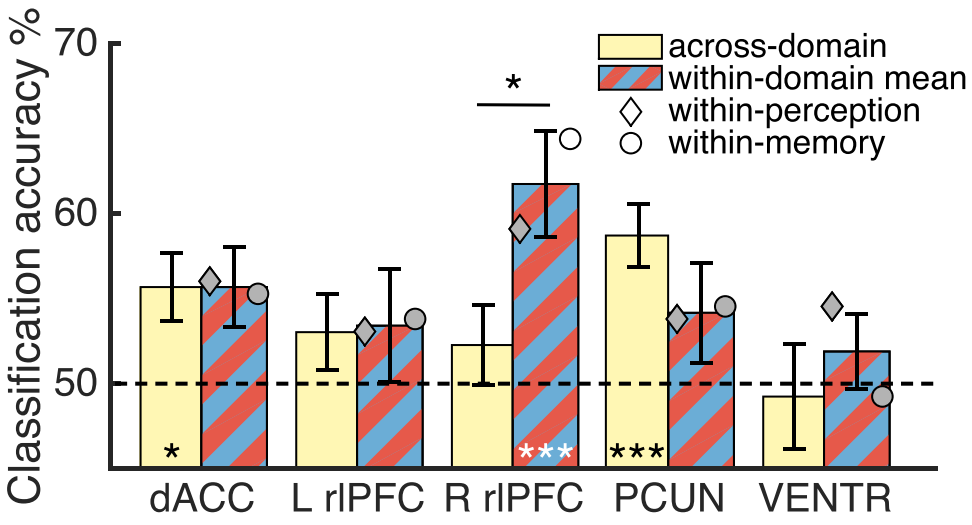


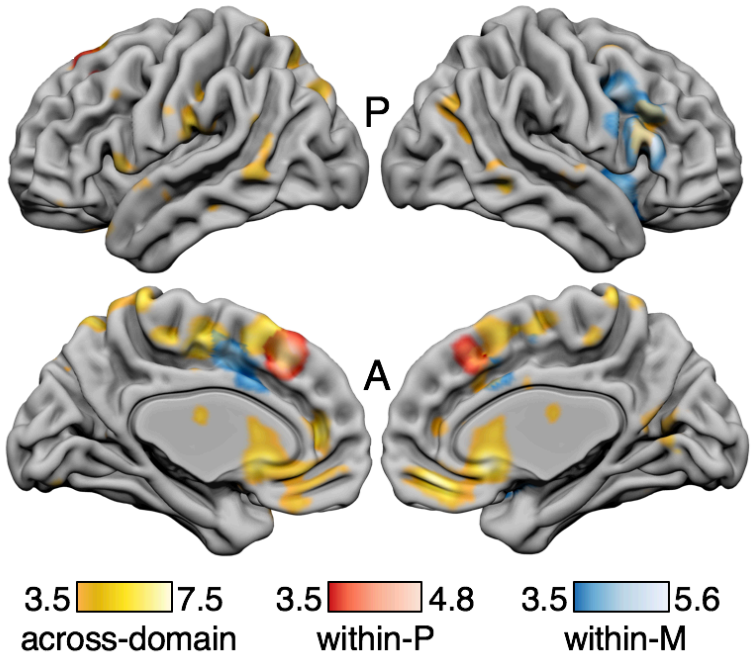
Morales, Lau & Fleming (2018) *J Neuro*

Shared signals for confidence across tasks?



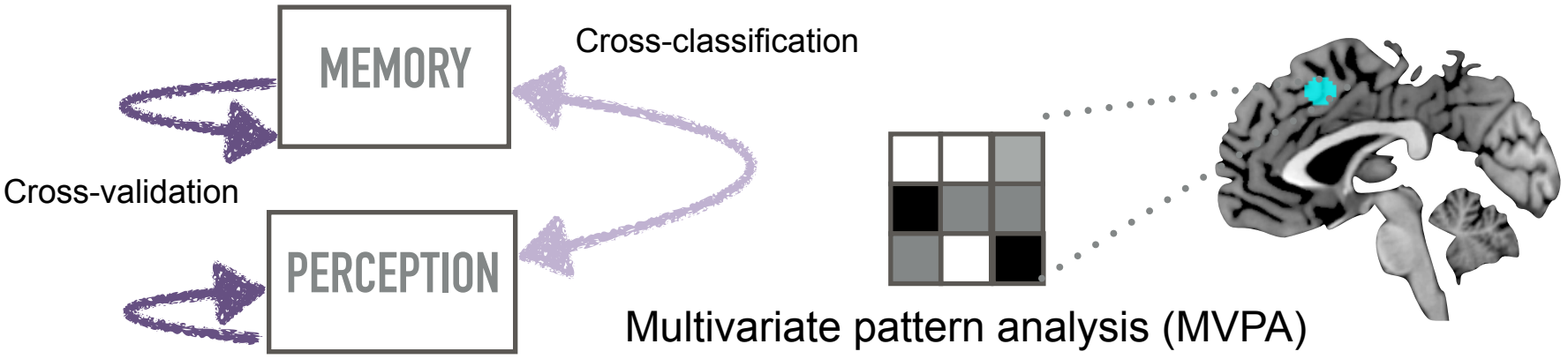
Confidence-related activity patterns





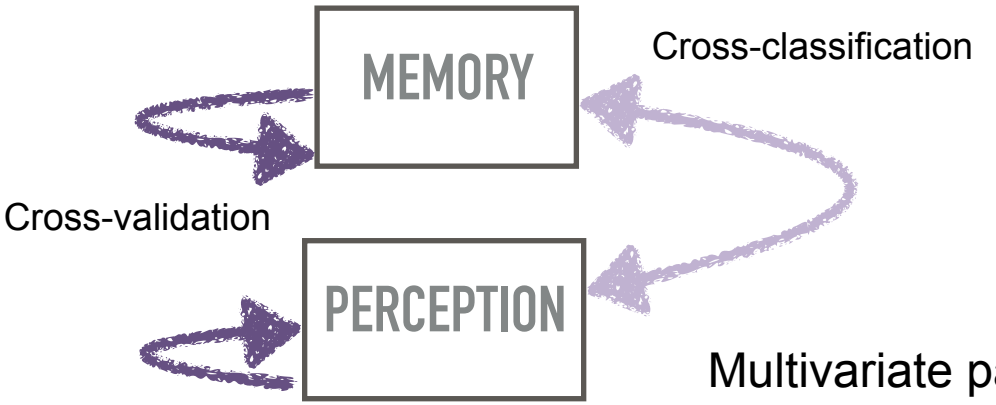
Morales, Lau & Fleming (2018) *J Neuro*

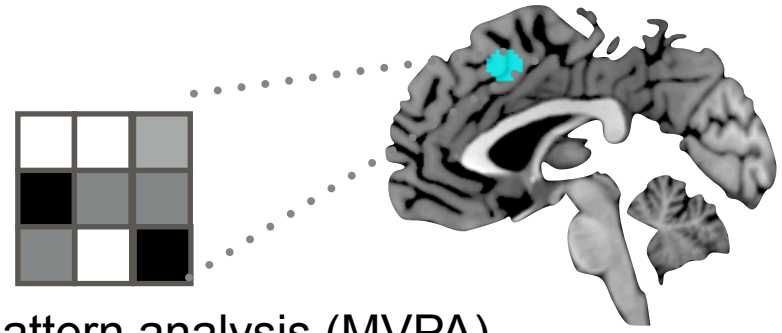
Judgment-related patterns



Morales, Lau & Fleming (2018) *J Neuro*

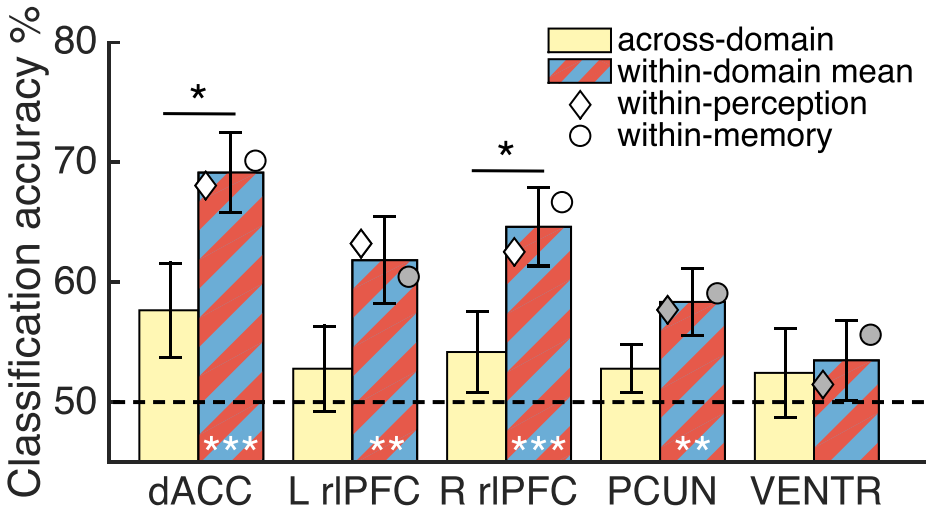
Judgment-related patterns

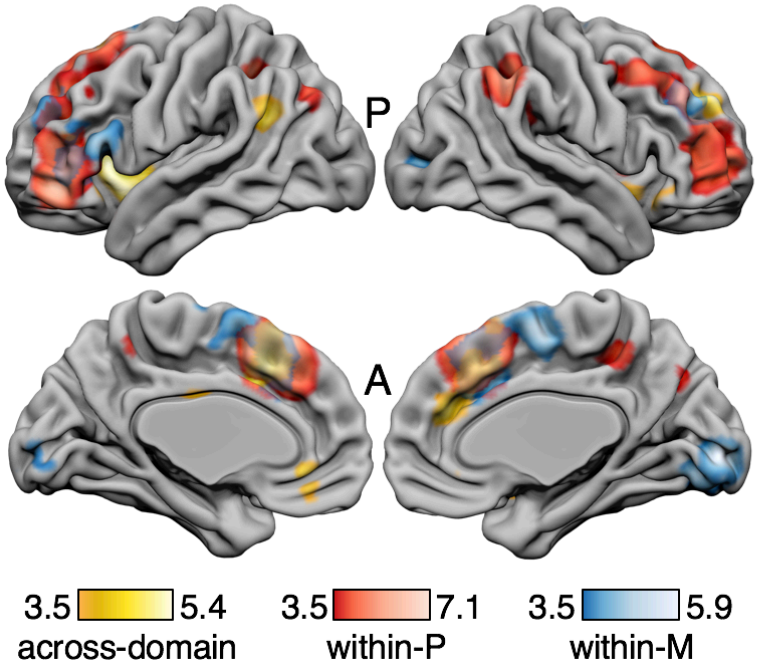




Multivariate pattern analysis (MVPA)

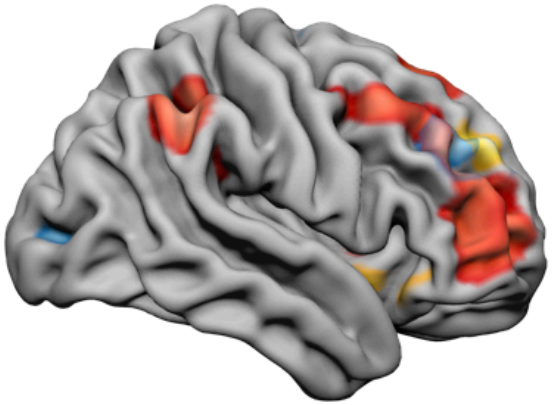
Judgment-related activity patterns



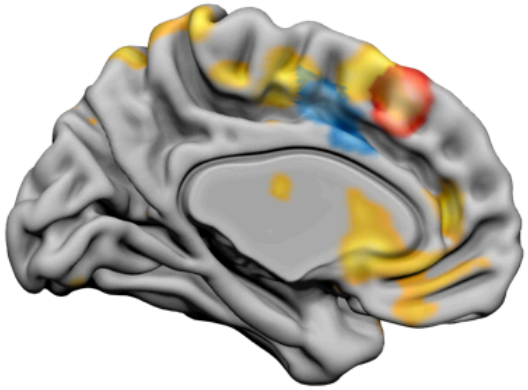


Morales, Lau & Fleming (2018) *J Neuro*

Domain-general and domain-specific confidence signals co-exist



Domain-specific
communication, control



?

Domain-general confidence
signals

Summary

Summary

- We can measure metacognition across in different tasks as the statistical association between behaviour and self-evaluation (confidence)

Summary

- We can measure metacognition across in different tasks as the statistical association between behaviour and self-evaluation (confidence)

Summary

- We can measure metacognition across in different tasks as the statistical association between behaviour and self-evaluation (confidence)

- Adopting a signal detection theory framework allows simultaneous estimation of both type 1 (d') and type 2 (meta-d') sensitivity

Summary

- We can measure metacognition across in different tasks as the statistical association between behaviour and self-evaluation (confidence)

- Adopting a signal detection theory framework allows simultaneous estimation of both type 1 (d') and type 2 (meta-d') sensitivity

Summary

- We can measure metacognition across in different tasks as the statistical association between behaviour and self-evaluation (confidence)

- Adopting a signal detection theory framework allows simultaneous estimation of both type 1 (d') and type 2 (meta-d') sensitivity

- Psychiatric symptom dimensions are associated with changes in metacognition over and above differences in behavioural performance

Summary

- We can measure metacognition across in different tasks as the statistical association between behaviour and self-evaluation (confidence)

- Adopting a signal detection theory framework allows simultaneous estimation of both type 1 (d') and type 2 (meta-d') sensitivity

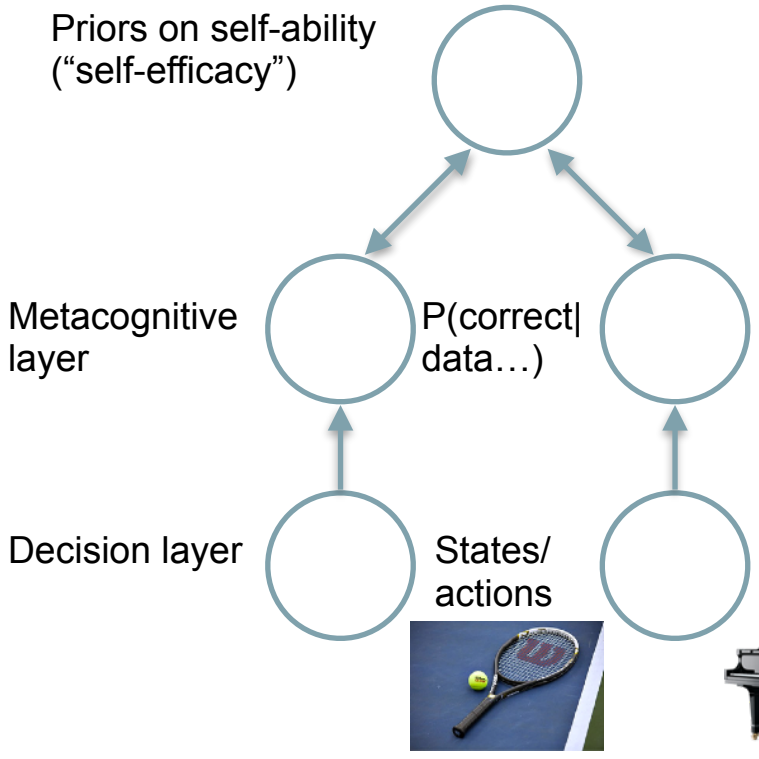
- Psychiatric symptom dimensions are associated with changes in metacognition over and above differences in behavioural performance

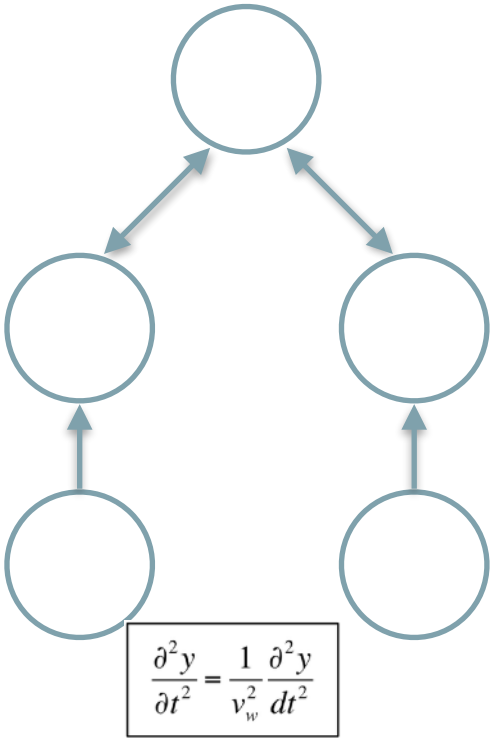
Summary

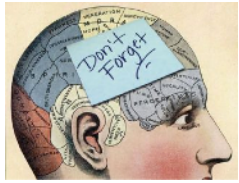
- We can measure metacognition across in different tasks as the statistical association between behaviour and self-evaluation (confidence)
- Adopting a signal detection theory framework allows simultaneous estimation of both type 1 (d') and type 2 (meta-d') sensitivity
- Psychiatric symptom dimensions are associated with changes in metacognition over and above differences in behavioural performance
- Domain-general aspects of metacognition may prove relevant targets for computational psychiatry; potential to generalise to new tasks/experiences

Metacognitive generalisation

The extent to which we **generalise** across domains may itself be an important/interesting individual difference



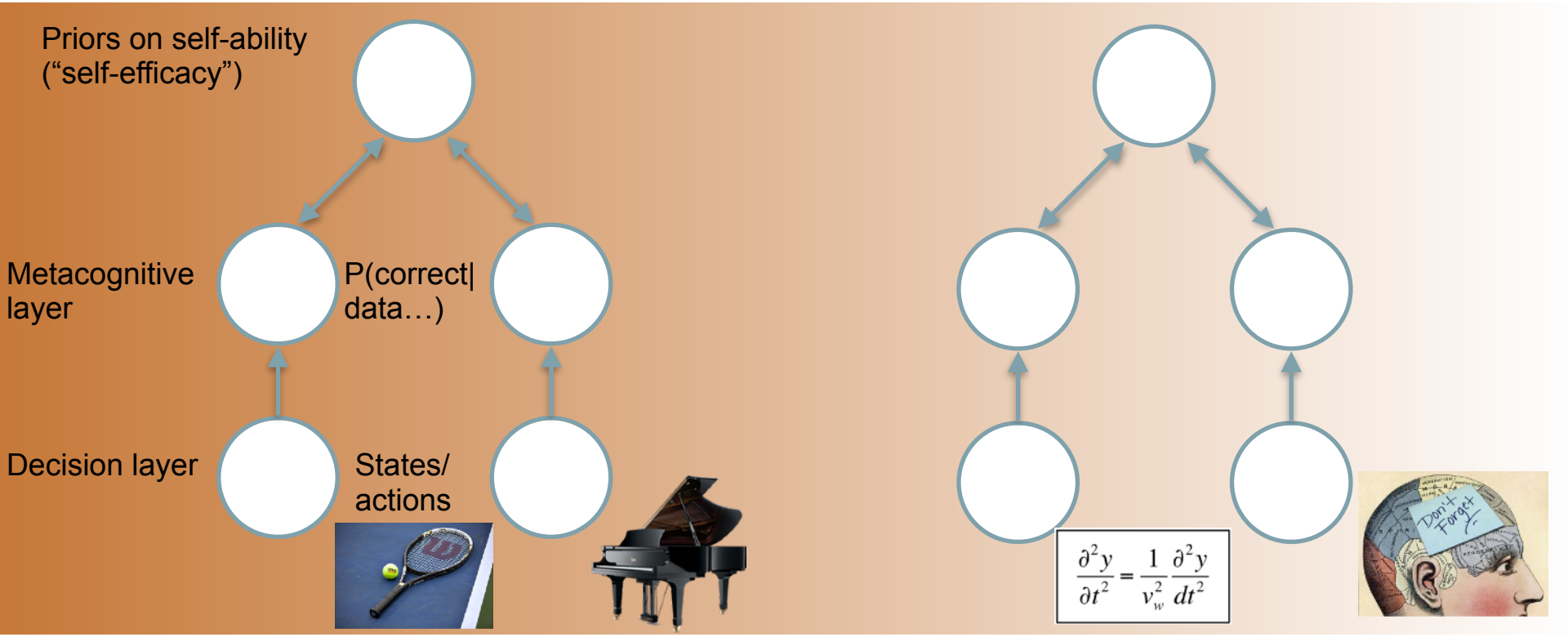




Rouault et al. (2018) *Personality Neuroscience*

Metacognitive generalisation

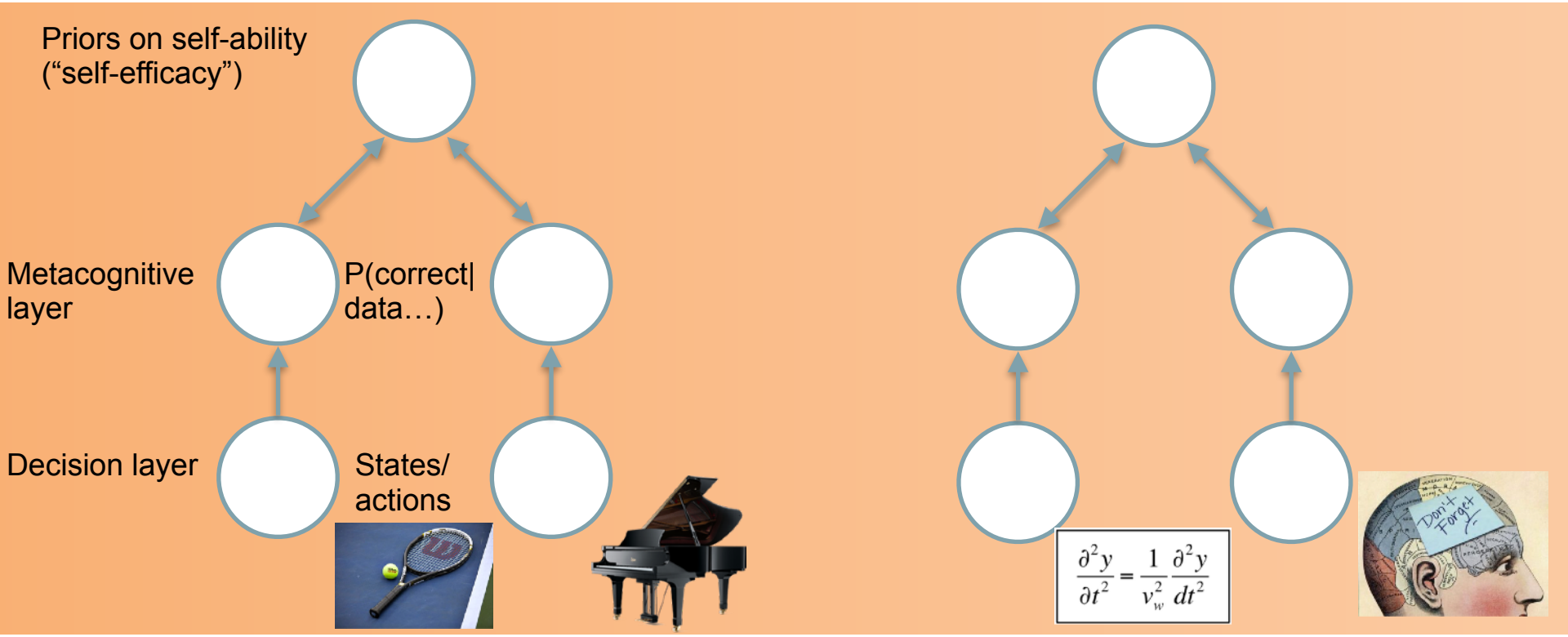
The extent to which we **generalise** across domains may itself be an important/interesting individual difference



Rouault et al. (2018) *Personality Neuroscience*

Metacognitive generalisation

The extent to which we **generalise** across domains may itself be an important/interesting individual difference



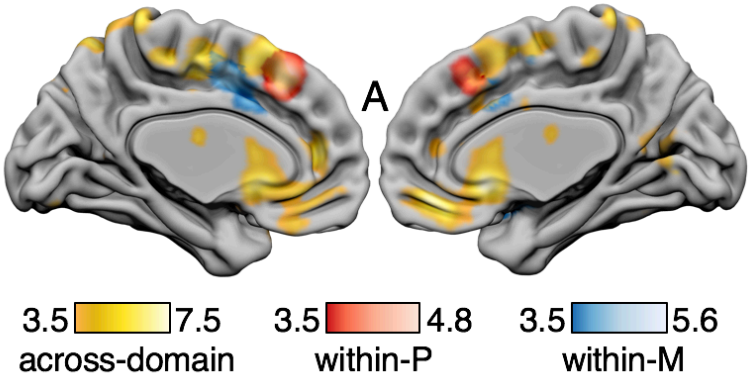
Rouault et al. (2018) *Personality Neuroscience*

Metacognitive generalisation

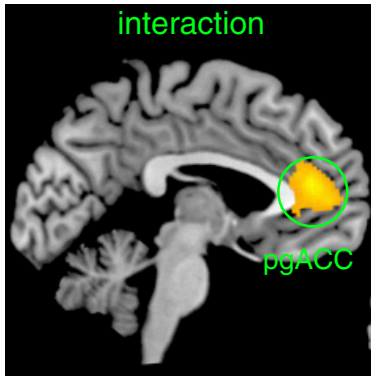
Rouault et al. (2018) *Personality Neuroscience*

Metacognitive generalisation and pgACC

Confidence formation:



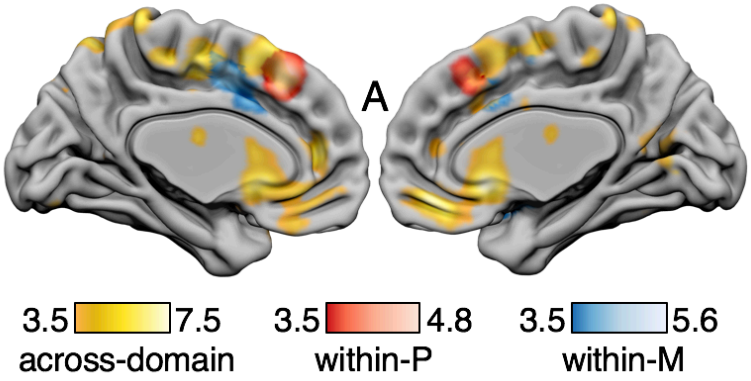
Morales et al. (2018) *J Neuro*



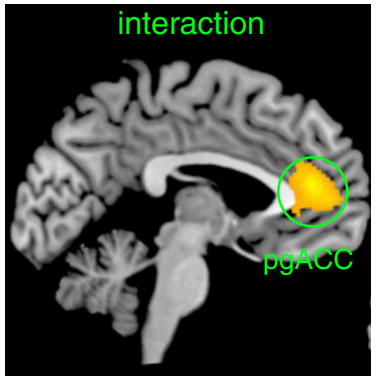
Bang & Fleming (2018) *PNAS*

Metacognitive generalisation and pgACC

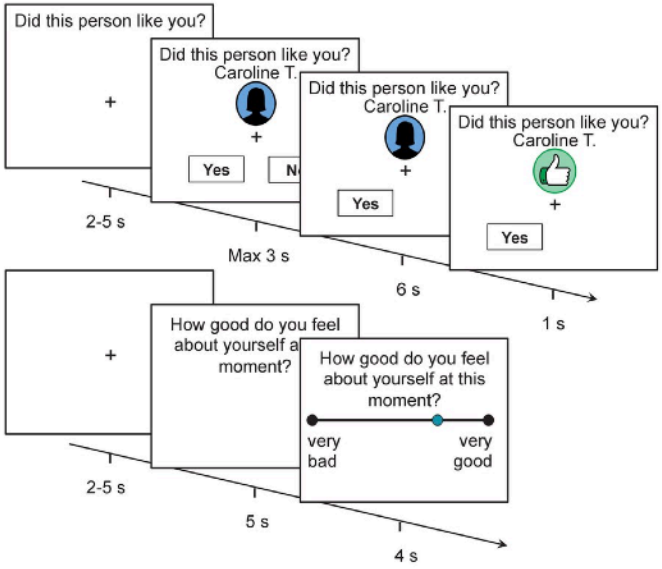
Confidence formation:



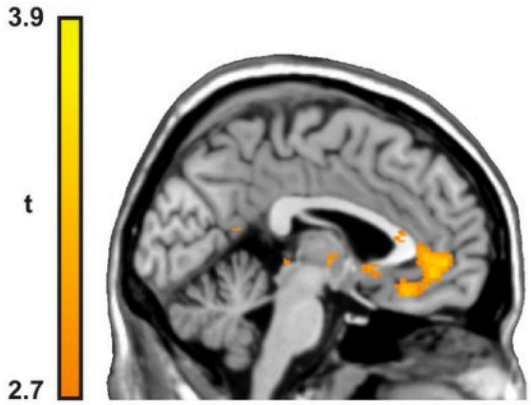
Morales et al. (2018) *J Neuro*

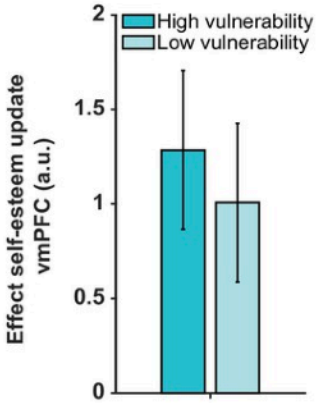


Bang & Fleming (2018) *PNAS*



Self-esteem updates:

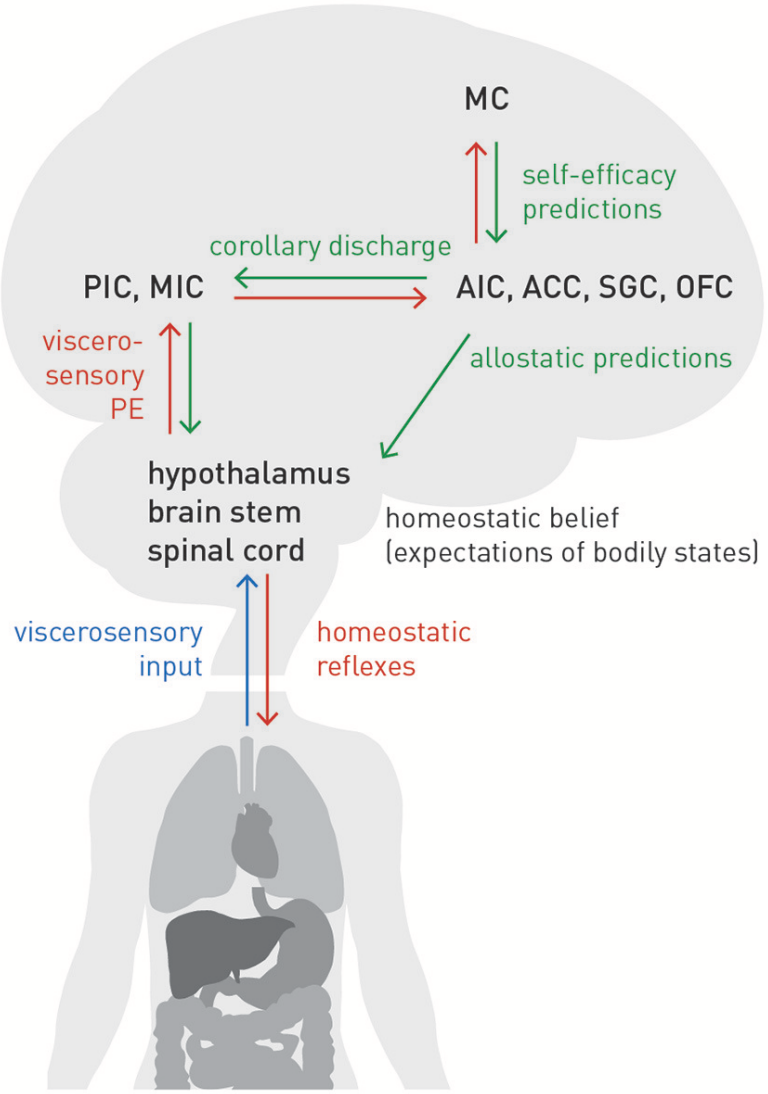




Will et al. (2017) *eLife*

Metacognitive generalisation

Generalisation may operate not only across exteroceptive domains, but also interoception



Allostatic Self-efficacy: A Metacognitive Theory of Dyshomeostasis-Induced Fatigue and Depression

Klaas E. Stephan[1,2,3], Zina M. Manjaly[1,4], Christoph D. Mathys[2], Lilian A. E. Weber[1], Saee Paliwal[1], Tim Gard[1,5], Marc Tittgemeyer[3], Stephen M. Fleming[2], Helene Haker[1], Anil K. Seth[6] and Frederike H. Petzschner[1]*

Stephan et al. (2016) *Frontiers in Human Neuroscience*

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

ISSN 0962-8436

volume 367

number 1594

pages 1279–1438

In this Issue

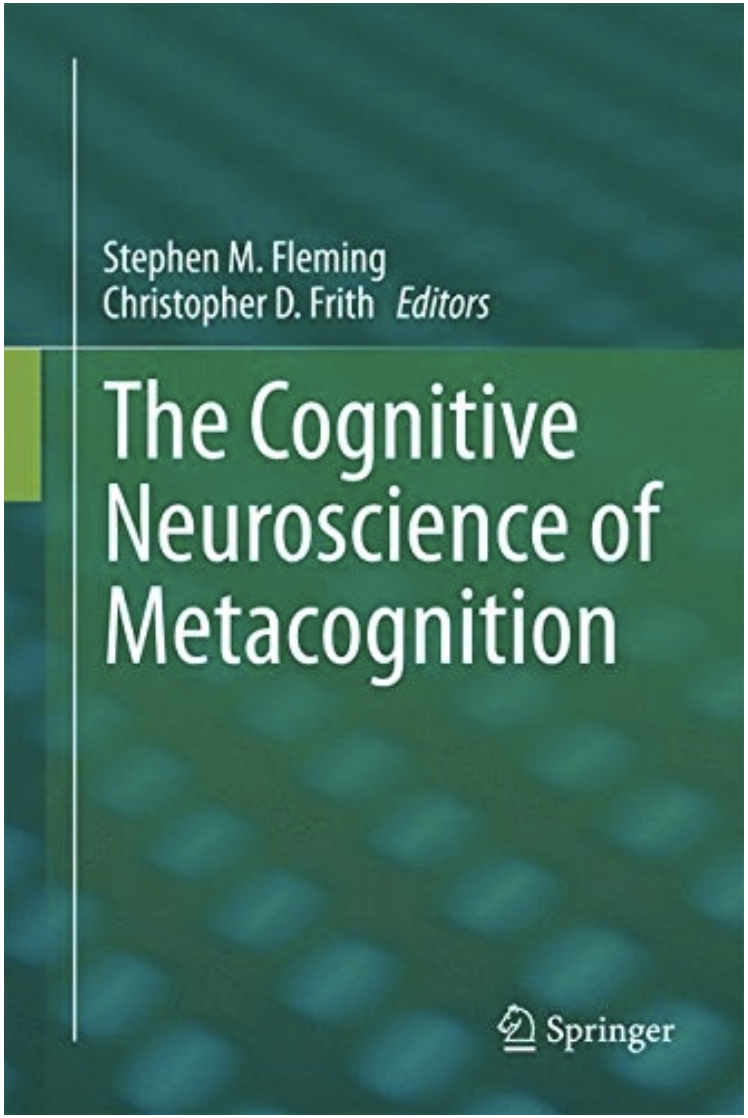
Metacognition: computation, neurobiology and function

Papers of a Theme Issue organized and edited by Stephen M. Fleming, Raymond J. Dolan, Christopher D. Frith

The world's first science journal

Royal Society Publishing
Informing the science of the future

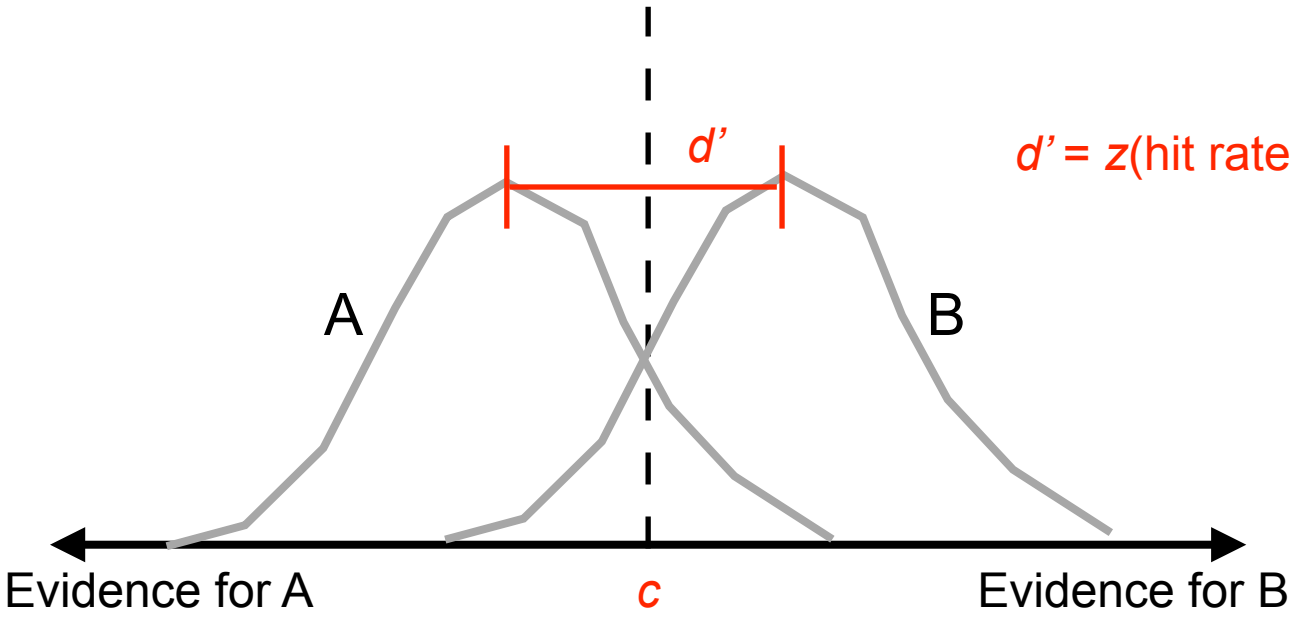
19 May 2012



Thank you

metacoglab.org

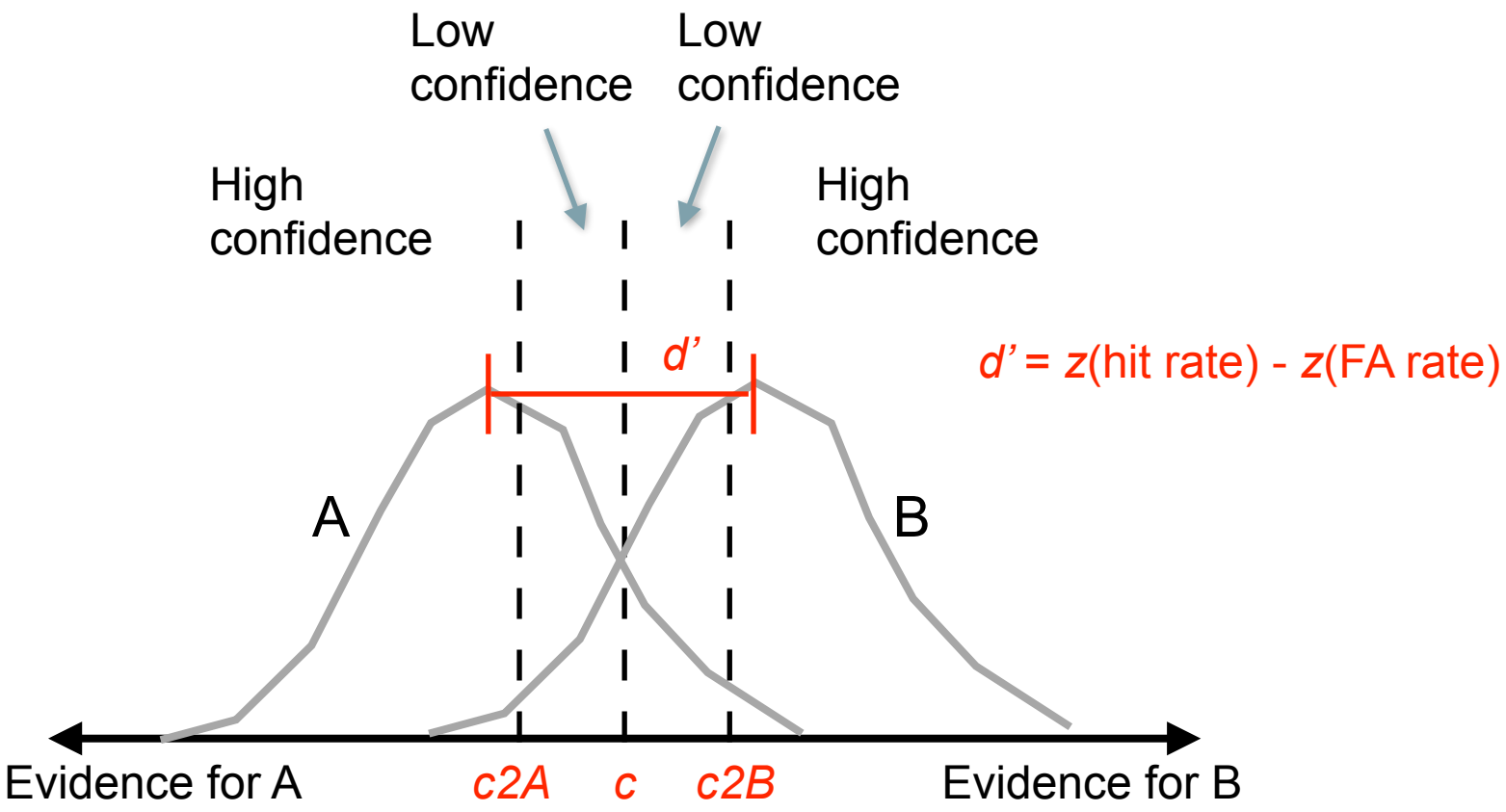
Signal detection theory (SDT)



d' = *z*(hit rate) - *z*(FA rate)

Green & Swets (1966)

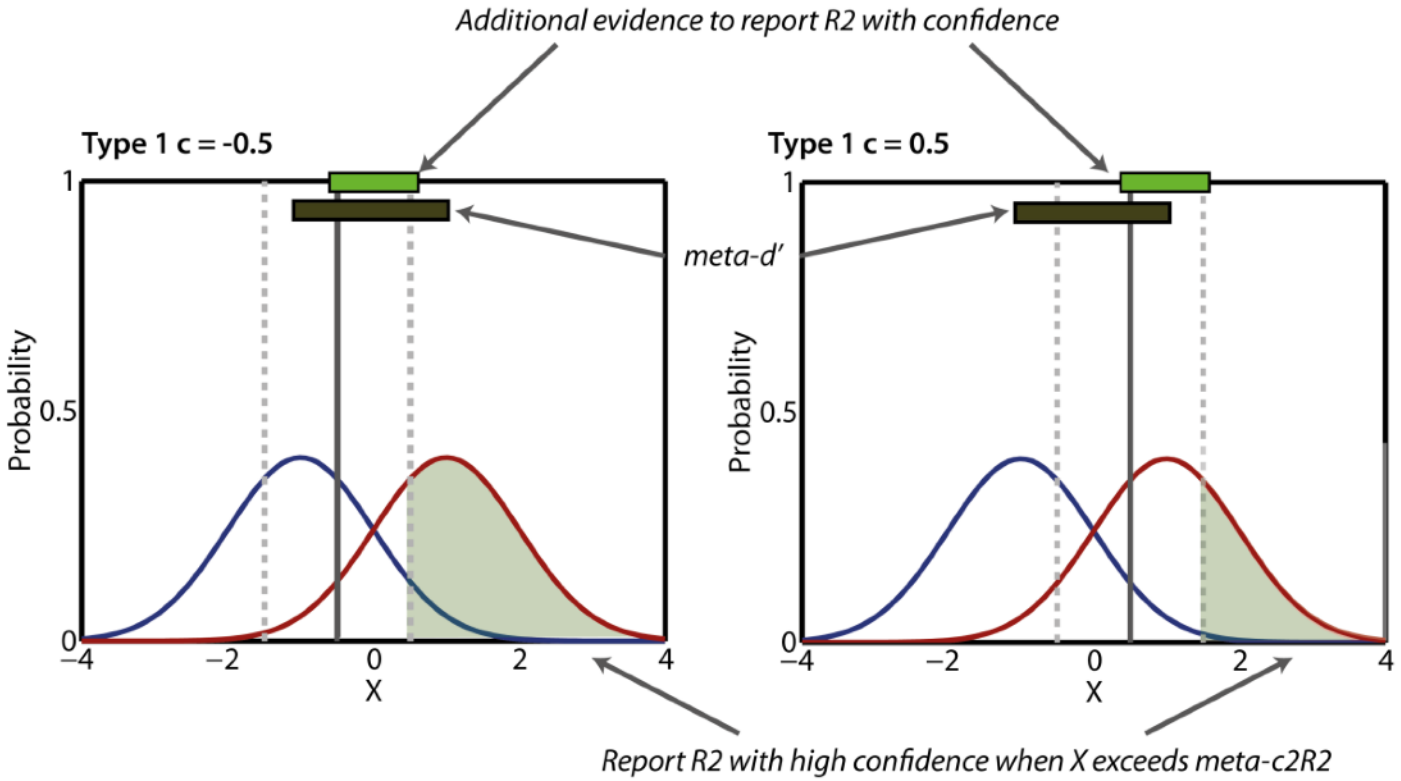
Signal detection theory (SDT)



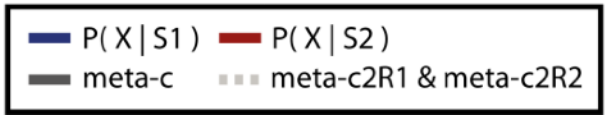
Confidence related to absolute distance to decision criterion

Green & Swets (1966)

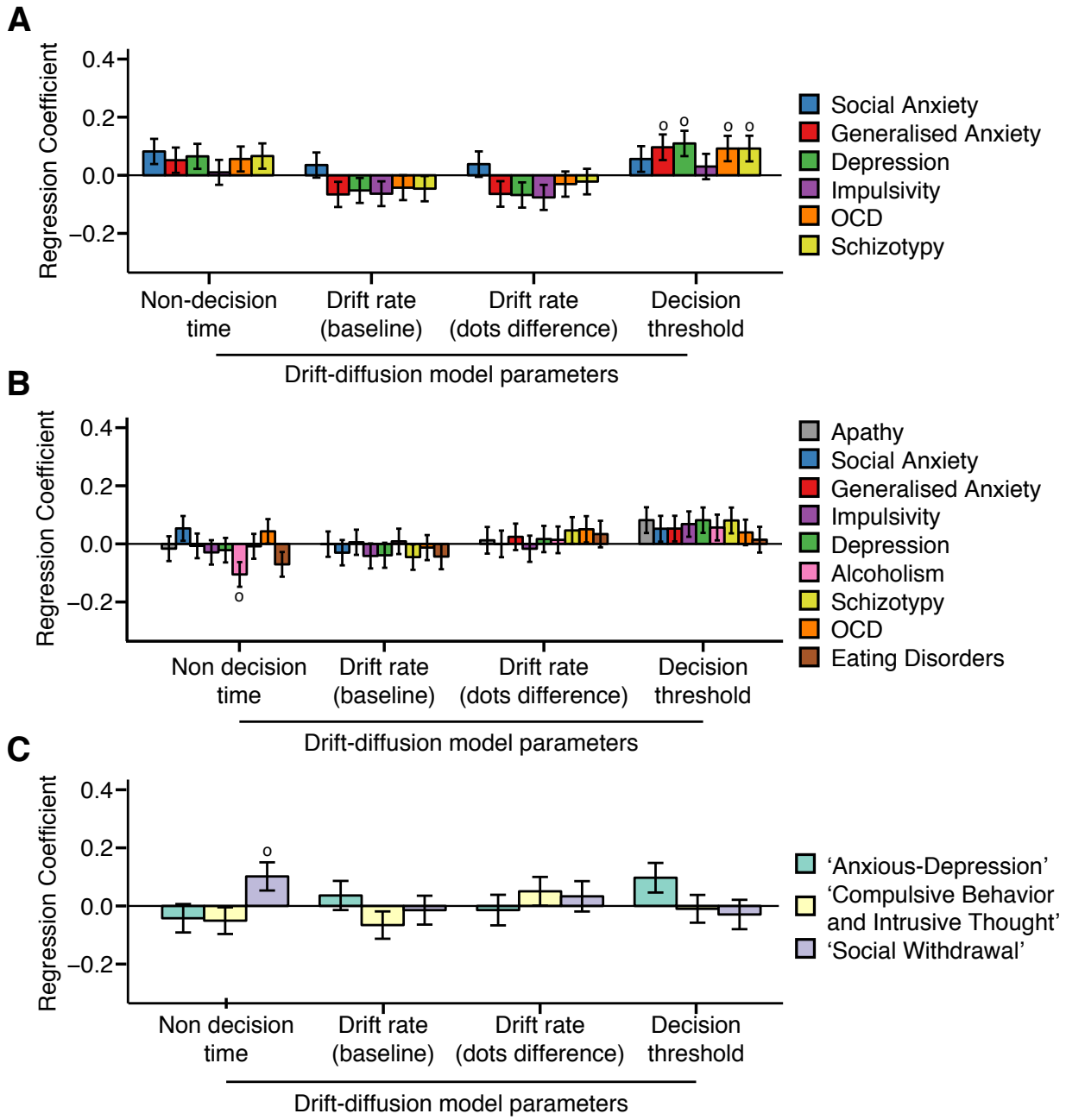
Quantifying metacognitive bias

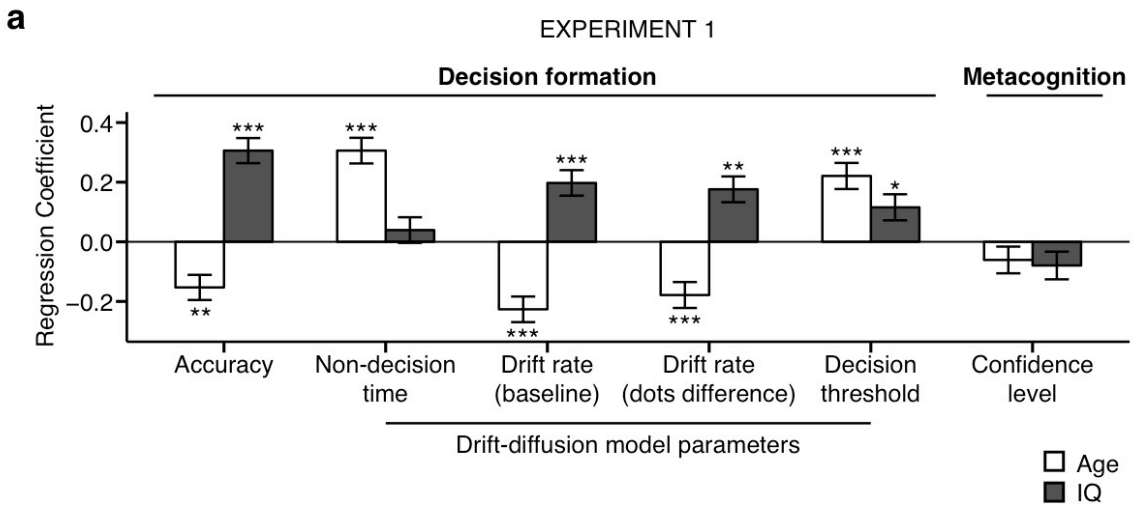


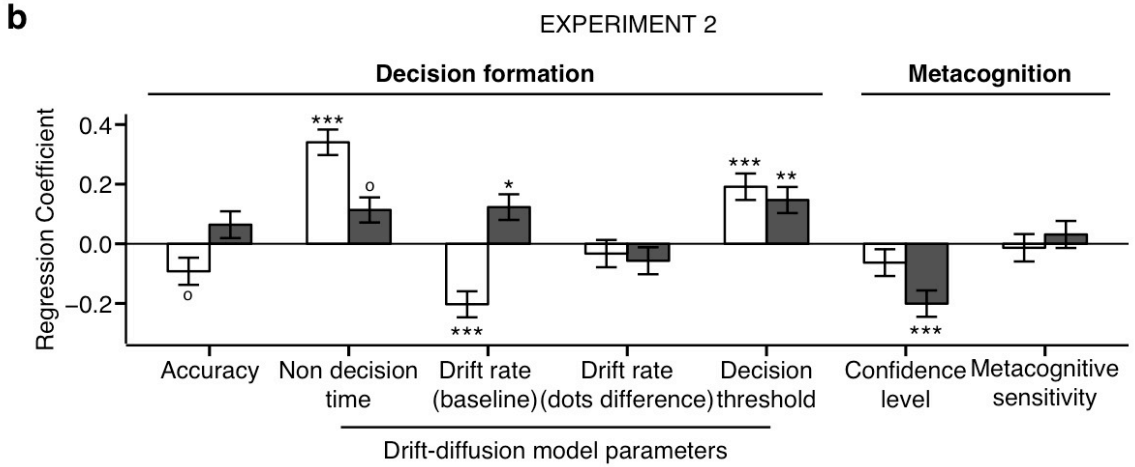
$$mdist_{R1} = \frac{metac - metac2_{R1}}{metad}$$

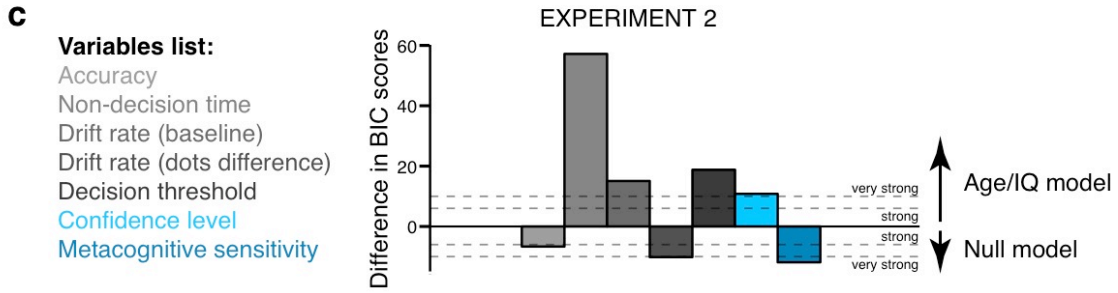


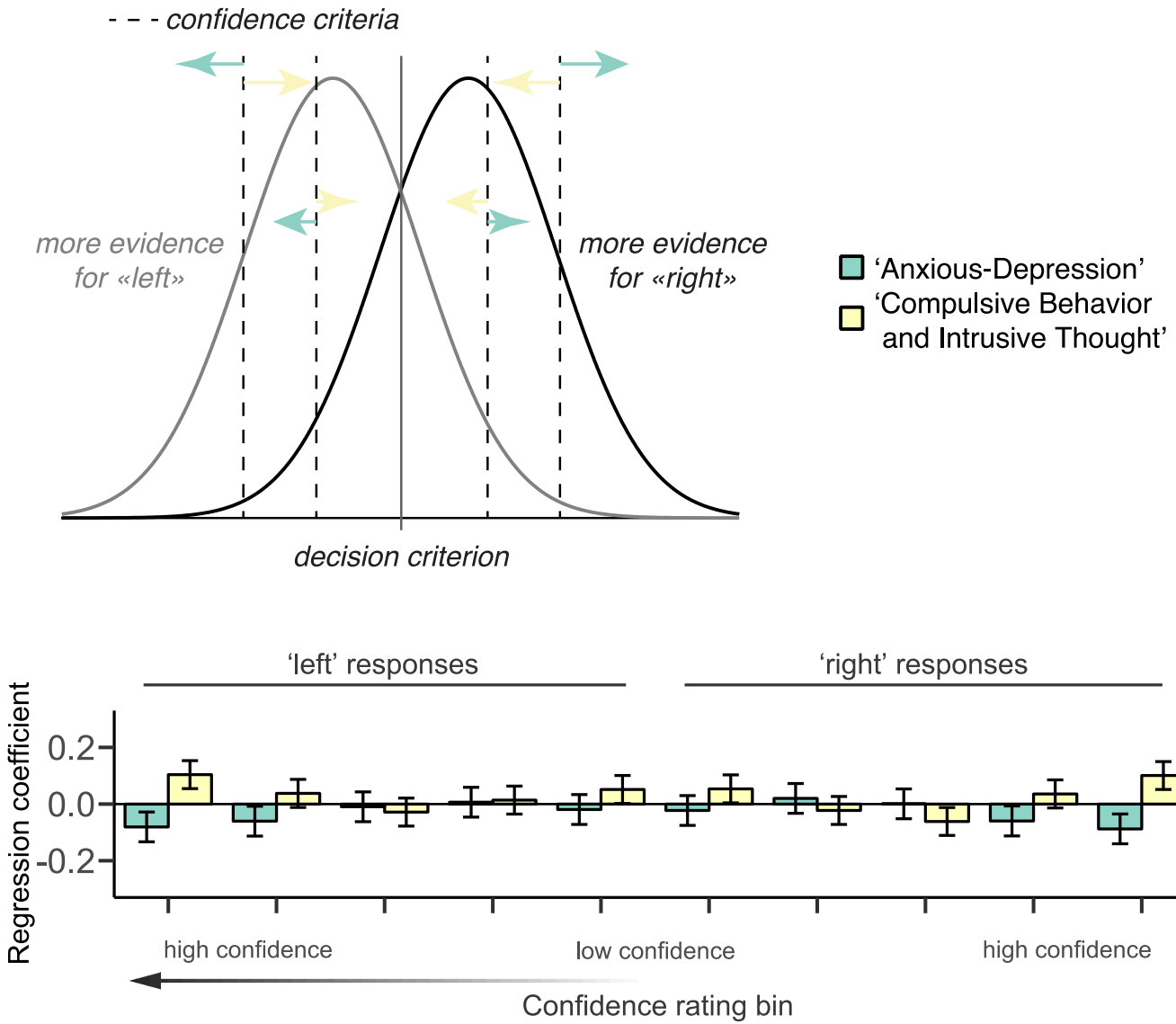
Sherman et al. (2018) *bioRxiv*

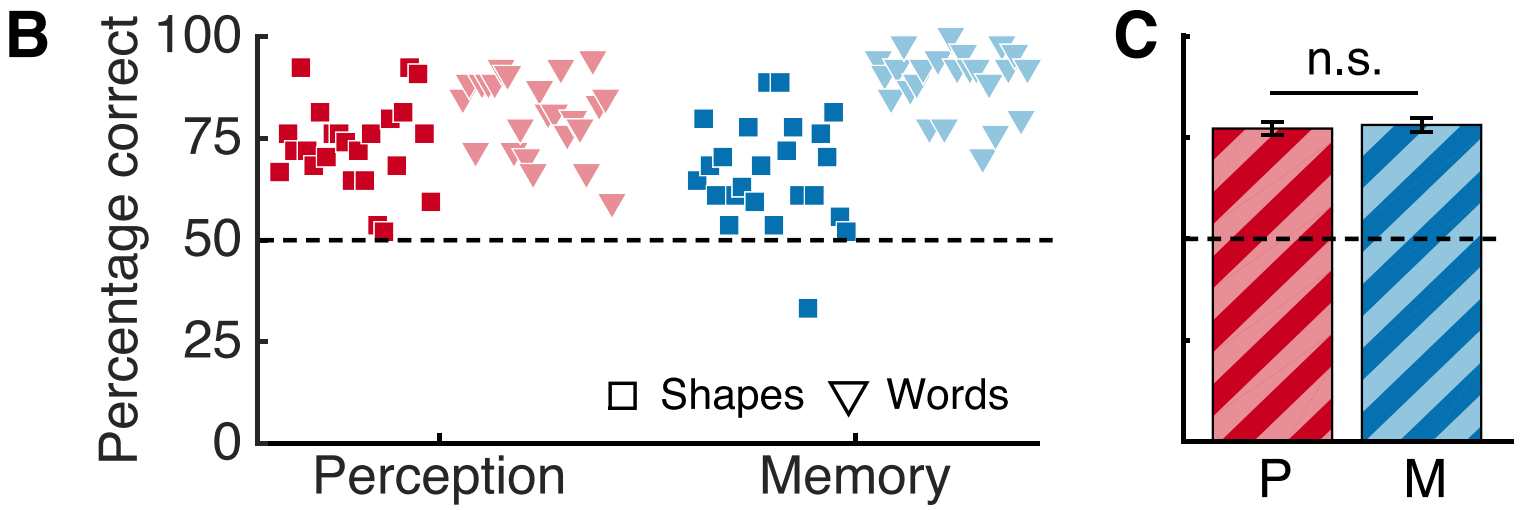

A
Regression Coefficient
0.4
0.2
0.0
−0.2
Non-decision time
Drift rate (baseline)
Drift rate (dots difference)
Decision threshold
Drift-diffusion model parameters
Social Anxiety
Generalised Anxiety
Depression
Impulsivity
OCD
Schizotypy
B
Regression Coefficient
0.4
0.2
0.0
−0.2
Non decision time
Drift rate (baseline)
Drift rate (dots difference)
Decision threshold
Drift-diffusion model parameters
Apathy
Social Anxiety
Generalised Anxiety
Impulsivity
Depression
Alcoholism
Schizotypy
OCD
Eating Disorders
C
Regression Coefficient
0.4
0.2
0.0
−0.2
Non decision time
Drift rate (baseline)
Drift rate (dots difference)
Decision threshold
Drift-diffusion model parameters
'Anxious-Depression'
'Compulsive Behavior and Intrusive Thought'
'Social Withdrawal'


a
EXPERIMENT 1
Decision formation
Metacognition
Regression Coefficient
0.4
0.2
0.0
−0.2
Accuracy
Non-decision time
Drift rate (baseline)
Drift rate (dots difference)
Decision threshold
Confidence level
Drift-diffusion model parameters
Age
IQ


b
EXPERIMENT 2
Decision formation
Metacognition
Regression Coefficient
0.4
0.2
0.0
−0.2
Accuracy
Non decision time
Drift rate (baseline)
Drift rate (dots difference)
Decision threshold
Confidence level
Metacognitive sensitivity
Drift-diffusion model parameters


c
Variables list:
Accuracy
Non-decision time
Drift rate (baseline)
Drift rate (dots difference)
Decision threshold
Confidence level
Metacognitive sensitivity
EXPERIMENT 2
Difference in BIC scores
60
40
20
0
very strong
strong
strong
very strong
Age/IQ model
Null model


- - - confidence criteria
more evidence for «left»
more evidence for «right»
decision criterion
'Anxious-Depression'
'Compulsive Behavior and Intrusive Thought'
'left' responses
'right' responses
Regression coefficient
0.2
0.0
-0.2
high confidence
low confidence
high confidence
Confidence rating bin



Morales, Lau & Fleming (2018) *J Neuro*