A deeper and multi-paradigm exploration of metacognition in aging – the AGEFOK Project

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* co-first

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the 12th Geneva Aging Series

Morges, September 24-26, 2024

Projet-ANR-21-CE28-0002 funded by anr agence nationale de la recherche

Note.

Items (images, sources) are clickable.

Who are we?

C. Bastin

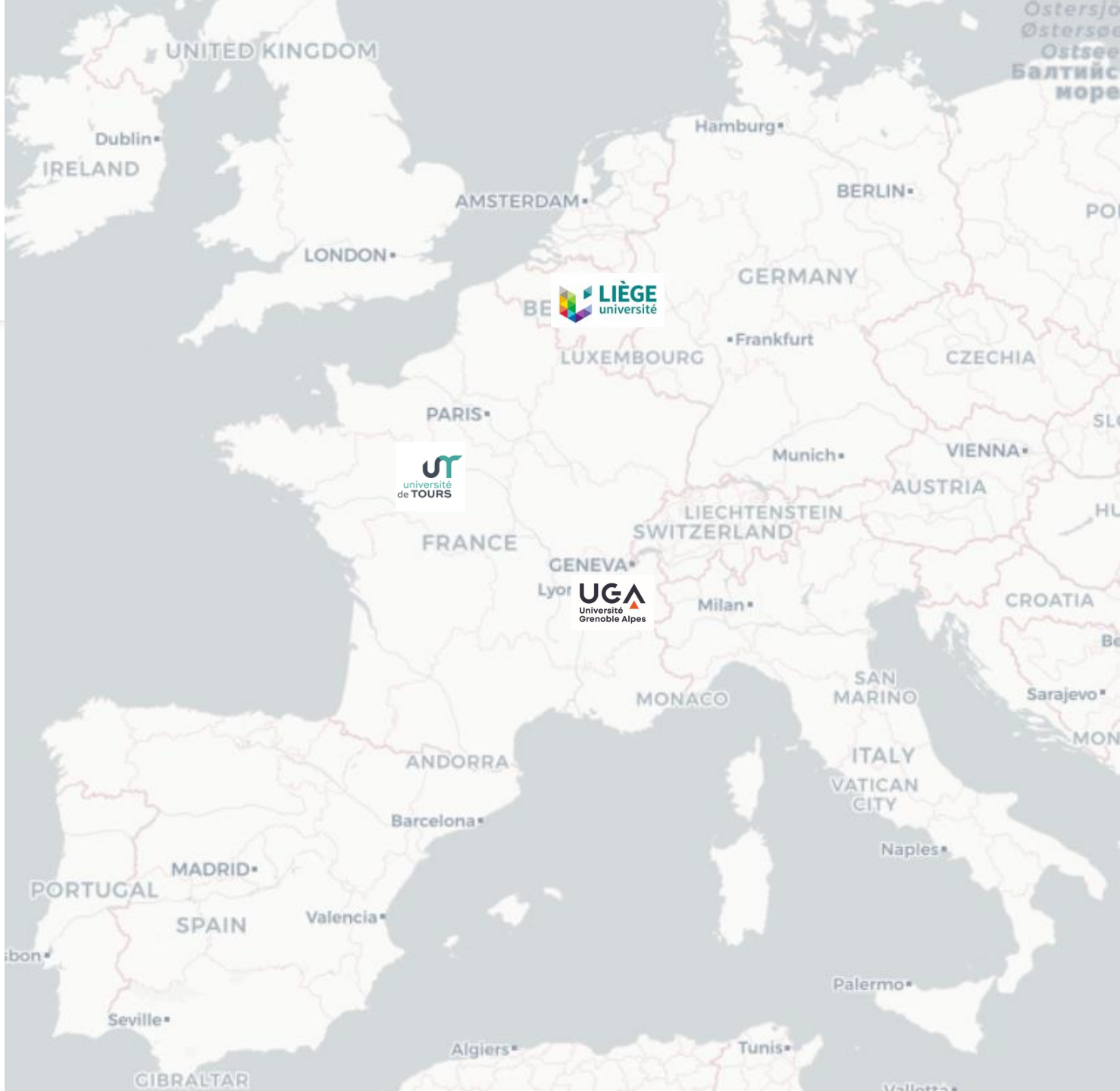
L. Angel

C. Grégoire

C. Moulin

C. Souchay

L. Meunier



Aims of the AgeFok Project

ESTIMATING EFFECT OF AGE ON DIFFERENT DOMAINS OF METACOGNITION

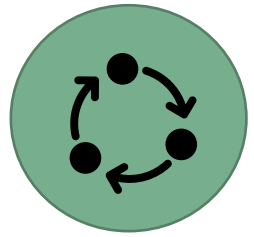
COMPARING THE IMPACT OF AGE ON DIFFERENT TYPES OF METAMEMORY JUDGEMENTS

EXPLORING THE NEURAL CORRELATES OF METAMEMORY

+ Citizens' Science: "Seniors pour la Science" Project

Metacognition: Back to basics

Knowledge people have about their cognitive abilities, strategies, tasks, …



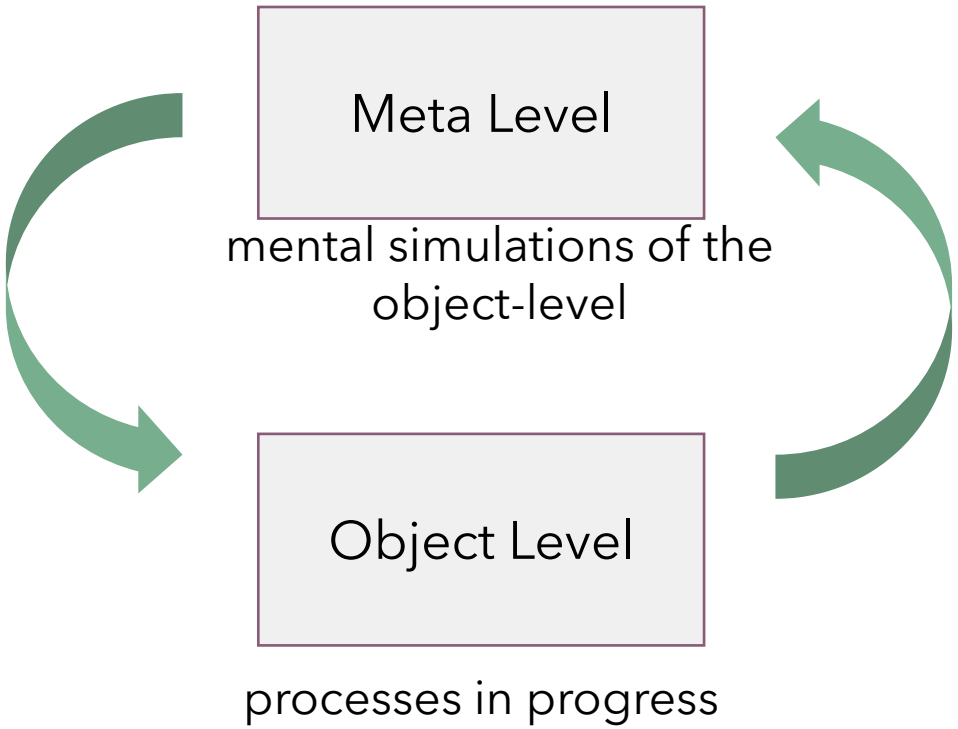
Regulation: ***cognitive monitoring*** (e.g., error detection, source monitoring in memory retrieval), ***cognitive control*** (e.g., conflict resolution, error correction, inhibitory control, planning, resource allocation)

Fernandez-Duque, Baird, & Posner (2000); Flavell (1979); Nelson & Narens (1990); Reder & Schum (1996)

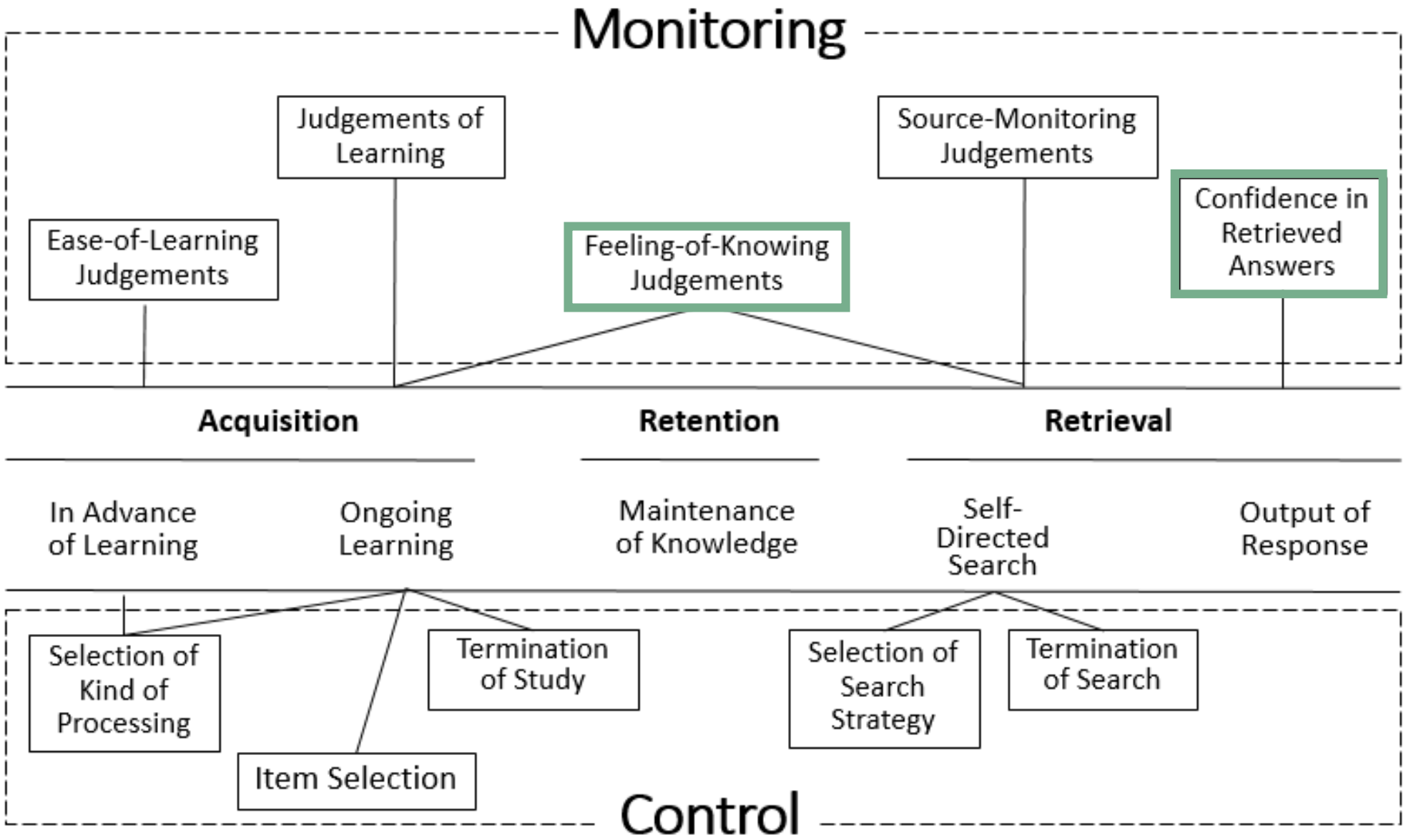
Theoretical Framework

Moulin et al. (2022)

Tip-of-the-tongue
Déjà-Vu
Jamais-Vu



Nelson & Narens (1990)



Nelson & Narens (1990)

But, How Do We Measure Metacognition?

Memory performances = Type 1 performance

Judgments

Metacognitive precision

Metacognitive bias

Metacognition efficiency

Metacognitive Accuracy

Feeeling Of Knowing (FOK)

Encoding phase

bird - land

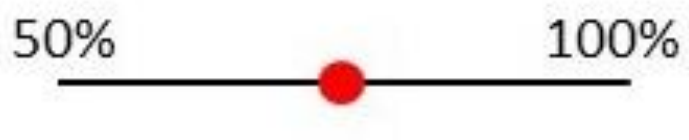
lake - secret

paper - cake

Recall

bird - ?

Do you think you will recognize this item "?" later?



Recognition

bird

banana - land

And Retrospective Confidence Judgments (RCJ)

Encoding phase

bird - land

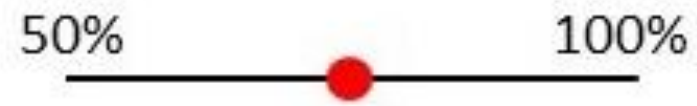
lake - secret

paper - cake

Recall

bird - ?

FOK

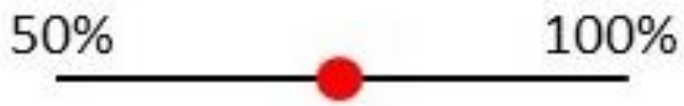


Recognition

bird

banana - land

How confident are you?



Assessing Metacognition with …

Metacognitive Bias

the individual tendency

to **underestimate or overestimate**

cognitive performance

Metacognitive Accuracy

the **ability to adapt**

confidence judgments,

considering the correctness of the response

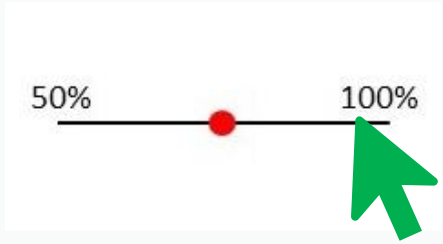
Gamma and phi correlations
(Goodman & Kruskal, 1979)

Gamma Scores

Congruent

bird

banana - land

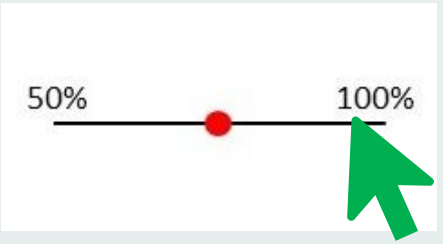


Yes-Success
No-Fail

Incongruent

bird

banana - land



Yes-Failed
No-Succeed

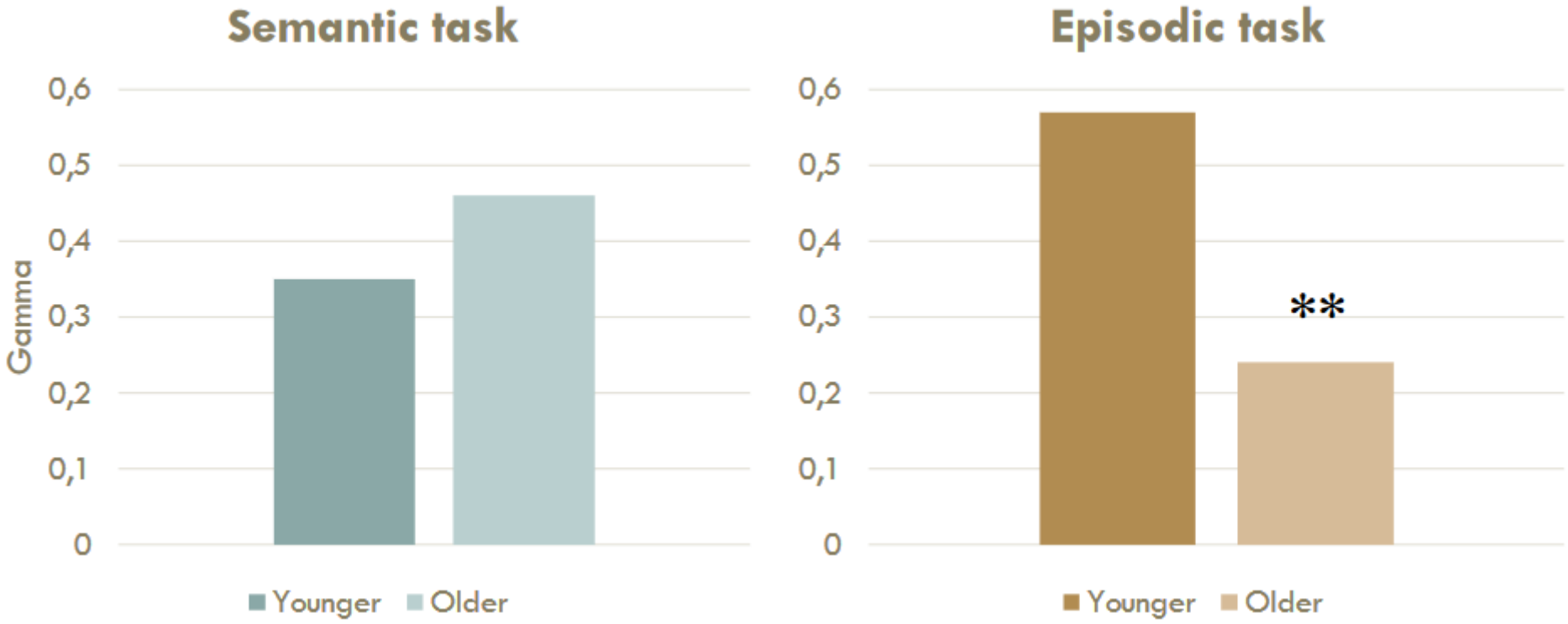
$$\gamma = \frac{N_c - N_d}{N_c + N_d}$$

Nc = number of congruent pairs
Nd = number of incongruent pairs

Example in Aging

Diminished episodic memory awareness in older adults: Evidence from feeling-of-knowing and recollection

Céline Souchay [a,*], Chris J.A. Moulin [a], David Clarys [b], Laurence Taconnat [b], Michel Isingrini [b]



But, no consideration of metacognitive bias

Souchay et al., 2007

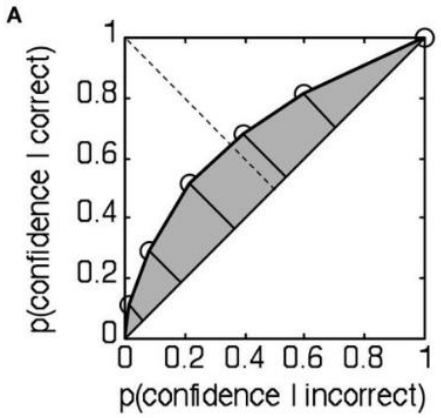
Methodological Issues Of The Measures

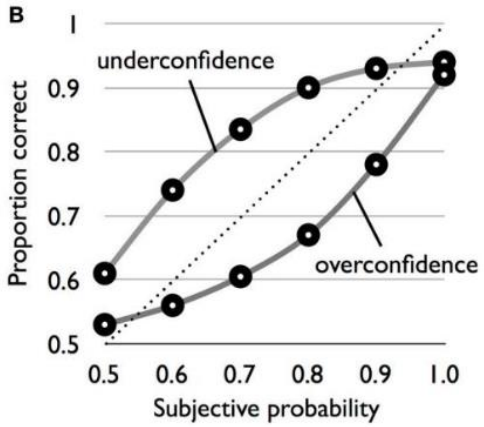
1

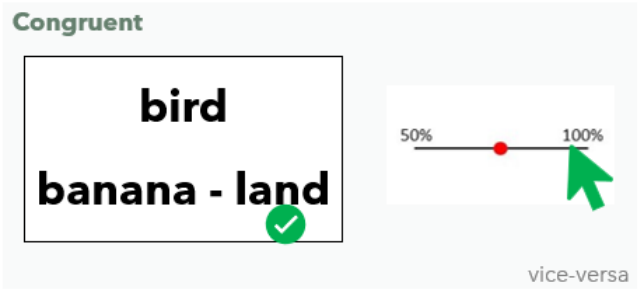
No consideration of metacognitive bias

2

Dependant of the memory performance







Beyond the Performance

scientific reports

OPEN

Episodic and semantic feeling-of-knowing in aging: a systematic review and meta-analysis

Méline Devaluez[1,3▷◁], Audrey Mazancieux[2,3▷◁] & Céline Souchay[1]

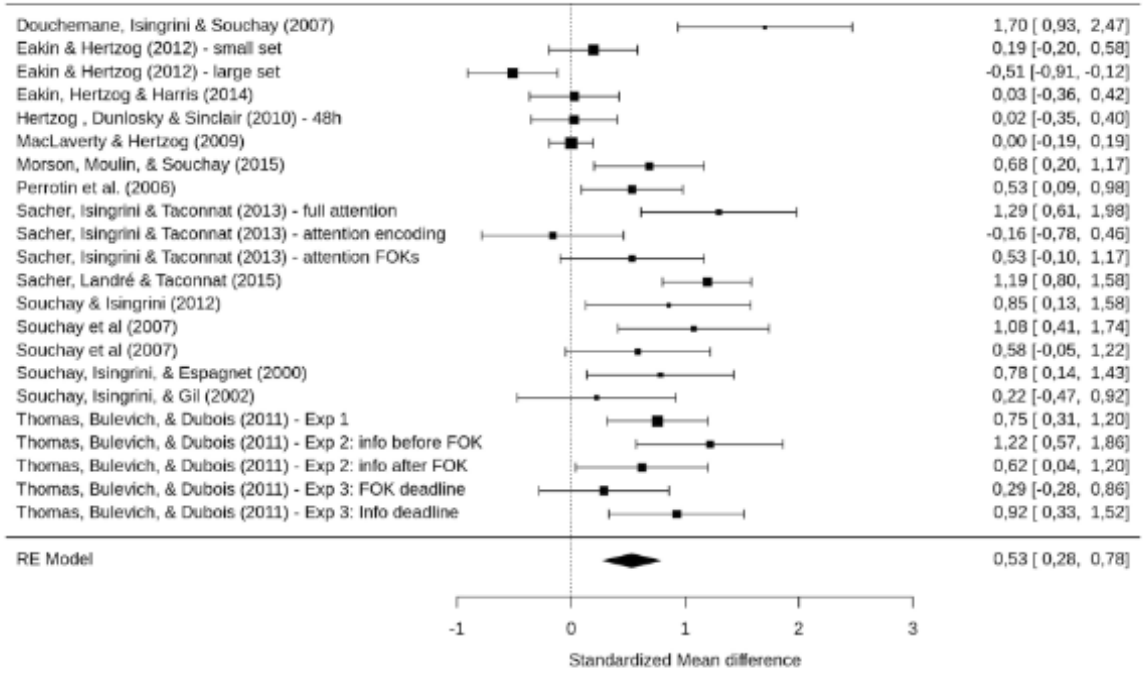


Figure 3. Forrest plot of the effect of eFOK deficit in OA. Confidence interval of the overall estimated effect does not overlap with 0.

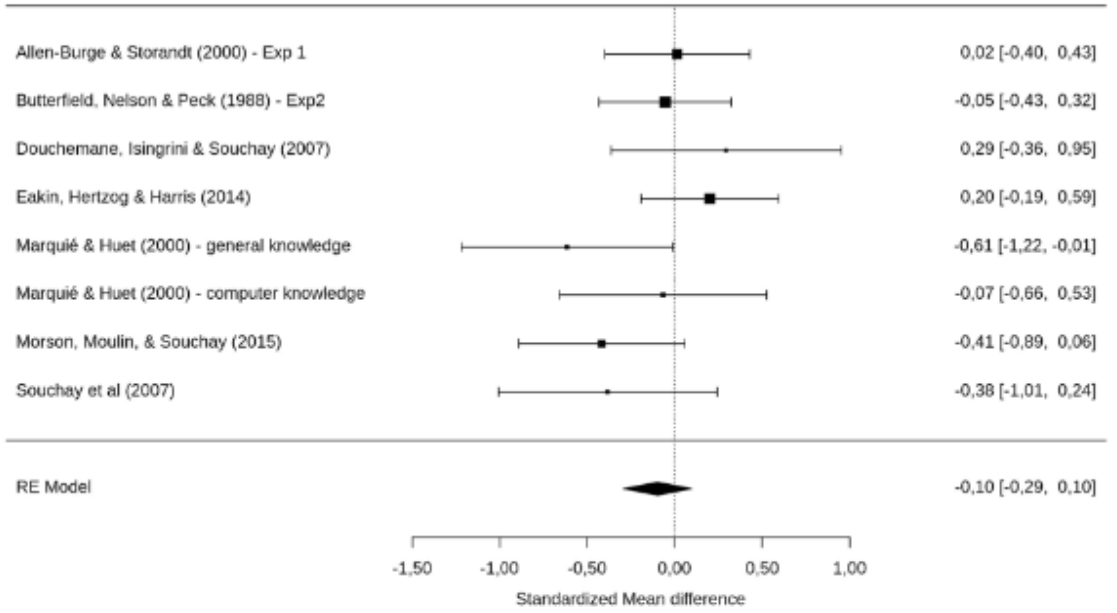


Figure 4. Forrest plot showing an absence of sFOK deficit in OA. Confidence interval of the overall estimated effect does overlap with 0.

Meta-analysis by Devaluez et al., 2023

No/Less difference when task performance is controlled

Meta-analysis by Devaluez et al., 2023

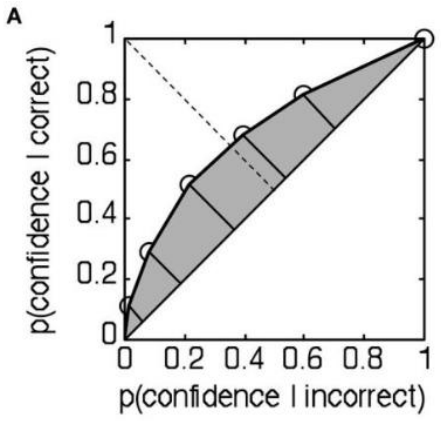
Methodological Issues Of The Measures

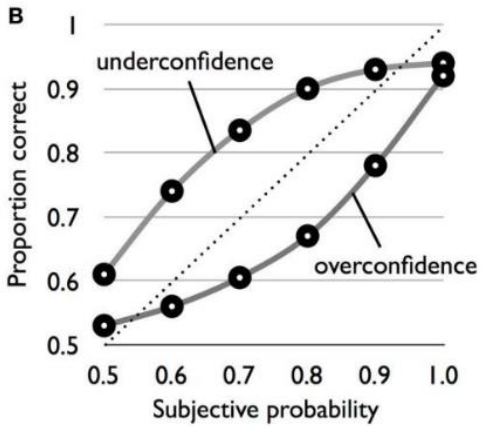
1

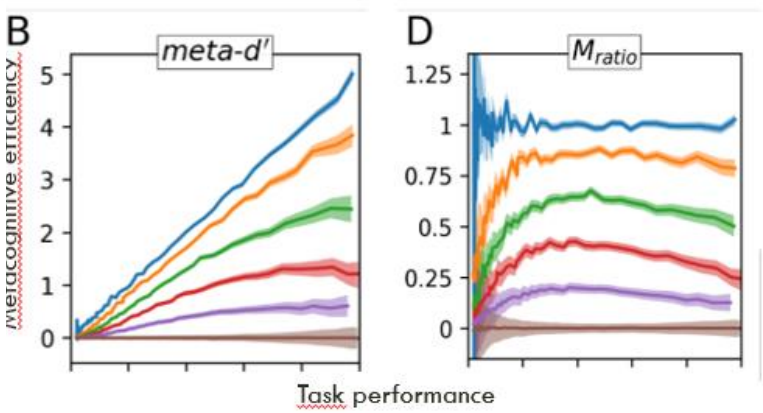
No consideration of metacognitive bias

2

Dependant of the memory performance







✓ **meta-d' = d' predicted on the basis of their second-order performance value** is interpreted in relation to first-order performance (d')

✓ **metacognitive efficiency** = **Mratio** = the ratio between meta-d' and d'

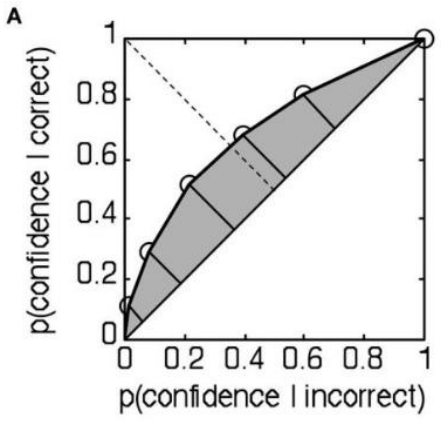
× Needs a lot of trials: difficult in Episodic Memory

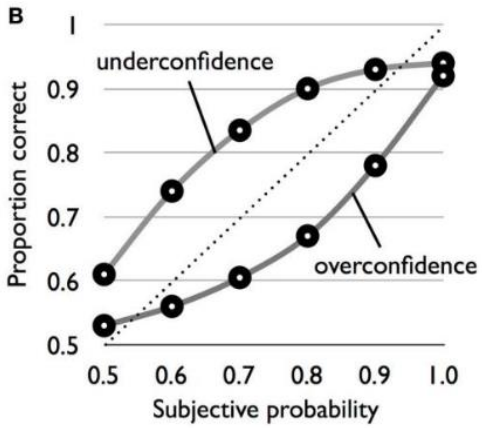
Methodological Issues Of The Measures

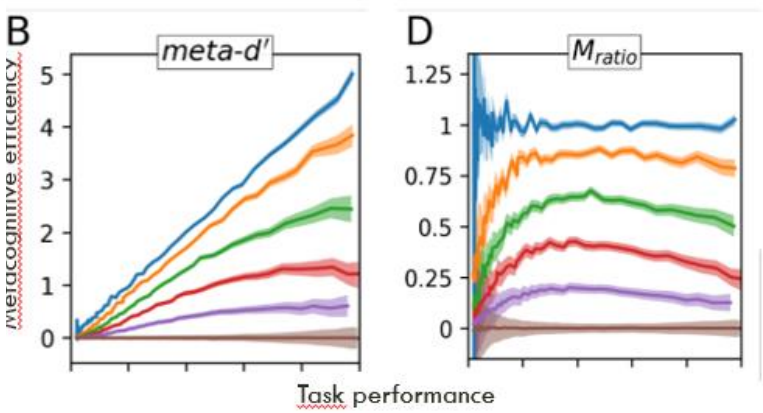
1. No consideration of metacognitive bias

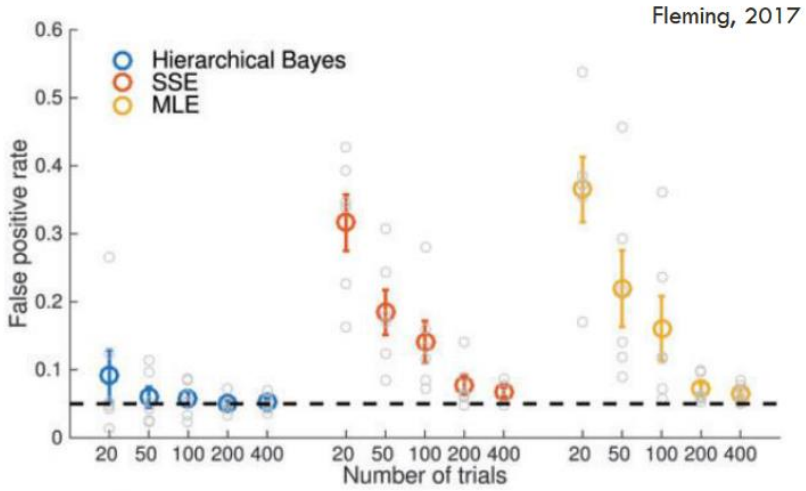
2. Dependant of the memory performance

3. Number of trials per conditions is limited









So, How Do We Measure Metacognition?

Metacognitive Bias

the individual tendency to **underestimate or overestimate cognitive performance**

Metacognitive Accuracy

the **ability to adapt** confidence judgments, **considering the correctness of the response**

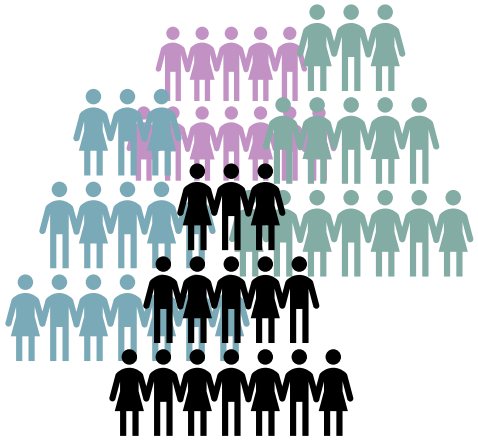
- ✓ AUROC2 (Galvin et al., 2003)
- ✓ Mratio (Maniscalco & Lau, 2012, 2014)
- ✓ **Hmeta-d** (Fleming, 2017) **estimates the metacognitive efficiency at the group level**

Then, How Did We Proceed in AgeFok?

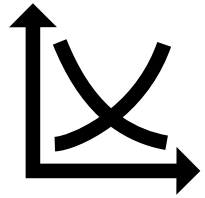
Estimating the accuracy of metacognitive judgments : **a modeling approach**

Hierarchical Bayesian framework (Hmeta-d; Fleming, 2017)

Large sample sizes



In **healthy aging** and in **different metacognitive domains**



Why?

Review Article | Published: 17 November 2023

Towards a common conceptual space for metacognition in perception and memory

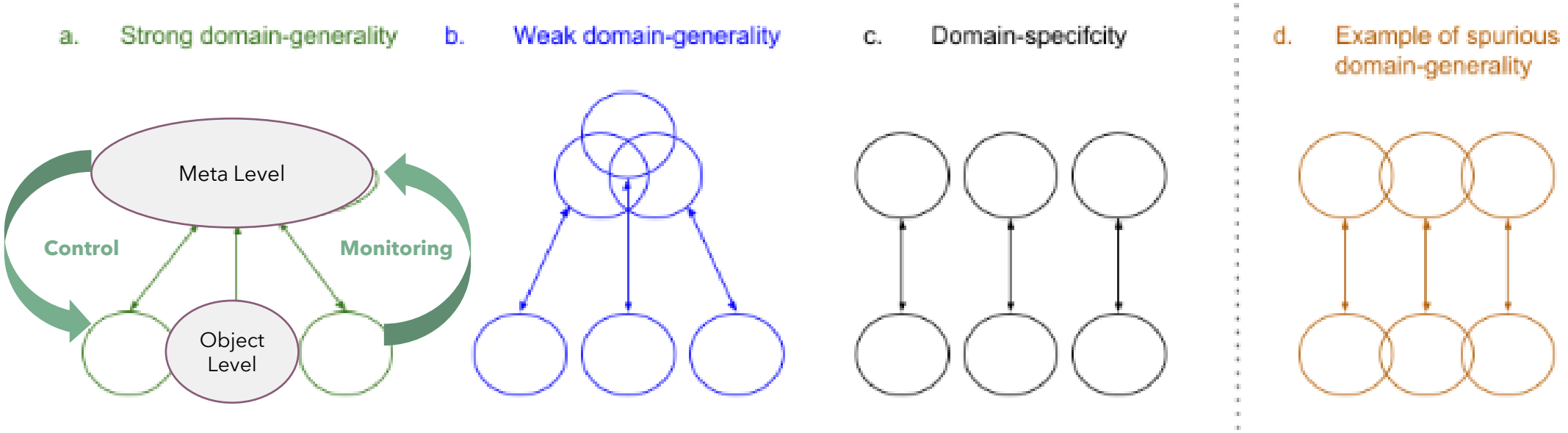
Audrey Mazancieux, Michael Pereira, Nathan Faivre, Pascal Mamassian, Chris J. A. Moulin & Céline Souchay

Nature Reviews Psychology **2**, 751–766 (2023) | Cite this article

→ Comparing different domains on a systematic manner

→ Confronting a correlational, a neuropsychological, and a neuroanatomical approach

→ Studying aging allows for potential differential trajectories and further comparisons



Metacognition & Cognitive Domains

American Psychological Association

Journal of Experimental Psychology: General

ISSN: 0096-3445

2020, Vol. 149, No. 9, 1788–1799
http://dx.doi.org/10.1037/xge0000746

Is There a G Factor for Metacognition? Correlations in Retrospective Metacognitive Sensitivity Across Tasks

Audrey Mazancieux
Grenoble Alpes University

Stephen M. Fleming
University College London

Céline Souchay and Chris J. A. Moulin
Grenoble Alpes University

Perception

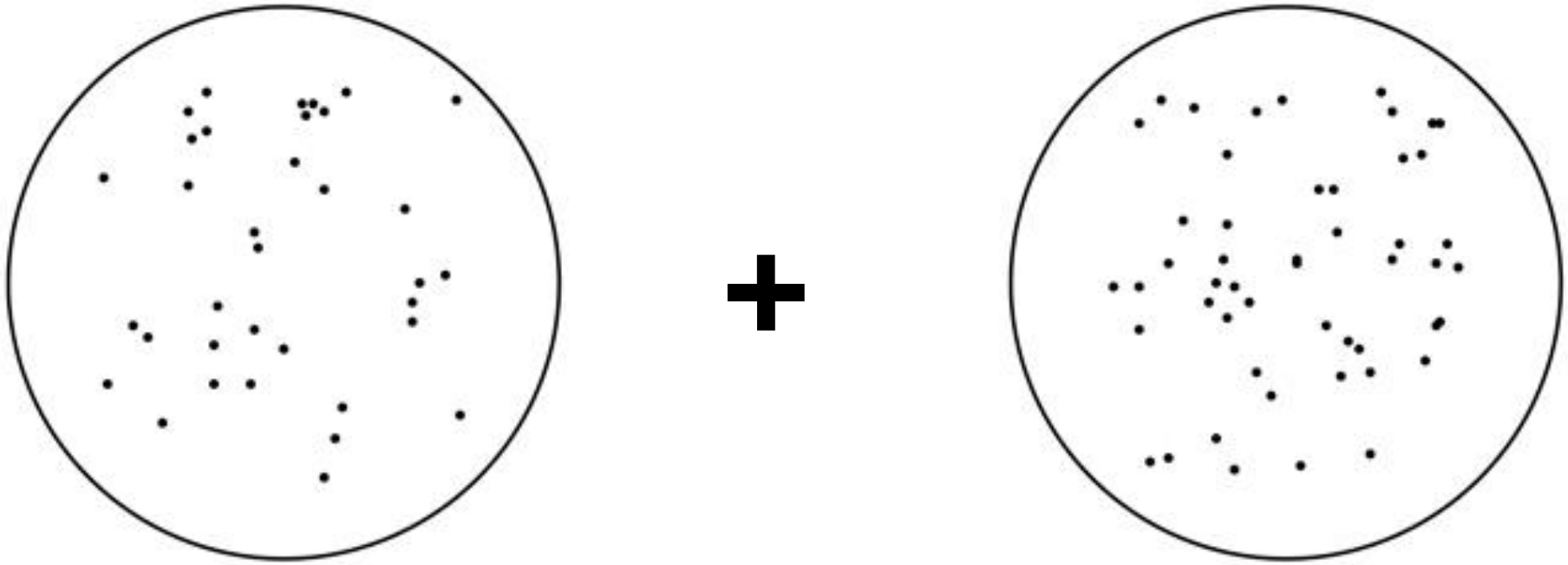
Episodic memory

Short-term Memory & Exceutive

Semantic memory

Metacognition & Cognitive Domains

Perception



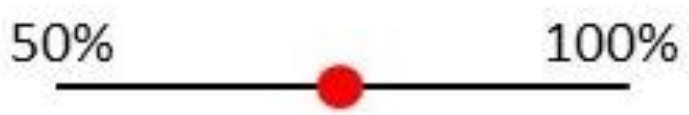
Metacognition & Cognitive Domains

Perception

Which circle contains the most dots?

left or right?

How confident are you?



Metacognition & Cognitive Domains

Short-term Memory & Executive

7A5N2

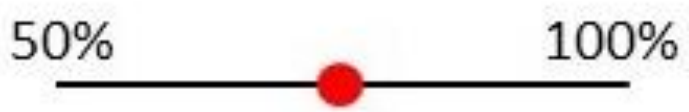
Metacognition & Cognitive Domains

Short-term memory

Which one of the two presented responses corresponded to the sum of all numbers and the relevant letters?

14AN or 16AN

How confident are you?



Metacognition & Cognitive Domains

Episodic memory

Encoding phase

bird - land

lake - secret

paper - cake

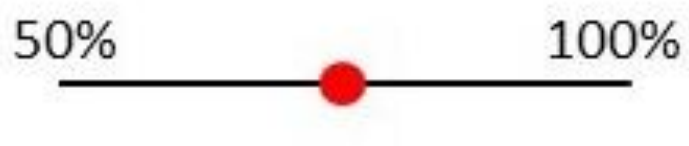
Retrieval phase

Which one matches the cue word?

bird

banana - land

How confident are you?



Metacognition & Cognitive Domains

Semantic memory

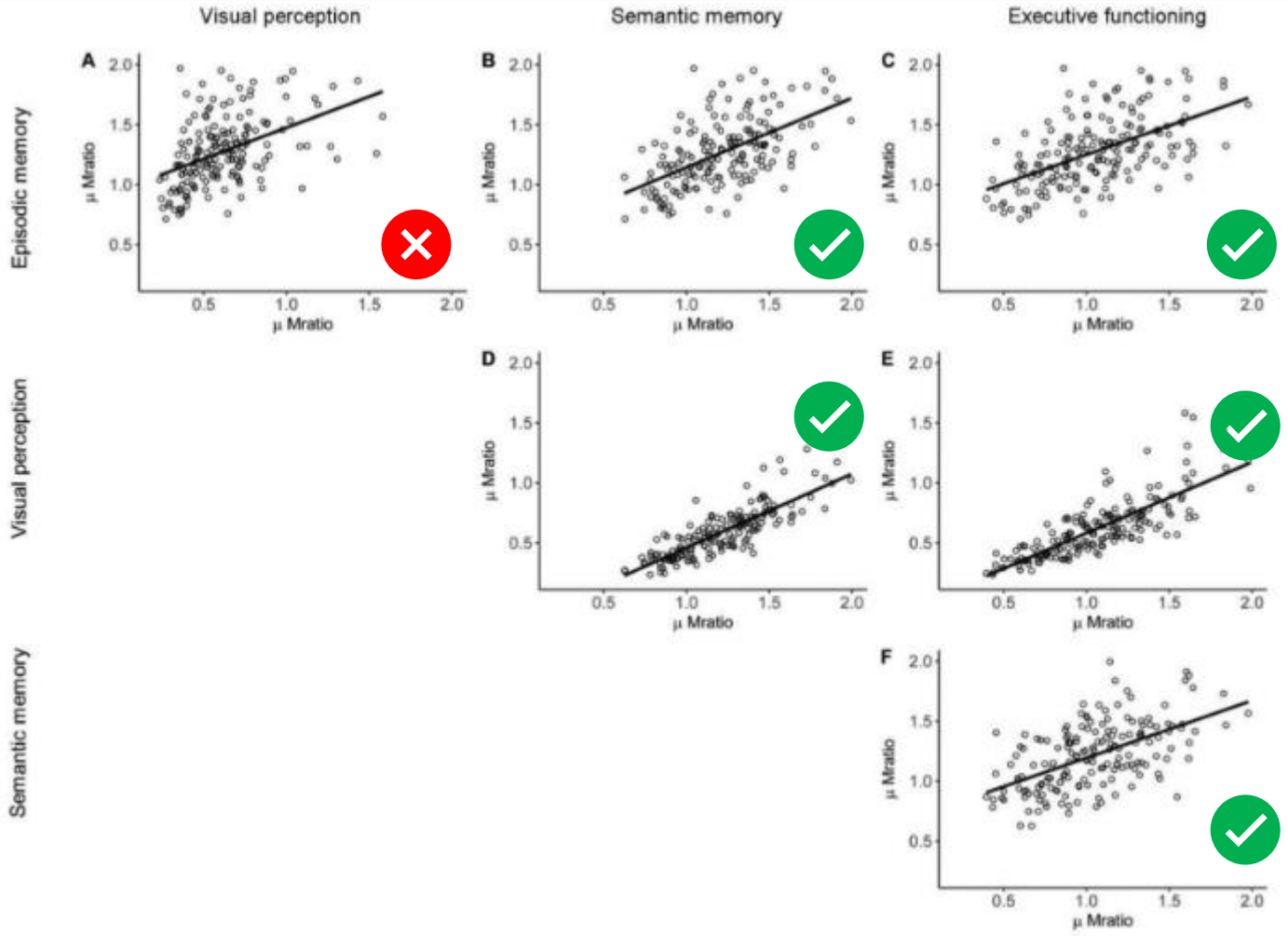
How high is the Mont Blanc?

4810m **4953m**

How confident are you?

Metacognition & Cognitive Domains

- ✓ N = 181 healthy young adults
- ✓ Four 2-alternative forced-choice tasks
- ✓ Across-domains correlations



And, in Aging?

PhD defense: October, 24th
3 to 5pm

THÈSE

Pour obtenir le grade de

DOCTEUR DE L'UNIVERSITÉ GRENOBLE ALPES

UGA Université Grenoble Alpes

École doctorale : ISCE - Ingénierie pour la Santé la Cognition et l'Environnement
Spécialité : PCN - Sciences cognitives, psychologie et neurocognition
Unité de recherche : Laboratoire de Psychologie et Neuro Cognition

Distinguer les changements de mémoire liés à l'âge des capacités de métamémoire des personnes âgées : Données comportementales et de neuroimagerie dans le vieillissement sain et pathologique

Distinguishing age-related memory changes from metamemory abilities of older adults: Behavioral and neuroimaging data in healthy and pathological aging

Présentée par :

Lucile MEUNIER ⇦ The lord

Direction de thèse :

Christopher MOULIN Professeur des Universités, Université Grenoble Alpes	Directeur de thèse
Céline SOUCHAY DIRECTRICE DE RECHERCHE, CNRS DELEGATION ALPES	Co-directrice de thèse

Metacognition in Aging & Cognitive Domains

Perception

✗ Palmer et al., 2014

✓ Filippi et al., 2020; McWilliams et al., 2023

Episodic memory

✗ Meta-analysis by Devaluez et al., 2023

Short-term Memory / Executive

✓ Bertrand et al., 2016; McWilliams et al., 2023

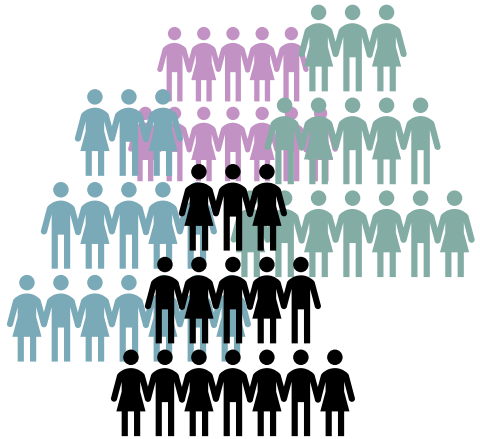
Semantic memory

✓ Meta-analysis by Devaluez et al., 2023

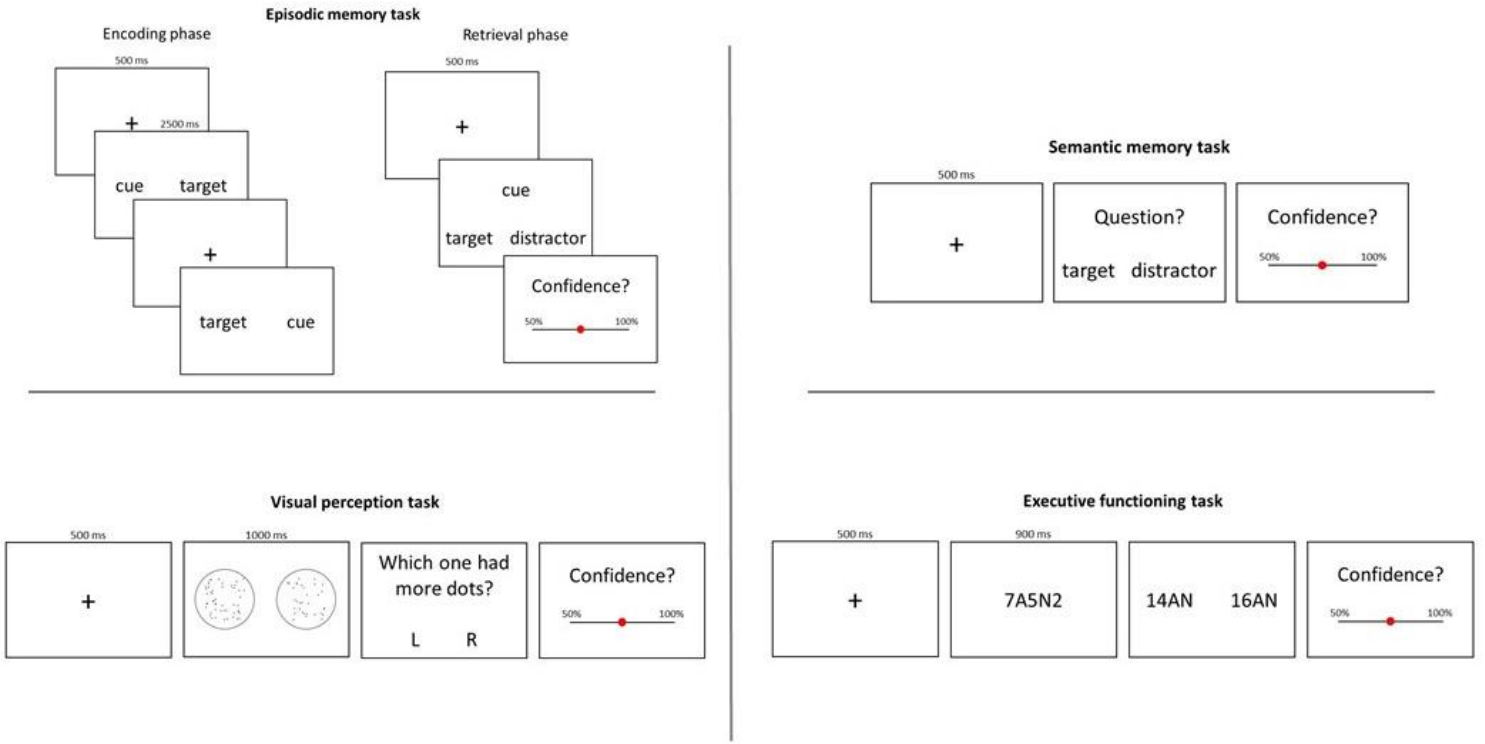
Does age affect metacognition? A cross-domain investigation using a hierarchical Bayesian framework

Meunier-Duperray et al. Under review in Cognition

442 participants aged 18 to 79



4 metacognitive tasks



The Bayesian framework: (R)HMeta-d model

✓**Metacognitive efficiency**

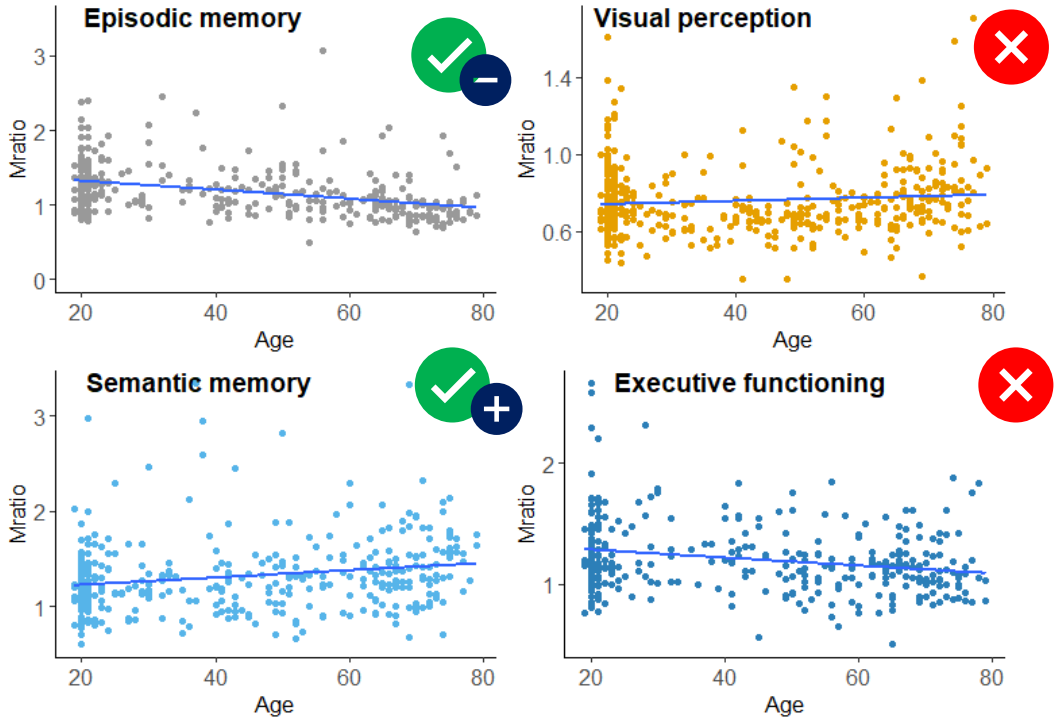
✓To estimate metacognition with a greater independence (but not perfect) from memory performances

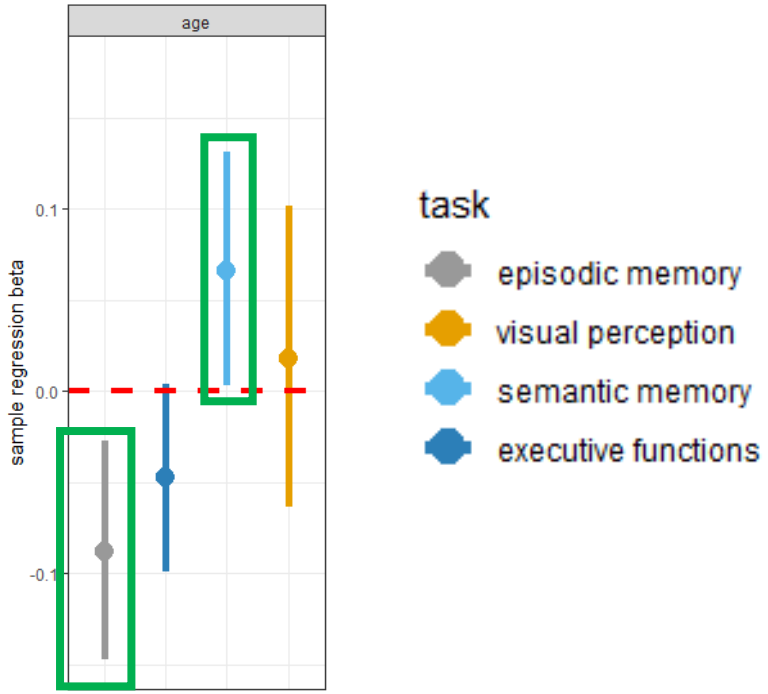
✓To better differentiate the effect of age on cognitive and metacognitive processes independently

✓an extended version of the HMeta-d model

✓developed to estimate metacognitive efficiency integrating within- and between subject uncertainty in parameter estimates (Fleming, 2017)

Age Effect on Metacognition





Evolution of metacognitive efficiency in the episodic and semantic tasks is progressive throughout aging

Cross-task Correlations

	Younger adults	Older adults
Memory Performance (*d'*)	✓ Executive functions **with** the other 3 domains ✓ Semantic & Episodic	Executive functions **with** Episodic & Semantic
Metacognitive bias	All 6 correlations	All 6 correlations
Metacognitive efficiency (HMeta-d)	✓ Executive functions **with** Visual & Semantic ✓ Semantic & Episodic	All correlations except ✗ Visual & Episodic

Summary

Metacognitive efficiency of episodic memory declined with age

Metacognitive efficiency of semantic memory increased with age

No age effect for Executive functionning and Visual perception

But, Haven't We Just Showed Between-tasks Correlations?

- ✓ Metacognitive efficiency appeared to rely on a domain-general process in older adults
- ✓ in line with the dedifferentiation hypothesis: Cerebral activations become less specific to the task in hand, impairing cognitive performance, thus being more correlated

↳ no consensus on the alteration and preservation of metamemory processes in aging depending on the metacognitive judgments used

Alterations and Preservations of Metamemory in Healthy Aging in two Domains: Episodic and Semantic Memory

Meunier-Duperray et al. To be submitted

- ✓Metamemory abilities
- ✓Episodic and Semantic tasks
- ✓Feeling-of-knowing (FOK)
- ✓ Retrospective confidence judgments (RCJs)
- ✓**240 participants aged 19 to 79**

Age-related decline of metamemory accuracy

For the FOK:

Devaluez et al., 2023: Episodic ↘ Semantic ↗

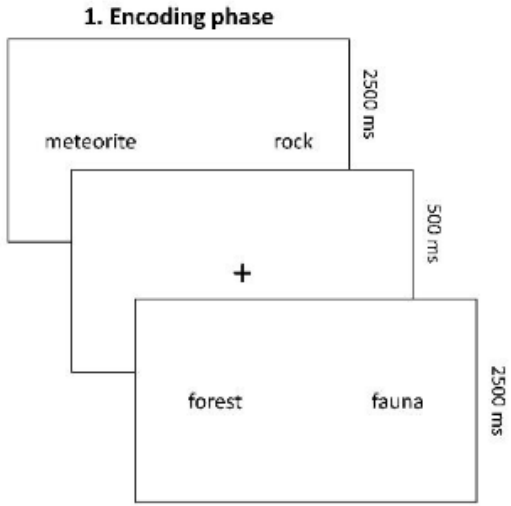
But Episodic ↘ is always observed, Why?

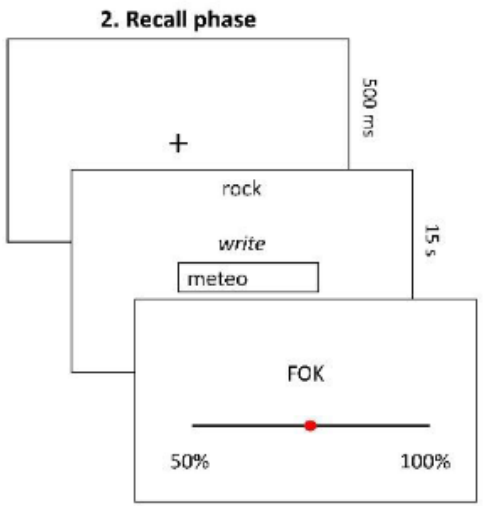
For the RCJ:

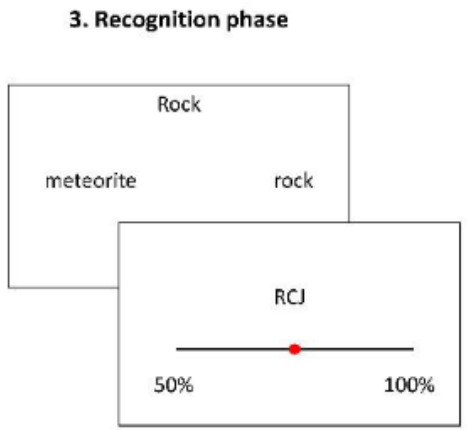
Semantic: no deficit with aging

Episodic: inconclusive

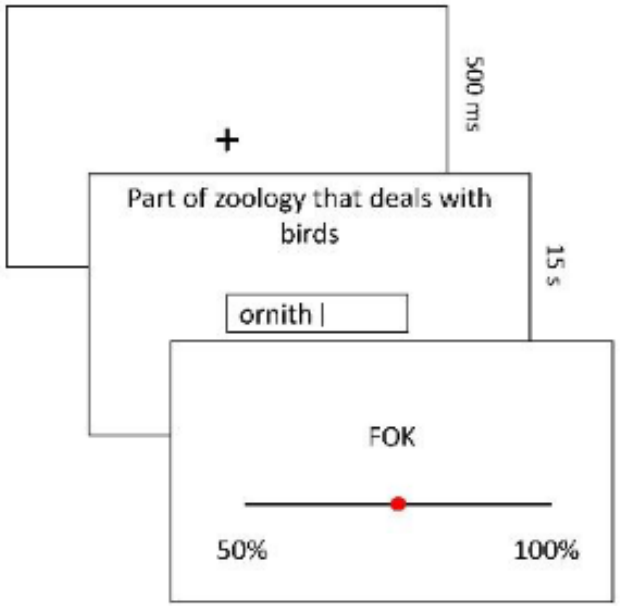
Episodic task

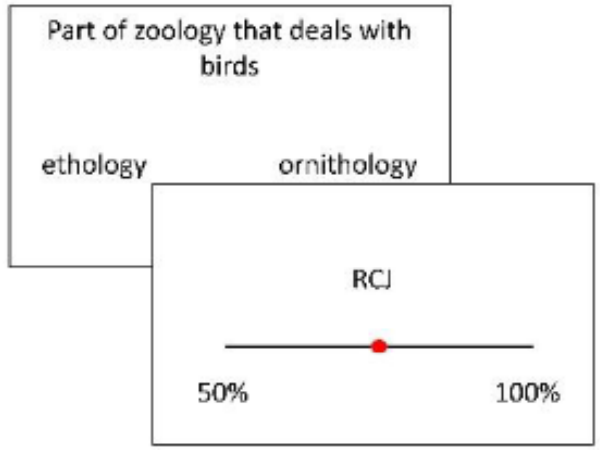




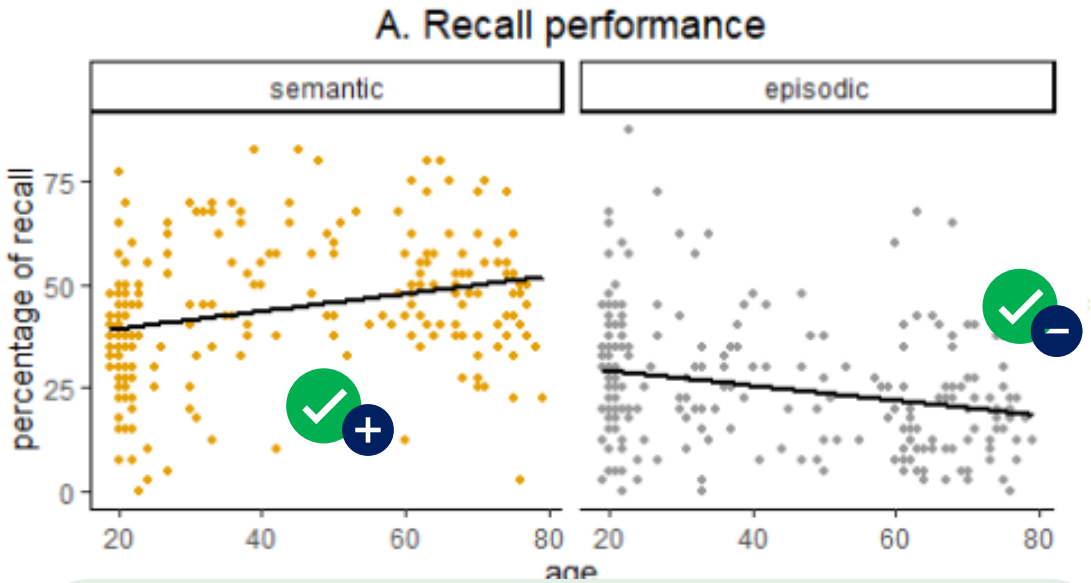


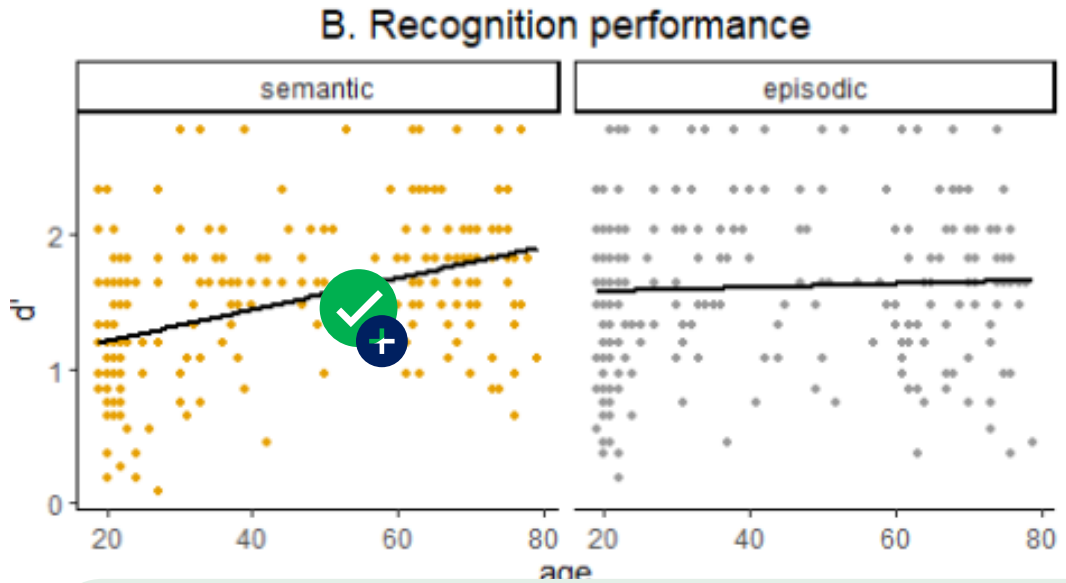
Semantic task





Type 1 Performance: Memory





- ✓ Age effect:

  Older adults recall more items
- ✘ No Task Effect

- ✓ Task Effect: Episodic > Semantic
- ✓ Age Effect:

  Older adults recognize more items

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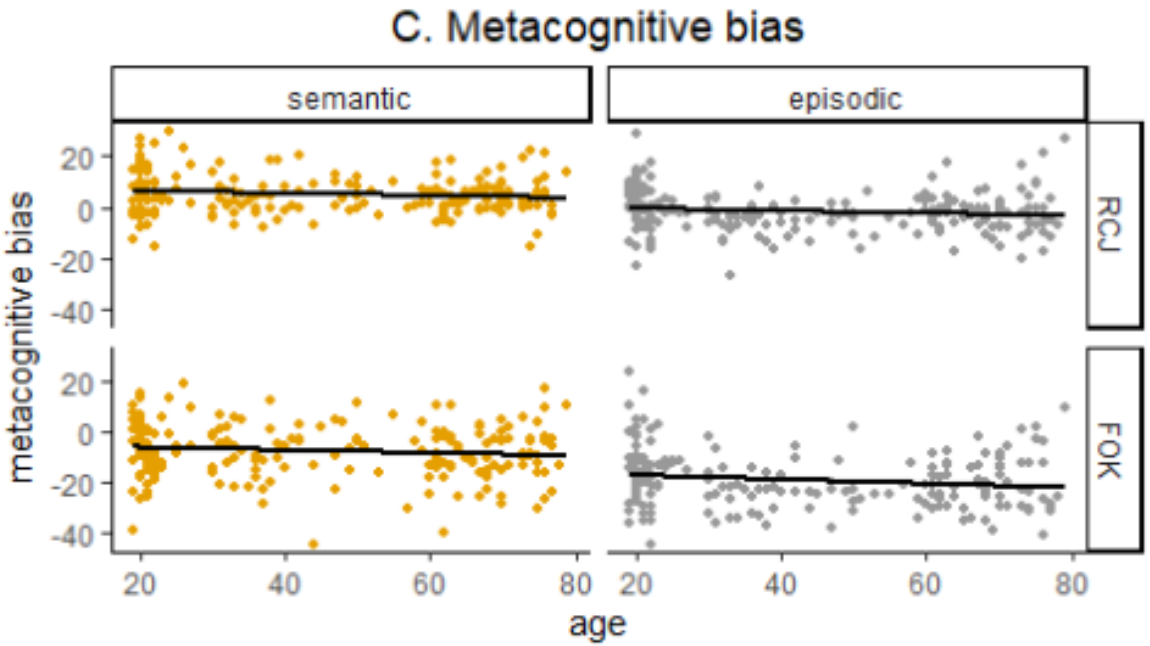
Metamemory



- ✓ Judgment Type: more underconfident in FOK > RCJ
- ✓ Age effect: increased bias = more underconfident
- ✓ Age*Task: Older Episodic > Semantic

The age effect between episodic and semantic was higher for FOK judgments than RCJs

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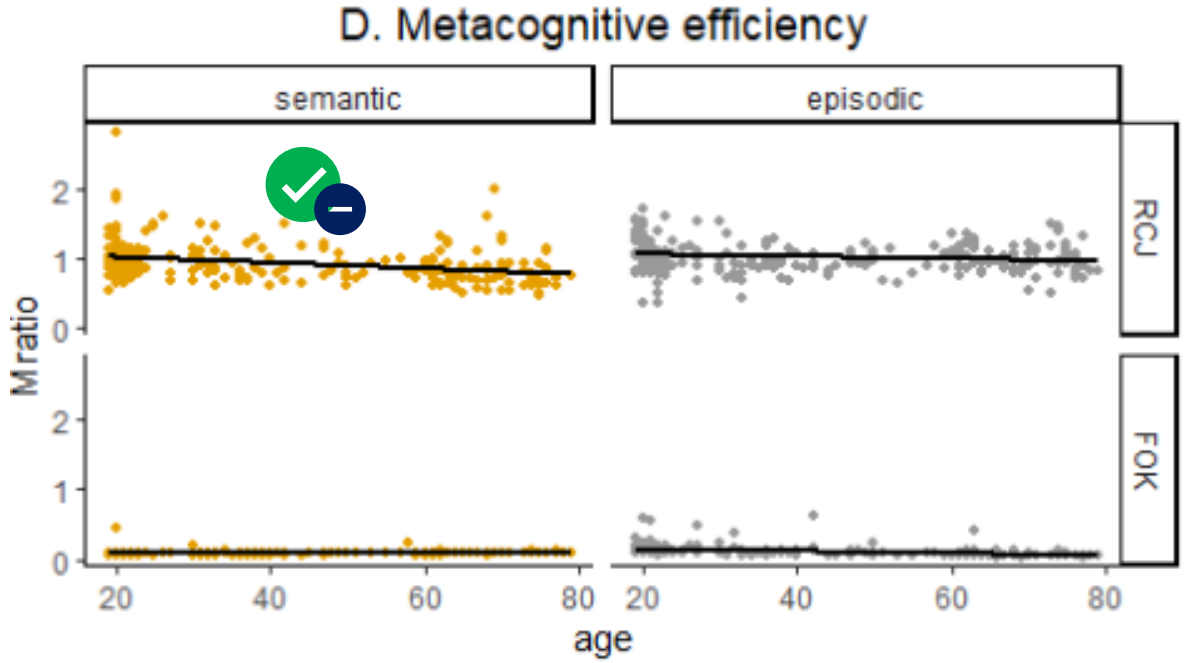
Metamemory

- ✓ Judgment Type:
  - FOK > RCJ in both tasks
- ✓ Age effect:
  - only in Semantic RCJ
- ✗ No Task Effect



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Discussion

✓ Metacognitive bias in older adults depends on the level of expertise they have in a domain

✗ No evidence of an age effect on metacognitive efficiency using FOK judgments in both episodic and semantic tasks
Very low in both groups!

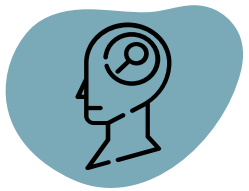
→ predominantly used the 50% rating: implication of **guessing**!

→ Problem in the instructions « how confident ..? »

→ Further analyses showed that FOK judgments were clearly based on recall accuracy rather than a prediction of future recognition

Discussion

Cues from recollection



Feeling of Knowing (FOK)

Hertzog et al., 2010; Morson et al., 2015;
Sacher et al., 2013; Souchay et al., 2000, 2007

Cues from familiarity

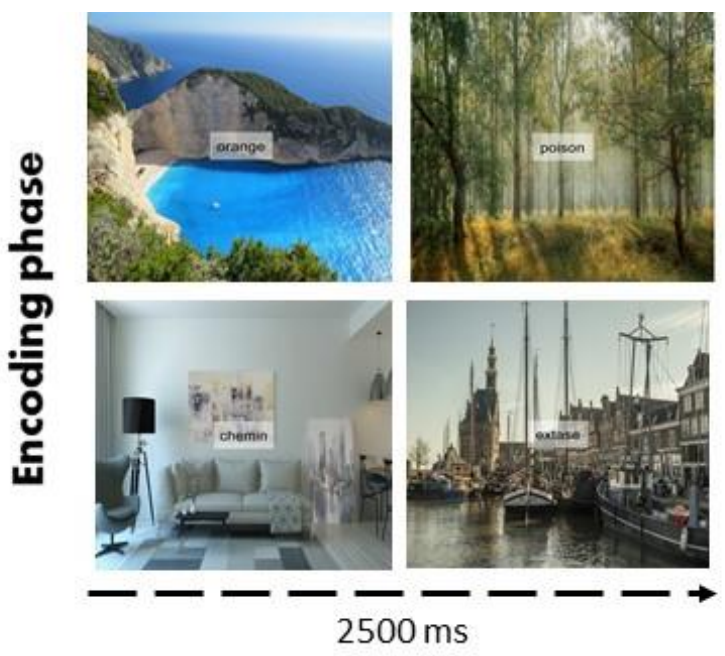
Retrospective Confidence Judgment (RCJ)

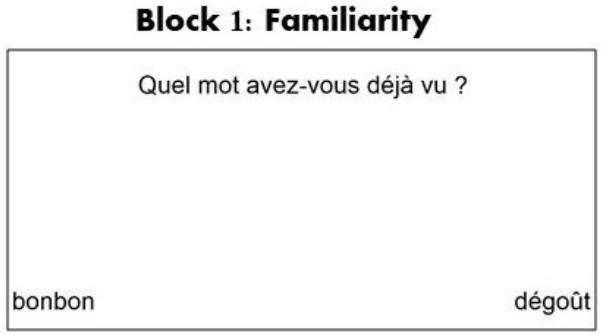
Cauvin et al., 2019; McWilliams et al., 2023

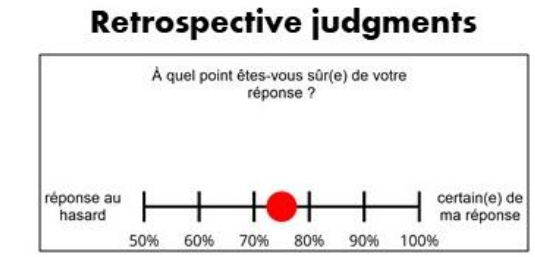
FOK Deficit In Older Adults Is May Be Due To Their Difficulties Of Recollection

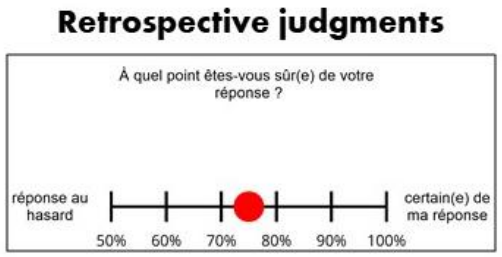
The role of Familiarity and Recollection for metamemory judgments

Preregistered Methodology: Meunier-Duperray et al., (2023), OSF









Discussion

↳ **The Role of Cognitive Reserve on Episodic Metamemory: An Aging Study**

Preregistered Methodology: Grégoire et al., (2024), OSF

A Higher Cognitive Reserve Will Contribute To Better Metamemory Efficiency in Older Adults

Chiara Scarampi: Unravelling cognitive reserve mechanisms in aging: The impact of metacognition

Education

Bherer et al., 2001; Guerrero-Sastoque et al., 2021

Physical activity

Audiffren et al., 2011; Carvalho et al., 2014

Leisure activites

Fallahpour et al., 2016; Sajeev et al., 2016

Work

Food

Sleep

Bubu et al., 2017; Hokett et al., 2021; Zavecz et al., 2023

Conclusion & Further Discussion

- ✓ ***Correlational approach***
- ✓ ***Using the Hierarchical Bayesian Framework***
- ✓ ***In Large and Different Samples***
- ✓ ***In Young and Older Adults***
- ✓ ***In 4 Different Domains***

Confronting a correlational, a neuropsychological, and a neuroanatomical approach

Neuroanatomical Approach

↳ Comparing Brain Activations in MCI Patients And Control

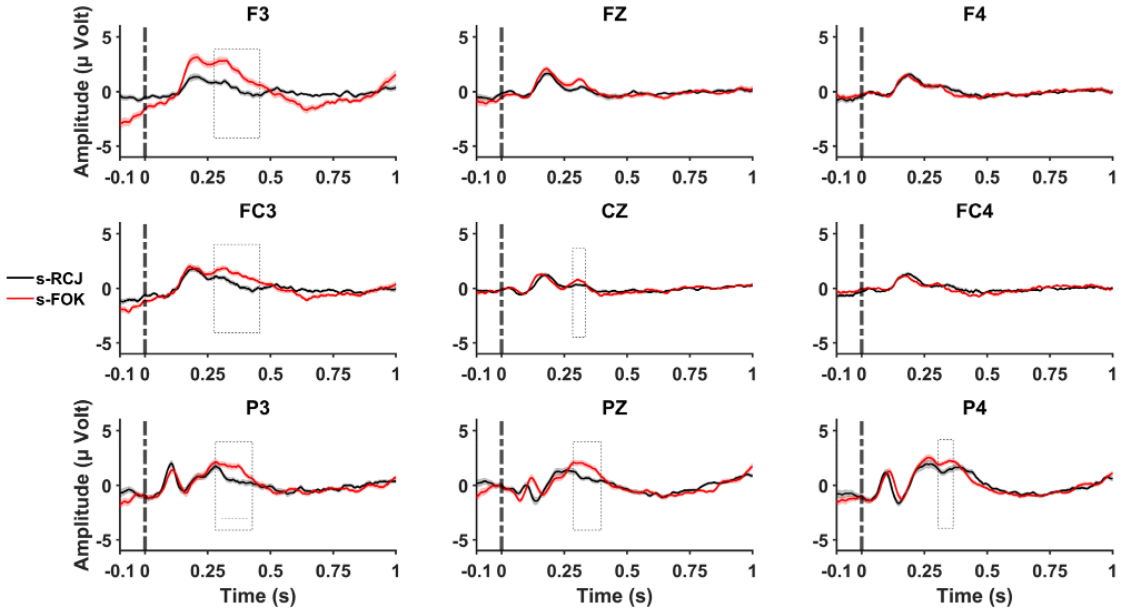
Exploring the Domain Specificity and the Neural Correlates of Memory Unawareness in Alzheimer's disease

Lucile Meunier-Duperray[1,2], Céline Souchay[1], Lucie Angel[2], Eric Salmon[3], Christine Bastin[3]

Under review in Neurobiology of Aging

↳ Neurocognitive Patterns for Episodic Metamemory Judgments In Young and Older Adults: An EEG Exploration

Preregistered Methodology: Grégoire et al., (2024), OSF



Irak et al. (2019, 2023)

Thank you for your attention!

A Special Thank You and Bravo to
Audrey Mazancieux & Lucile Meunier

Any questions?

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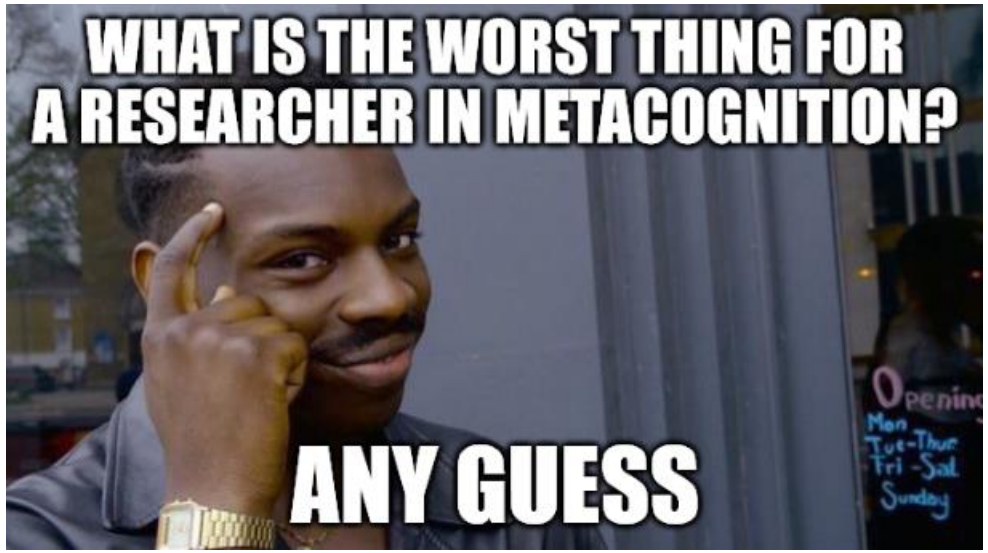

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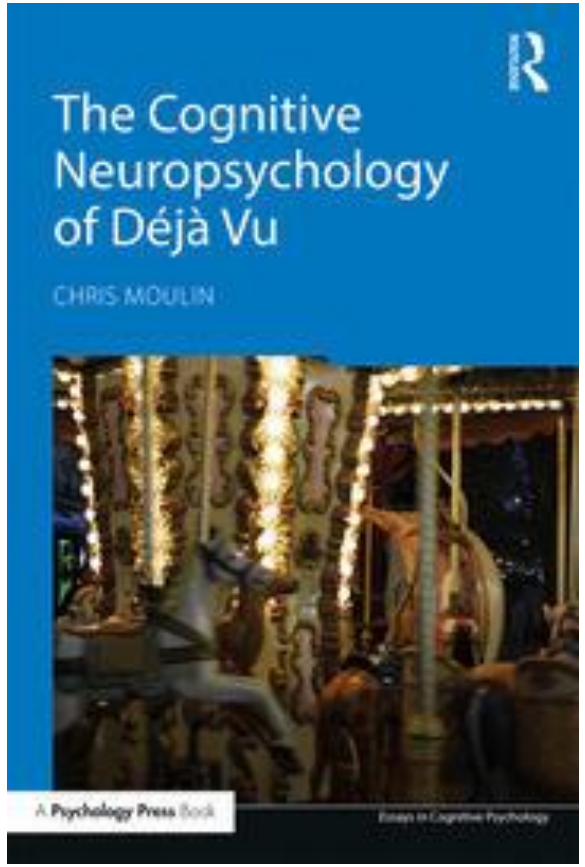
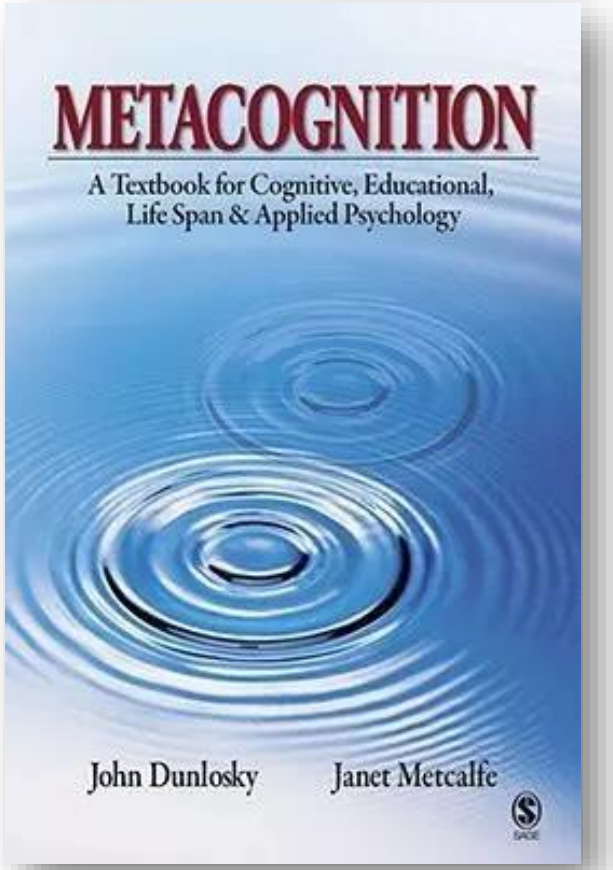
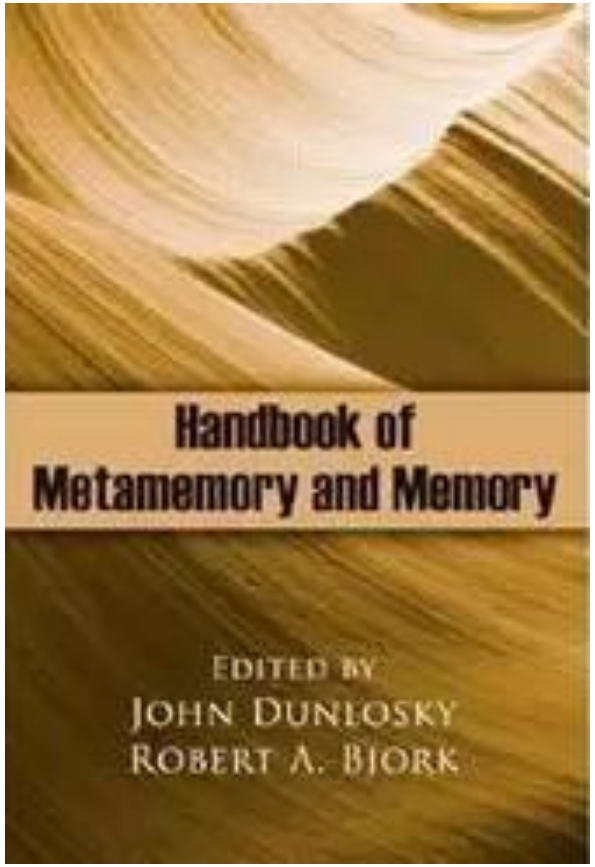
Table 2. *Summary of the metacognitive measures.*

Index	Framework	Measure of…	Calculation	Advantages	Disadvantages
Gamma and phi correlations (Goodman & Kruskal, 1979)	Correlational approach	Metacognitive sensitivity	Non-parametric correlation between accuracy and confidence	Valid measure of metacognition	Influenced by bias and first-order performance
AUROC2 (Galvin et al., 2003)	Signal detection theory	Metacognitive sensitivity	Area under the Type-2 ROC curve	Bias free	Influenced by first-order performance
***M*$_{ratio}$** (Maniscalco & Lau, 2012, 2014)	Signal detection theory	Metacognitive efficiency	Ratio between *meta-d'* (i.e., *d'* value estimated from second-order performance) and *d'*	Bias free, independent from first-order performance	Need many trials to be reliable
HMeta-d (Fleming, 2017)	Model-based approach	Metacognitive efficiency	*M*$_{ratio}$ estimates using a hierarchical Bayesian framework	Task-performance independency and strong test-retest reliability, even when the number of trials is limited	

Useful books







Lucile Meunier, PhD Thesis: defense

« Distinguer les changements de mémoire liés à l'âge des capacités de métamémoire des personnes âgées : Données comportementales et de neuroimagerie dans le vieillissement sain et pathologique » (résumé détaillé ci-dessous).

La soutenance se déroulera en hybride le **jeudi 24 octobre 2024 à 15h**.
Pour assister à la présentation, deux options sont disponibles :

En ligne via Zoom : https://univ-grenoble-alpes-fr.zoom.us/j/91396692477?pwd=4yvXibzFXjsuXrP6L54xTRHlMxwr7I.1
ID de réunion: 913 9669 2477
Code secret: 991001
Merci d'éteindre votre micro et caméra