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Metacognitive domain specificity in feeling-of-knowing but not retrospective confidence

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Abstract

Previous research has converged on the idea that metacognitive evaluations of memory dissociate between semantic and episodic memory tasks, even if the type of metacognitive judgement is held constant. This often observed difference has been the basis of much theoretical reasoning about the types of cues available when making metacognitive judgements of memory and how metacognition is altered in memory pathologies. Here, we sought to revisit the difference between episodic and semantic feeling-of-knowing (FOK) judgements in the light of recent research which has supported a domain general account of metacognition. One hundred participants performed classical episodic and semantic memory tasks with FOK judgements and confidence judgements. Using the meta-d′ framework, we applied a hierarchical Bayesian model to estimate metacognitive sensitivity and cross-task covariance. Results revealed a significant correlation in metacognitive efficiency (meta-d′/d′) between the episodic memory task and the semantic memory task for confidence judgements; however, no evidence was found for a cross-task correlation for FOK judgements. This supports the view that FOK judgements are based on different cues in semantic and episodic memory, whereas confidence judgements are domain general.

Keywords: metacognition; feeling-of-knowing; confidence; episodic memory; semantic memory

Introduction

When people fail to retrieve information from memory, they may have a feeling that they nonetheless know this information. Such feelings-of-knowings (FOKs) are a self-evaluation of cognitive abilities and can be thought of as a metacognitive experience, akin to the tip-of-the-tongue state (see Moulin and Souchay 2014). In experiments, FOKs refer to the predictions of future stimulus recognition when this stimulus has not been recalled. They are a special kind of judgement in that they are cued by a retrieval attempt but pertain to future performance, and in this sense, they are prospective judgements. In the episodic FOK (eFOK) paradigm (e.g. Schacter 1983; Souchay *et al.* 2000), participants learn cue-target paired-words. In a subsequent recall phase, a cue word is presented and the participants are asked to recall the target word. In cases where participants

are not able to remember the target, they judge whether they will be able to recognize the target amongst a set of distracter words (the FOK prediction). Finally, participants perform the recognition task. In the semantic FOK (sFOK) paradigm (e.g. Hart 1965; Nelson *et al.* 1990) instead of learning paired-words, word definitions or general knowledge questions are presented to participants (e.g. "A movement, passage, or composition marked to be performed in slow time") and they are asked to recall the answer or word referring to this definition (*adagio*). As in the episodic task, they make an FOK if they are not able to find the correct word, and later perform a recognition task. In the current experiment, we address the question of whether sFOK and eFOK share similar basis or resources.

The literature shows striking dissociations between the accuracy of judgements in sFOK and eFOK and especially in what is named "metacognitive sensitivity" (i.e. the ability to

discriminate between correct and incorrect responses). In several neuropsychological populations, a profile of impaired eFOK despite preserved sFOK has been reported (e.g. Alzheimer's disease, Souchay 2007; schizophrenia, Bacon *et al.* 2001; Souchay *et al.* 2006; patients with frontal lobe lesions, Schnyer *et al.* 2004). The same dissociation is observed in older adults (e.g. Souchay *et al.* 2007). This profile is proposed to occur because sFOK and eFOK are based on different retrieval processes. Hicks *et al.* (2002) suggest that eFOK rely on autonoetic consciousness in order to retrieve partial information from the study phase on which to base the FOK prediction such as being able to recall what you were thinking when you first saw the pair. Such a process is exclusively involved in episodic memory. In comparison, sFOK judgements do not rely on autonoetic consciousness but can be inferred from the retrieval of lexical or semantic information associated to the target question such as when trying to answer the question: "word obtained by transposing the letters of another word," one can know that the word ends with "gram." Finally, in terms of neural regions, sFOK and eFOK seem to be based on both common and distinct regions (Reggev *et al.* 2011; Elman *et al.* 2012).

This distinction is a critical one in theories of metacognition and memory, helping identify the cues used to make metacognitive evaluations of retrieval, and pointing to a domain specificity of FOK accuracy in human memory. Despite being such a robust finding in the neuropsychological and aging literatures, to our knowledge no research has examined the episodic–semantic distinction in correlational tasks in healthy participants. This is of interest for two reasons which we develop below. First, it seems that metacognitive failure for episodic materials only tends to occur in special populations with an episodic memory deficit (the Memory Constraint Hypothesis; Hertzog *et al.*, 2010) limiting the generalizability of this theory. Moreover, a number of methodological issues raise questions about the nature of the episodic–semantic dissociation (for a recent review, see Renoult *et al.* 2019). Secondly, research in other cognitive domains has found evidence of domain generalizable processes in metacognition (e.g. Mccurdy *et al.* 2013; Ais *et al.* 2016; Samaha and Postle, 2017; Lee *et al.* 2018; Mazancieux *et al.* 2018), contrasting with the observed neuropsychological dissociation between semantic and episodic memory. We introduce these two areas in turn.

Firstly, several methodological issues cloud the results of studies comparing sFOK and eFOK. As shown in Table 1, few studies have directly compared these two types of FOK and most of the dissociations related above are driven by distinct studies with different pools of participants. Moreover in the metamemory literature, metacognitive sensitivity is mainly assessed by Goodman–Kruskal gamma correlations (Kruskal and Goodman 1954) which is a within-subject non-parametric correlation between metacognitive judgements and the accuracy of the memory task. It has been shown that gamma correlations are sensitive to metacognitive bias (i.e. the tendency to be overconfident or underconfident) as well as task performance (Fleming and Lau 2014). Task performance differences are obviously a critical issue in neuropsychological and aging populations, especially where the key theory is that eFOK judgements are less accurate due to deficits in episodic memory (e.g. in Alzheimer's disease, Ernst *et al.*, 2016). As such, differences in FOKs in the studies of Table 1 are concomitant with a deficit in either episodic recall of recognition (except in autism, see Wojcik *et al.* 2013). Another solution to evaluate the potential dissociation between eFOK and sFOK is to estimate the cross-task correlations for metacognitive sensitivity in FOK. However,

this has rarely been performed as sample sizes are typically small (most of the studies being with patients, see Table 1).

Secondly, investigating the question of whether sFOK and eFOK share common resources relates to the domain-generality of metacognition. This assumes that if metacognitive sensitivity depends on domain-general resource, sensitivity indices across two different domains will be correlated. Research to date has exclusively focused on retrospective confidence judgements (RCJs). In contrast to FOKs, RCJs refer to a subjective evaluation of the confidence in a previous decision. As this metacognitive judgement can be performed for decisions in several cognitive domains (e.g. memory, visual perception, and language), it is a good candidate to answer the question of the domain-generality of metacognition. As well as an interest in sensitivity, researchers have also examined bias, finding it is domain-general (e.g. Baranski and Petrusic 1995; Ais *et al.* 2016) that is, people who are over confident on one task will tend to be over confident on another task. The correlation is less clear for sensitivity across tasks. However, under controlled conditions and with appropriate statistical power, it is possible to find cross-domain correlations for metacognitive sensitivity in RCJs (Lee *et al.* 2018; Mazancieux *et al.* 2018). In support, a recent meta-analysis of neuroimaging studies has identified a domain-general neural network involved in RCJs for decision-making and memory tasks (Vaccaro and Fleming 2018).

A further question arises regarding when the metacognitive evaluation is made. As metacognitive judgements can be performed prospectively and retrospectively, it is of interest whether metacognition dissociates according to this variable, especially since the above literature on domain generality tends to focus on retrospective judgements. Several findings support the idea that prospective and retrospective judgements measure distinct aspects of metacognition. They are uncorrelated (e.g. Kelemen *et al.* 2000), supported by separate brain regions (Chua *et al.* 2009), and seem to rely on different cues and processes. In the memory field, FOKs are proposed to be based on both the access of partial information of stimuli and the familiarity of the cue (Koriat 1993; Metcalfe *et al.* 1993; Koriat and Levy-Sadot 2001), whereas RCJs are proposed to be related to the strength of the memory trace (e.g. Yonelinas 1994). Neuroimaging studies support the idea that common and distinct neural mechanisms underpin FOKs and RCJs in memory (Chua *et al.* 2009). Moreover, studies with neurological populations often exhibit a pattern of impaired sensitivity for prospective judgements and preserved sensitivity for retrospective judgements (e.g. Pannu and Kaszniak 2005). Within the visual perception decision-making field, RCJs are mainly influenced by reaction time and the correctness of the decision, whereas prospective judgements rely more on the judgements made for previous tasks (Fleming *et al.* 2016). In both literatures, prospective judgement sensitivity is lower than retrospective judgement sensitivity (Carlson 1993; Perfect and Hollins 1996; Fleming *et al.* 2016). There is some variability in the procedures used and hence in the definition of "prospective." For instance, in perceptual tasks, the "prospective" judgement is not a prediction before having seen the trial, but are made just before the motor response of the first-order decision, and with all the on-screen information necessary to perform the task. Even so, with such paradigms, there is still significantly lower sensitivity in prospective tasks (e.g. Siedlecka *et al.* 2016) In contrast to sensitivity, metacognitive bias seems consistent across judgement type (Fleming *et al.* 2016). FOK judgements, however, have a particular status because they are prospective evaluations but made

Table 1. Review of studies comparing episodic FOK and semantic FOK

No.	References	Participants	Metacognitive sensitivity index	Main result—FOK sensitivity	Main result—performance
1	Bacon *et al.* (1998)	12 placebo 12 low lora-zepma dose 12 high lorazepma dose	Gamma	Lower eFOK for lorazepma groups No difference for sFOK	Lower recall and recognition for both tasks in lorazepma groups
2	Eakin *et al.* (2014)	50 young adults 56 older adults	Gamma	No difference between groups in both FOKs Trend for higher sFOK	Lower episodic recall and recognition for older adults
3	Morson *et al.* (2015)	35 young adults 16 older adults	Gamma	Lower eFOK for older adults No difference for sFOK	Better semantic recall and recognition for older adults
4	Pappas *et al.* (1992)	12 older adults 12 patients with AD	Gamma	Lower sFOK for AD No difference for eFOK (low for both)	Lower recall for both tasks for AD Lower recognition for AD only in episodic memory
5	Perfect and Hollins (1996)	46 young adults	Gamma	Lower for eFOK No difference for sFOK	No difference in recall Higher recognition for semantic memory
6	Reggev *et al.* (2011)	23 young adults	Gamma Hamann	No difference between eFOK and sFOK	Task performance differences not tested
7	Souchay and Smith (2013)	16 older adults 16 patients with PD	Gamma	Lower sFOK and eFOK for PD	Better semantic and episodic recall and recognition for older adults
8	Souchay *et al.* (2007)	20 young adults 40 older adults	Gamma	Lower eFOK for older adults No difference for sFOK	Lower recall and recognition for both tasks for older adults
9	Wojcik *et al.* (2013)	18 children with ASD 18 neurotypical children	Gamma	Lower eFOK for children with ASD No difference for sFOK	No difference in task performance between groups

Using the keywords "feeling-of-knowing," "episodic," and "semantic" in PubMed, we identified 16 articles. After having screened the abstracts, we selected seven articles. Our inclusion criteria were as follows: (1) eFOK and sFOK have to be compared in the same study (2) judgements have to be related to retrospective memory (3) metacognitive sensitivity has to be measured. Two more articles were found in the references of the above studies. All the studies rely on gamma correlations for assessing metacognitive sensitivity.

AD, Alzheimer's disease; ASD, autism spectrum disorder; PD, Parkinson's disease; eFOK, episodic feeling of knowing; sFOK, semantic feeling of knowing.

after a retrieval attempt, and in that way they share characteristics of both prospective and retrospective judgements.

Here, we expected to reproduce previous results regarding the domain-generality of metacognitive efficiency for RCJs (Mazancieux *et al.* 2018) and to investigate the same issue in FOKs. The clearest hypothesis to formulate is that we will find cross-task (i.e. episodic/semantic) correlations for RCJs, and such a finding will help ground our studies in the work on domain general contributions to metacognition. The novel hypothesis tested here is that FOKs too will show some domain generality. Based on neuroimaging studies (Reggev *et al.* 2011) and on the idea that methodological issues exist in the estimation of metacognitive sensitivity in previous work on FOKs, we suggest that episodic and semantic FOKs will produce low, but significant, correlations.

As we claim for a more general view of metacognition, we here wanted to use novel methods to estimate metacognitive sensitivity stemming from the visual perception literature rather than the classic methods used in the metamemory field. Therefore, we chose to estimate metacognitive sensitivity using the *meta-d′* framework (Maniscalco and Lau 2012). Based on signal detection theory, this framework allows the calculation of metacognitive efficiency which is a ratio between task performance (*d′*) and metacognitive performance (*meta-d′*). Metacognitive efficiency has the advantage of being independent from task performance and metacognitive bias which is less the case for classical correlational methods such as phi and gamma correlations (Fleming and Lau 2014). Moreover, as we are interested in cross-task correlations, we estimated meta-d′ in a hierarchical Bayesian model (Fleming 2017) which allows an estimation of metacognitive efficiency for individual participants and group level parameters (mean per task and cross-task correlations). Preregistration of the study, raw data, model, and analysis scripts are available in OSF (https://osf.io/p5gaq/).

Materials and methods

Participants

Based on a power calculation, 100 young adults (M_{age} = 20.50, SD_{age} = 4.45; 87% women) were included in the study, recruited through an advertisement at the Grenoble-Alpes University. Because one of our aims was to reproduce the correlation for metacognitive efficiency between episodic and semantic memory in RCJs, we focused on this effect in a previous study (Mazancieux *et al.* 2018; ρ = 0.41, sample size estimation was made with a power of 0.99 at the standard 0.05 alpha error probability).

In accordance with our preregistration, we excluded six participants who performed close to chance or ceiling (below 55% or above 95% correct) in the recognition of one of the two tasks. We also excluded two participants who used only one point on the metacognitive scale. Thus, we performed analyses on 92 participants.

Materials and procedure

The procedure included two tasks: an episodic task and a semantic task (Fig. 1). In the episodic task, participants studied 40 cue-target word-pairs each presented for 1500 ms. After this phase, the cue was presented, and participants attempted to recall the target with a time limit of 15 s. In any case (with or
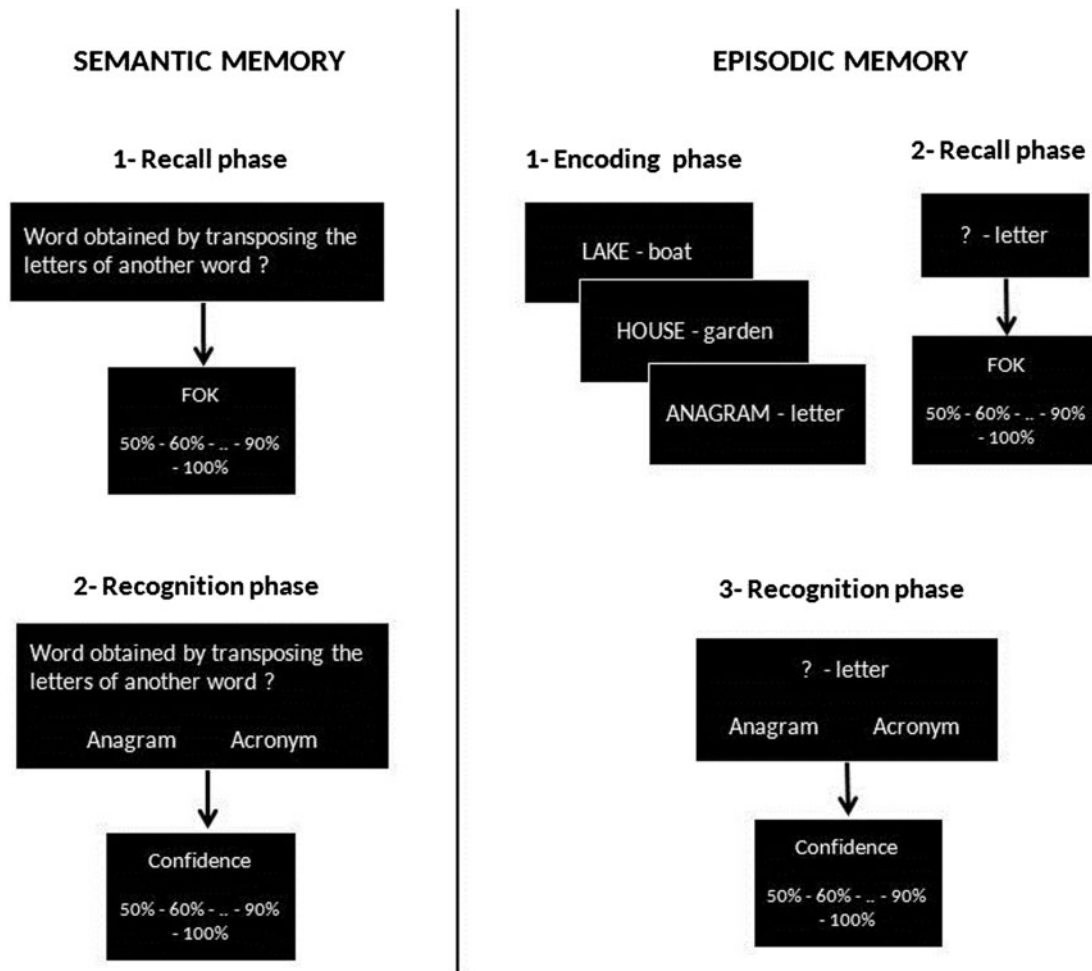
SEMANTIC MEMORY

1- Recall phase

Word obtained by transposing the letters of another word ?

↓

FOK

50% - 60% - .. - 90% - 100%

2- Recognition phase

Word obtained by transposing the letters of another word ?

Anagram   Acronym

↓

Confidence

50% - 60% - .. - 90% - 100%

EPISODIC MEMORY

1- Encoding phase

LAKE - boat

HOUSE - garden

ANAGRAM - letter

2- Recall phase

? - letter

↓

FOK

50% - 60% - .. - 90% - 100%

3- Recognition phase

? - letter

Anagram   Acronym

↓

Confidence

50% - 60% - .. - 90% - 100%

Figure 1. Summary of the two tasks. The semantic memory task includes two phases and the episodic memory includes three phases.

without a response in the recall phase), participants performed an FOK judgement. More specifically, they had to judge their confidence in recognizing the correct target between two words in a next phase. To do so, they used a 6-point scale ranging from 50% (I will guess the answer) to 100% (very confident in finding the answer). During the last phase, participants performed a 2AFC recognition task where the 40 cues were presented for a second time and participants had to choose between a target and a distractor by pressing either the "s" or the "l" letter. Finally, for each trial, participants had to estimate their level of confidence in their response using the same 6-point scale (ranging from "guessing" to "very confident").

In the semantic task, participants responded to 40 general-information questions. These questions were word definitions and the participants were asked to recall the word given the definition with a time limit of 15 s. As in the episodic task, in either case, they judged their ability to recognize in a next phase the correct definition between two alternatives. Then in a recognition phase, the definitions were presented a second time and participants had to select the correct answer in a 2AFC task by pressing either the "s" or the "l" letter. They also estimated their level of confidence in their response using the same scale as the episodic memory task.

The stimuli were based on a previous experiment (see Souchay *et al.* 2007), with the exception that in order to use the meta-d′ framework we presented two alternatives and not four

in the recognition phase. We used a feature of the Souchay *et al.* task, in that the same target words were used in the episodic and the semantic tasks in a counterbalanced fashion (see Fig. 1). Each target has a cue for the episodic memory task and a definition for the semantic memory task. Two lists of 40 targets were created such that each participant was randomly allocated to one set of targets in the episodic condition, and the other in the semantic condition. For both tasks, participants had three training trials in order to familiarize themselves with the task before the test trials. They had 15 s to recall the word before the performing their FOK judgement. For the recognition phase, there was no time limit. The task order was random (on the 92 non-excluded participants, 49 begun with the episodic memory task and 43 begun with the semantic memory task) for each participant and the entire procedure lasted around 45 min.

Data and statistical analyses

Our analyses focused on task performance, metacognitive bias, and metacognitive sensitivity. Metacognitive bias was estimated by calculating the difference between mean RCJs or FOKs and mean performance for each participant and each task. Sensitivity was estimated as metacognitive efficiency (meta-d′/d′). Meta-d′ is the d′ that would be expected if the Type 2 receiver operating characteristics (ROC) curve observed for a participant was his or her ideal ROC curve given the task

performance (d′ value). It refers to the signal that is available to perform the Type 2 task (discrimination between correct and incorrect responses). Meta-d′ is in the same unit as d′, thus a ratio can be computed to compare the two. If meta-d′ = d′, participants performed the Type 2 task ideally given their level of Type 1 task performance. A ratio lower than 1 indicates a lower metacognitive sensitivity and a higher ratio a greater metacognitive sensitivity. Several methods exist to estimate meta-d′. Here, we chose a hierarchical Bayesian model (Fleming 2017) using an extension of the HMeta-d toolbox (https://github.com/ metacoglab/HMeta-d) in R software. Two models were used: one for the FOKs and one for the RCJs. Both models estimated a meta-d′/d′ ratio for each participant and each task as well as a group-level parameter for both the episodic and the semantic task and the cross-task correlation. To assess the significance of group-level parameters, we calculated the 95% highest density intervals [HDIs; the smallest interval containing 95% of the Markov chain Monte Carlo (MCMC) samples; Kruschke 2014] on the posterior distributions and looked at its potential overlaps with zero.

The HMeta-d toolbox uses MCMC sampling to estimate posterior distribution over model parameters using JAGS (Plummer 2003) in R ("rjags" package). We modified the HMeta-d code to allow estimation of parameters in R using rjags. As in the HMeta-d toolbox, we discarded early samples of the posterior distributions and ran three chains in order to diagnose convergence problems. We estimated convergence of the three chains with the "potential scale reduction factor" $\hat{R}$ (Gelman and Rubin 1992). This approach was exactly the same as in Mazancieux *et al.* (2018) and was carried out according to our preregistration document. Other analyses include analysis of the variance (ANOVA), t-test, and Pearson's correlations. Outliers were detected using Leverage, RSS, and Cook's distance. When necessary, Bonferroni corrections were applied.

Results

Type 1 performance

Task performance was estimated in two ways (Fig. 2). First, we calculated the proportion of correct recall for episodic recall and semantic recall. A recalled item was judged as correct when the exact word was retrieved (we judged as correct those that were recalled in the plural form, even though all targets were singular). Second, we calculated a Type 1 d′ for performance in the recognition task. Paired t-tests showed that performance on the semantic recall (M = 0.27; SD = 0.13) was better than the episodic recall (M = 0.15; SD = 0.09), $t(91) = 9.68$, $P < 0.001$, $d_z = 1.01$. However, the reverse pattern was observed regarding recognition for all items: episodic memory recognition (M = 1.48; SD = 0.68) was better performed than semantic memory recognition (M = 1.23; SD = 0.56), $t(91) = 3.10$, $P = 0.003$, $d_z = 0.32$. The pattern of results was the same when comparing proportion of correct recognition only for unrecalled items, $t(91) = 5.98$, $P < 0.001$, $d_z = 0.62$, episodic recognition being higher (M = 0.73; SD = 0.11) than semantic recognition (M = 0.65; SD = 0.10).

We were also interested in the intersubject correlations in first-order performance across the two tasks. These analyses revealed positive correlations between episodic and semantic memory for both recall, $r = 0.50$ [0.32; 0.64], $P < 0.001$, and recognition for all items, $r = 0.26$ [0.05; 0.44], $P = 0.013$, suggesting that participants who performed well on one task also performed well on the other.

Metacognitive bias

Metacognitive bias (mean confidence minus mean performance) was calculated for each participant, each task, and for both FOKs and RCJs (Fig. 3). We performed an ANOVA with judgement types and task as factors on metacognitive bias score. It revealed a main effect of task, $t(91) = 8.99$, $P < 0.001$,
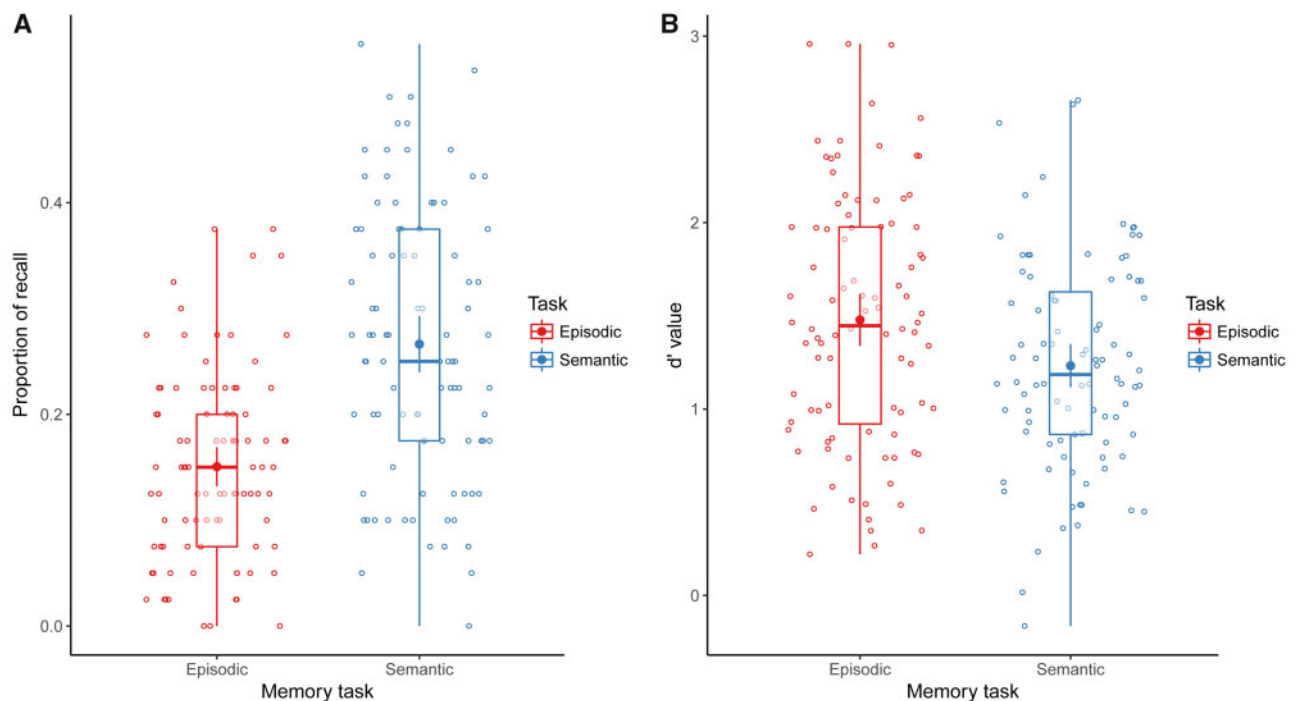

Figure 2. (A) Proportion of recall for the episodic and the semantic task. **(B)** Recognition performance (d′ value) for the episodic and the semantic task.
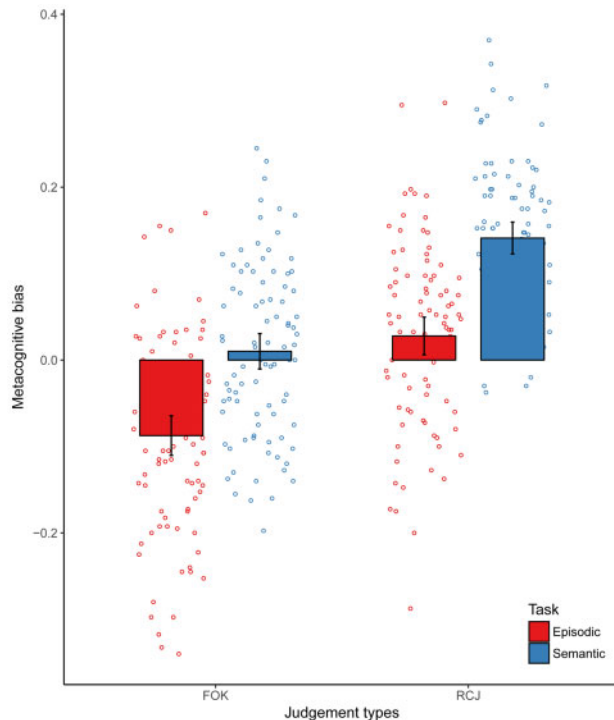
Figure 3. Metacognitive bias (mean judgements—mean performance) for FOKs and RCJs in the episodic memory task and semantic memory task.

$d_z = 0.94$, with participants being more overconfident in the semantic memory task compared to the episodic memory task. We also found a main effect of judgment, $t(91) = 18.91$, $P < 0.001$, $d_z = 1.91$, with participants being more overconfident for RCJs compared to FOKs. Finally, the interaction, $t(91) = 2.41$, $P = 0.018$, $d_z = 0.25$, showed that the difference between the semantic memory task and the episodic memory task was smaller for FOKs, $t(91) = 7.64$, $P < 0.001$, $d_z = 0.80$, compared to RCJs, $t(91) = 9.80$, $P < 0.001$, $d_z = 1.02$.

We were also interested in the intersubject correlations in metacognitive bias across the two tasks for both FOKs and RCJs. These analyses revealed positive correlations between eFOK and sFOK, $r = 0.32$ [0.13; 0.50], $P = 0.002$, and episodic RCJ (eRCJ) and semantic RCJ (sRCJ), $r = 0.36$ [0.16; 0.52], $P < 0.001$.

Metacognitive efficiency

We estimated the group meta-d'/d' ratio for each task and for both FOKs and RCJs (see Fig. 4). To test difference across the four distributions, we performed the difference distribution for each two-by-two comparisons (Table 2). According to overlaps of 95% HDIs with 0, metacognitive efficiency was better for eFOK compared to sFOK. Efficiency for eFOK was however lower than efficiency for both eRCJ and sRCJ. The same pattern was observed for sFOK. Finally, metacognitive efficiencies were the same for eRCJ and sRCJ.

Hierarchical models allow us to estimate correlations between metacognitive efficiency eFOK and sFOK on the one hand and eRCJ and sRCJ on the other hand (Fig. 5). According to overlaps of 95% HDIs with 0, we found no cross-task correlation (0.22 [−0.89; 0.99]) for FOKs but a positive correlation ($\rho = 0.47$ [0.13; 0.78]) for RCJs.

Exploratory analyses

Note that the following analyses were not preregistered.

Logistic regressions

Following the idea that FOK can be related to the quality of memory (the memory constraint hypothesis), we were also interested in the relationship between FOK and prior recall. As FOK occurs *after* a recall attempt, the idea here is to calculate the retrospective sensitivity and bias of the FOK. Therefore, we performed exploratory analyses to see if FOK judgements are related to prior recall. We quantified metacognitive sensitivity using mixed effect logistic regressions, rather than meta d′, as meta-d′ assumes that target and distractor distributions are Gaussian with equal variance. Although this is the case for 2AFC recognition, we suggest that this is less applicable for remembered and forgotten words, which limits the use of SDT in this context. Moreover, the estimation of the Type 2 ROC curve from the Type 1 parameters in the meta-d′ model as based on the average or response-specific Type 2 ROC curves (i.e. the construction of one curve for "S1" responses for "S2" responses, Maniscalco and Lau 2014).

Consequently, we performed mixed effect logistic regressions to see if FOKs track task performance accuracy for recognition on the one hand and recall on the other hand. This method has been already used as a quantification of metacognitive sensitivity because it is independent from metacognitive bias although not independent from task performance (e.g. Faivre et al. 2019). We created two models per task: one model in which FOK ratings explain first-order accuracy for the recognition task and a second in which FOK ratings explain first-order accuracy for the recall task. Each model includes confidence as a fixed effect and the estimation of an intercept per participant. For the episodic memory task, the models reveal that accuracy of recognition was predicted by FOK [*estimate* = 0.37, $z = 11.70$, $P < 0.001$, odds ratio (OR) = 1.45] which was also the case for the accuracy of recall (*estimate* = 1.65, $z = 22.26$, $P < 0.001$, OR = 5.22). OR comparison revealed that the effect size was higher for the model in which FOKs explain the accuracy of recall compared to the model in which FOKs explain the accuracy of recognition (OR are 3.6 times larger in the recall model). For the semantic memory task, models reveal that accuracy of recognition was predicted by FOK (*estimate* = 0.23, $z = 9.52$, $P < 0.001$, OR = 1.30) as well as the accuracy of recall (*estimate* = 0.97, $z = 24.61$, $P < 0.001$, OR = 2.63). As for eFOK, the OR comparison shows that the effect size was higher for the model in which FOK explain the accuracy of recall compared to the model in which FOK explain the accuracy of recognition (OR are 2.02 times larger in the recall model).

Correlational analyses

Exploratory analyses revealed that eFOK metacognitive efficiency was correlated with episodic recall, $r = 0.32$, $P = 0.002$, which was not the case for eRCJ, $r = 0.03$, $P = 0.781$ (these correlations being significantly different, $z = 2.01$, $P = 0.036$). Similarly, while sFOK metacognitive efficiency was correlated with semantic recall, $r = 0.33$, $P = 0.002$, this correlation was significantly not different from the non-significant correlation between semantic recall and sRCJ metacognitive efficiency, $r = 0.09$, $P = 0.406$ (difference, $z = 1.68$, $P = 0.093$).
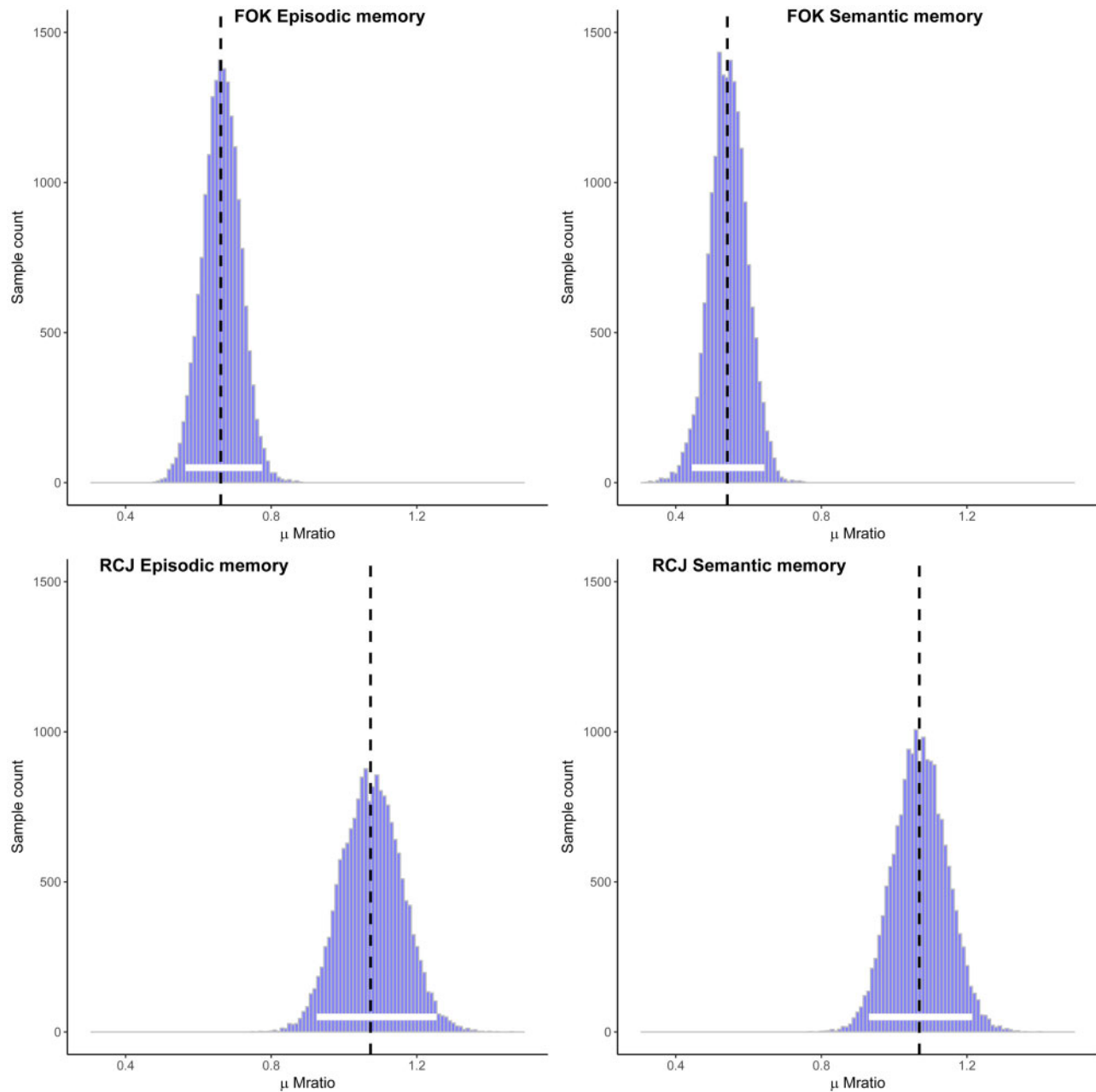
Figure 4. Posterior μ Mratio (meta-d'/d' ratio) distributions for FOKs and RCJs for both the episodic memory task and the semantic memory task.

Discussion

The present study focused on the domain-generality of metacognition in two dimensions. First, we wanted to investigate cross-task correlations in episodic and semantic memory indicating a potential general metacognitive resource as in previous works (Lee *et al.* 2018; Mazancieux *et al.* 2018; Morales *et al.* 2018). Second, we wanted to take into account the multifaceted nature of metacognition by comparing two types of metacognitive judgements: FOKs and RCJs. We computed metacognitive efficiency in both the episodic memory task and the semantic memory task separately for FOKs and RCJs. As our tasks contained relatively few trials due to the FOK procedure which requires recall and so cannot use too many items, we estimated metacognitive efficiency in a Bayesian manner (Fleming 2017) and used hierarchical models to estimate cross-task correlations.

First, we reproduced previous findings (Mazancieux *et al.* 2018) regarding the group-level estimation of the correlation between metacognitive efficiency for episodic and semantic RCJs ($\rho = 0.47$ [0.13; 0.78] vs. $\rho = 0.41$ [0.14, 0.66]), although the estimation of the current correlation is less precise (with a larger HDI), which can be explained by having roughly half the number of participants in this study (N = 92 vs. N = 181). This nonetheless suggests that there is a common resource in judging our confidence across episodic and semantic memory. As RCJs are performed after the first-order decision, a suitable candidate for this, especially in memory, is response fluency. That is, we suggest that participants use a common cue from the ease of answering as a basis for gauging the correctness of their response. In support, retrieval or answer fluency (shown as shorter response times) in both general knowledge tasks (Kelley and

Table 2. Means and HDIs of the posteriors of the difference between μ Mratio distributions for each task pairing

	Difference distributions			
	FOK episodic memory	FOK semantic memory	RCJ episodic memory	RCJ semantic memory
FOK episodic memory		**0.20** [0.06, 0.34]	**0.51** [0.39, 0.64]	**0.52** [0.39, 0.63]
FOK semantic memory			**0.71** [0.57, 0.84]	**0.71** [0.58, 0.84]
RCJ episodic memory				0.01 [−0.11, 0.09]
RCJ semantic memory				

Only the difference distribution between episodic memory and semantic memory overlaps with 0.
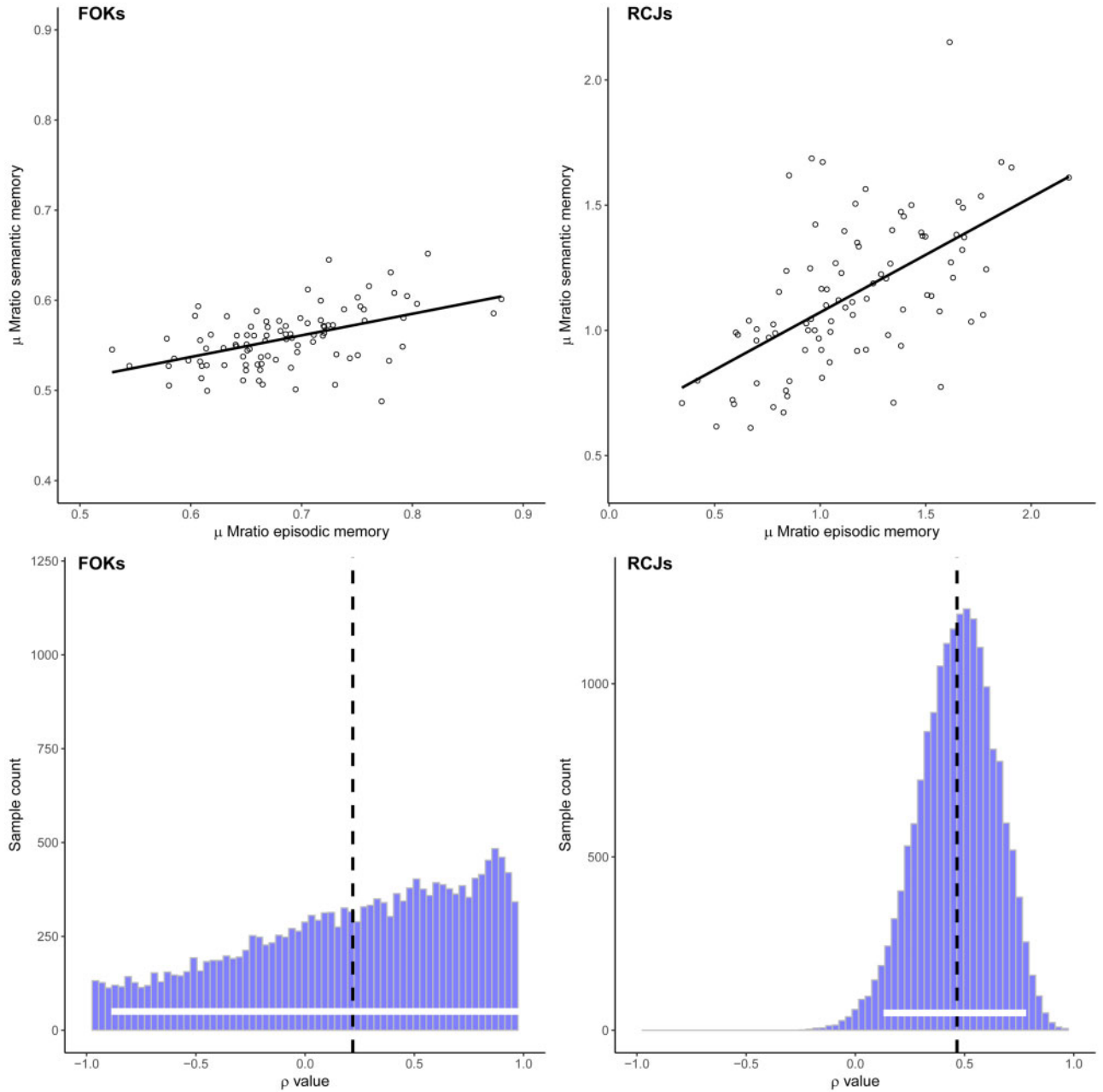

Figure 5. Single-subject parameter estimates from the hierarchical model of meta-d'/d' and posterior distributions over ρ in the two covariance matrix determining the correlations between meta-d'/d' across FOKs and RCJs. Distribution of ρ values overlaps with 0 for FOKs (0.22 [−0.89; 0.99]) which is not the case for RCJs (0.47 [0.13; 0.78]).

Lindsay 1993) and episodic recognition tasks (e.g. Benjamin *et al.* 1998) is associated with higher confidence. Hence, we suggest that retrieval fluency is a diagnostic cue allowing the discrimination between correct and incorrect responses. This cue could even be used beyond the memory domain as answer fluency has been shown to influence confidence in reasoning (Thompson *et al.* 2013) and response time is negatively correlated with confidence in visual perception decision-making (e.g. Grimaldi *et al.* 2015).

Second, and most importantly, we found no evidence for a cross-task correlation in eFOK and sFOK. One possible explanation is that even if FOKs imply a prospection of a future recognition task, these judgements are made after a recall test. People can use the output of the retrieval attempt to perform the FOK and therefore use recall as a heuristic for performing FOKs (Schwartz *et al.* 2016). In contrast with semantic recall, episodic recall involves autonoetic consciousness as a re-experience of the remembered information. Exploratory analyses revealed that for the episodic memory task FOKs metacognitive efficiency was correlated with episodic recall which was not the case for RCJ metacognitive efficiency. This is consistent with the FOK literature showing that FOK judgments are partly based on the recollection process (e.g. Hicks *et al.* 2002) and especially the retrieval of the encoding context; retrieving information or details about the original encoding context (see the *non-criterial recollection hypothesis of episodic FOK*; Hertzog *et al.* 2014; Isingrini *et al.* 2016). This is also consistent with the classical discrepancy found between impaired episodic FOK and preserved semantic FOK in older adults (e.g. Castel *et al.* 2016) as recollection is the most impaired process with age (e.g. Clarys *et al.* 2002), as well as several neurological diseases involving episodic memory impairment (e.g. Alzheimer's disease, Souchay *et al.* 2002; multiple sclerosis; Beatty and Monson 1991; patients with frontal lobe lesions, Schnyer *et al.* 2004). This difference in terms of processes involved in both retrieval mechanisms can also explain why we found a better metacognitive efficiency for eFOK compared to sFOK: partial retrieved information can be used as a cue for performing the FOK judgement eFOK but not sFOK.

A classic distinction in the basis of metacognitive judgements is between experience-based metacognition and information-based metacognition (Koriat and Levy-Sadot 1999). Experience-based metacognition is based on heuristics that are used automatically and that give rise to feeling (as epistemic feelings, see Moulin and Souchay 2014). As an example mentioned above, the fluency heuristic has been shown to influence FOKs (e.g. the cue-familiarity heuristic, Metcalfe *et al.* 1993). On the contrary, information-based metacognition is based on the application of explicit beliefs or naïve theories. Although it is possible that heuristics influence metacognitive judgements across tasks (e.g. the fluency heuristic), we suggest here that beliefs are different in semantic and episodic memory tasks. Semantic memory refers to general knowledge which is shared across people who tend to have an accurate appreciation of what others know (e.g. Juslin 1993). Thus, Koriat (2008) has shown that metacognitive judgements correlate more with the consensual response (the one which is the most chosen by participants) compared to the actual correct response. In episodic memory tasks, such consensus is less likely to occur as retrieval abilities are closely related to the self (e.g. the self-reference effect; Symons and Johnson 1997) and can be thought of as *idiosyncratic* (Klatzky 1984) and therefore differs across people. Self-referencing has been shown to improve episodic FOK accuracy (Boduroglu *et al.* 2015).

Going toward the idea that beliefs used for FOKs differ across tasks, Perfect and Hollins (1996) have found a between-subject correlation between FOKs and task performance for semantic memory despite no such relation for episodic memory. We also suggest that explains why sFOK are rarely impaired in patients with memory problems (e.g. Pannu and Kaszniak 2005): information-based cues in sFOK rely more on consensus and do not necessitate autonoesis to be accurate. Semantic FOKs rely more on the inference of what people know or should know based on the activation of a network of related information, whereas episodic FOKs depend on self-knowledge and outputs from the retrieval attempt. That is, if you do not know anything about capitals of African countries, for instance, the semantic FOK will not be able to retrieve any partial information on which to make an accurate FOK judgement: the process is somewhat all-or-nothing. However, in episodic memory, the integration of autonoetic consciousness and the results of the deliberative memory search will likely yield information which is pertinent to episodic FOK judgements. Whilst these inferential processes can occur as well in RCJs, we suggest here that they are less important, as RCJs rely more on the evidence driven by the given response and experience-based metacognition (e.g. answer fluency) therefore explaining the cross-task correlation observed in the present study. Complementing this hypothesis, the exploratory analyses showed that FOK ratings better explains the accuracy of the recall task compared to the accuracy of the recognition. In support, recall was correlated with FOK metacognitive efficiency (albeit in both episodic and semantic tasks).

We therefore here suggest that FOKs are more based on the output of retrieval attempt during the recall (a kind of retrospective recall metacognition) rather than actual prospection of future performance. Thus, the two types of judgement are not correlated because they rely on different types of retrieval process. Future research should experimentally manipulate the semantic and episodic information available at different phases of the task, in order to test the hypothesis that eFOK and sFOK differ according to the cues used, especially because other variables not controlled in this experiment, familiarity, fluency, etc. may bring to bear on the metacognitive decision. Also, here we matched the target word in the two conditions, but it would be of interest to run a task with identical cues (rather than targets) used in the semantic and episodic conditions, such as asking someone to define a word, or retrieve something that was associated with it. It is perhaps possible that our particular pattern of recall and recognition scores have led to the pattern of FOK correlations shown here. Of note we have a higher level of semantic recall, but a lower level of semantic recognition, and there is a large variance in recall scores (see Fig. 2). Whilst the pattern of cross-task correlations in recall but not in FOK, suggests that recall is not a particular concern here, an interesting future experiment would be to manipulate difficulty levels in recall and recognition across the two tasks. Also, FOK sensitivity in the two tasks was correlated to recall.

Finally and regarding metacognitive bias, our results revealed that participants had a lower magnitude of judgement for FOKs compared to RCJs. This is consistent with the fact that less sensory evidence is available for prospective judgements because the task is not yet performed. Therefore, participants are less confident in the FOKs reported here compared to RCJs. We also found that participants tend to give a higher metacognitive judgement for the semantic memory task resulting in more accurate FOKs but an overestimation for RCJs. In accordance with previous work in retrospective judgments (Ais *et al.* 2016; Mazancieux *et al.* 2018), we found a cross-task correlation

for metacognitive bias in FOKs and RCJs. This is congruent with the fact that metacognitive bias is domain-general but also consistent across judgements types (Fleming *et al.* 2016).

To conclude, this study revealed a cross-task correlation for RCJs in episodic memory and semantic memory suggesting a common resource for metacognitive efficiency in these two tasks. However, no correlation was found across eFOK and sFOK. According to the dual-process view of metacognition (Koriat and Levy-Sadot 1999), we suggest that FOKs and RCJs rely on both experience-based and information-based cues although the amounts of each process differ across judgements. We propose that these processes differ across tasks: sFOK uses inferences based on simply what we know about a subject (noesis) whereas eFOK relies more on inferences based on self-knowledge and an access to the personal past (autonoesis).

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