Conceptual promises and mechanistic challenges of the Creative Metacognition framework : Comment on "A systematic framework of creative metacognition" by I. Lebuda and M. Benedek

Alizée Lopez-Persem, Marion Rouault, Emmanuelle Volle

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Corresponding Author:	Emmanuelle Volle, PhD, MD Paris Brain Institute FRANCE
First Author:	Alizée Lopez-Persem, PhD
Order of Authors:	Alizée Lopez-Persem, PhD
	Marion Rouault, PhD
	Emmanuelle Volle, PhD, MD

Institut du Cerveau ICM

To Xinyi Xu and Cristina Becchio
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Dear Editors,

Please find enclosed our manuscript entitled "Conceptual promises and mechanistic challenges of the Creative Metacognition framework", by Lopez-Persem, Rouault and Volle.

This manuscript is an invited comment on "A systematic framework of creative metacognition" by Izabela Lebuda and Mathias Benedek (same issue).

We sincerely appreciate your consideration of our manuscript for publication in PHYSICS OF LIFE REVIEWS. Thank you for your time and attention.

Yours sincerely,

Dr Emmanuelle Volle
on behalf of all co-authors

Institut du Cerveau / *Paris Brain Institute* • ICM
Hôpital de la Pitié-Salpêtrière
CNRS UMR 7225 – Inserm U 1127 – Sorbonne Université UM75
47 boulevard de l'Hôpital, CS21414 75646, Paris, France
Tél. +33 (0)1 57 27 40 00 • Email : info@icm-institute.org
institutducerveau-icm.org

Inserm SORBONNE UNIVERSITÉ cnrs

Conceptual promises and mechanistic challenges of the Creative Metacognition framework:

Comment on "A systematic framework of creative metacognition" by Izabela Lebuda and Mathias Benedek

Alizée Lopez-Persem*, Marion Rouault* & Emmanuelle Volle*
*Equal contributions

Correspondence: Emmanuelle Volle

Creativity is classically defined as the ability to produce original and adequate ideas [1,2]. In the current view, supported by behavioral [3–6] and neuroimaging studies [7–12], creativity relies on two main components: generating spontaneous associations (candidate ideas) and evaluating whether candidates are original and adequate. Nevertheless, the processes allowing this evaluation are poorly understood. For instance, the evaluation phase does not distinguish between monitoring processes (assessing adequacy and originality of ideas) and control processes (deciding to select a candidate idea or pursue the search for other ideas).

In this issue, Lebuda and Benedek [13] introduce a new theoretical "creative metacognition framework" (CMCfw) that involves a combination of cognitive and metacognitive processes. Cognitive processes are typically non-self-reflective, encompassing engagement in specific tasks. For example, when solving a riddle, cognitive processes produce potential solutions. In contrast, metacognitive processes are typically defined as the ability to evaluate, monitor, and control our own cognitive processes, for example, reporting how sure you are about your riddle solution. In creative thinking, if we consider the candidate ideas pondered by an individual as mental entities, then these ideas are the products of cognitive processes. Consequently, any cognitive process that takes these mental entities as inputs can be regarded as a metacognitive operation. This perspective broadens the horizon for reevaluating the traditional view of creativity in terms of metacognitive processes.

The CMCfw consists of five main components, organized along two axes: the cognition-metacognition axis and the static-dynamic axis. The cognitive dynamic process involves the cognitive processes required to perform the task. The cognitive static process, "problem-relevant knowledge", entails knowing what the task and stimuli are. The metacognitive processes are subdivided into two dynamic components: monitoring (MMC) and control components (MCC), and a static knowledge component (MKC), which can be applied to three levels of assessment: the response level (MMC: "Is my current idea creative?", MCC: "Should I revise my current idea?", MKC: "What should be the creativity of my response?"), the performance level (MMC: "Am I performing well in this task?", MCC: "Should I change my strategy?", MKC: "Which strategy should I use?") and the task level (MMC: "What are the characteristics of the task?", MCC: "How much should I engage in the task?", MKC: "Am I familiar with this creativity task?").

In the CMCfw, the division of the evaluation phase of creativity into two components - monitoring and controlling - naturally aligns with the historical distinction between metacognitive evaluation and control [14,15]. While metacognitive evaluation refers to the set of processes engaged in evaluating our own cognition or memory, metacognitive control refers to how, in turn, we use this knowledge to guide behavior [16]. This distinction further aligns with the decision-making literature, where monitoring behavior-related variables (e.g., decision outcomes) is necessary to subsequently apply and regulate cognitive control and effort engagement [17,18].

Moreover, the separate modules echo a recently proposed distinction between hierarchical levels of metacognition, from local to global [19], which has received initial empirical support [20,21]. It suggests that metacognition operates across various levels of abstraction, such as evaluating our confidence in a decision, in a task (e.g., 'Did I do well in this creativity test?'), in a domain (e.g., 'Am I a creative person?'), up to most global, unified notions, such as self-confidence. Whether these levels of abstraction align with the response-performance-task levels of the CMCfw or with its static (global) vs dynamic (local) distinction remains to be tested.

Overall, the CMCfw is consistent with current views on both creativity and metacognition. Delineating explicit, quantifiable variables or metrics for each component and their interactions would help to maximize the CMCfw's impact. These metrics would allow operationalizing the CMCfw, facilitating its empirical analysis, and testing it against alternative hypotheses. For instance, specifying measurements for the MCC, such as thresholds for deciding to allocate control given variables extracted from the MMC and/or the MKC, would contribute to the CMCfw's utility. Lebuda and colleagues have conducted two experimental studies in this direction [22,23].

To further capture the underlying computational mechanisms, the CMCfw could be inspired by the Expected Value of Control theory [18]. In brief, the theory proposes that we allocate control in a task if the expected benefits (e.g., probability and magnitude of anticipated outcomes) are superior to the expected costs (e.g., mental resources). A large swathe of empirical research has characterized how humans estimate the different components at play in this cost-benefit trade-off [24,25]. An extension of this theory incorporates metacognitive confidence in the estimation of expected benefits: decisions to invest effort should depend on the subjective estimation of one's capacity to obtain said benefits, i.e., on subjective confidence [26].

Hence, in the CMCfw, the computational mechanisms by which individuals monitor and allocate control processes during creative thinking remain to be further investigated. How do the outputs of the MMC trigger control engagement? This process may be akin to the Expected Value of Control theory. The static MKC can provide priors [27–29] acting as reference points against which the current output of the MMC can be compared. The MCC can then apply control during creative thinking to decide, for instance, to reject an idea and keep searching versus select it and stop. The output of the creative thinking process can then be forwarded back to the two other modules to adjust priors and monitoring settings.

The mechanisms underlying the MMC could also be related to recent research showing the role of valuation processes in monitoring at the response level during the production of remote ideas [30]. This study proposes a new computational model, introducing a "valuator" cognitive module, interacting with an "explorer" module that mimics semantic search and a "selector" module that selects an idea to be provided as a response. The Explorer-Valuator-Selector model proposes an integration of attribute evaluations (adequacy and originality of ideas) into an evaluation of the overall likeability of generated ideas. Hence, valuation (how appealing and rewarding the idea is for the agent) belongs to response monitoring. The Explorer-Valuator-Selector model provides operational and empirical metrics for investigating the metacognitive monitoring mechanisms at the response level of the CMCfw. Conversely, the CMCfw can inspire future developments of the Explorer-Valuator-Selector model to incorporate metacognitive module(s) that encode confidence levels in evaluating ideas.

In sum, the CMCfw offers a valuable perspective formalizing the role of metacognition in creativity. It also raises questions for future research (See Box). A better characterization of the underlying mechanisms, considering theories based on subjective confidence and valuation, will be essential in understanding how the interaction between metacognitive and cognitive components drives creativity. This augmented mechanistic framework can impact the development of concrete tools and targets for interventions to facilitate and foster creativity.

Open questions box

- How can we empirically dissociate control and meta-control, monitoring and meta-monitoring processes during creative thinking, and quantify them? For instance, is response monitoring necessarily metacognitive? Is it based on value assignment, expectations, and/or conflict/error detection?
- In "creative thinking," are all evaluation processes metacognitive?
- What are the computational mechanisms underlying metacognitive monitoring and control, and how do they interact with the other components during creative thinking? For instance, how do they interact with the knowledge module, and how is the latter updated during the task when expectations are not met?
- How does the CMCfw relate to recent theories that link the "Eureka" moment or insight to prediction error and metacognition [31,32]?
- Does the CMCfw architecture map onto the brain systems known to support metacognitive and creative operations?
- How can this framework inform us of the relevant targets and methods for fostering individual creativity?

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Declaration of interests

☒The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: