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Current Opinion in Behavioral Sciences

Measuring spontaneous processes in creativity research

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Spontaneous cognitive processes, operating in combination with controlled (executive) processes, are critical for creative ideation. Whereas decades of research have produced numerous validated methods for measuring controlled processes, the development of tasks and measurement tools that can capture spontaneous processes is still in relatively early stages. We review the most recent advancements in measuring spontaneous processes specifically in creative cognition. The methods we discuss include mind-wandering-based methods, incubation designs, brain imaging methods, and targeted behavioral tasks — specifically tasks based on generation of (free) associations. We point to means of refining each approach to better capture spontaneous processes, and suggest directions for future development.

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Current Opinion in Behavioral Sciences 2018, **27**:64–70

This review comes from a themed issue on **Creativity**

Edited by **Rex Jung** and **Hikaru Takeuuchi**

https://doi.org/10.1016/j.cobeha.2018.09.009

Introduction

Artists, scientists and other thinkers have long recognized the role of spontaneous cognitive processes in creativity, describing bursts of inspiration in which ideas suddenly pop into their minds [1]. This notion is supported by a vast stream of neurocognitive research indicating that spontaneous processes, in combination with controlled (executive) processes, are fundamental to the production of creative ideas [1–6]. Such research characterizes spontaneous (or 'type 1') processes as associative in nature and suggests that they involve rapid, mostly unconscious retrieval of information [7] from episodic (i.e., personal experiences) and semantic (i.e., conceptual knowledge stores) memory [8]. Spontaneity of thought can refer to the manner in which the thoughts arise (e.g. not-deliberately), and to the manner in which they unfold; that is, free from constraints, flowing flexibly in a dynamic manner (see Ref. [9••] for a precise conceptualization of spontaneous thought).

In order to gain a comprehensive understanding of creativity — and to identify interventions that enhance creative performance, a key aim of neurocognitive research in this vein (e.g. [10••])—it is crucial to isolate the individual contributions of spontaneous versus controlled processes in creative cognition [2,6]. Decades of research have provided substantial insight regarding the role of controlled processes in creativity and in other aspects of the mind (e.g. [11]), relying on an expansive array of established measurement tools (e.g. measurement of working memory; see Ref. [1] for a review). Knowledge on spontaneous cognitive processes, in contrast, remains somewhat limited by the fact that the development of tools for measuring such processes is still in relatively early stages. This lag is partially attributable to the fact that, compared with executive cognitive processes, spontaneous processes are by nature more difficult to induce and to translate into constrained quantitative measures. Additionally, the unique brain activity involved in spontaneous processes was identified only in 2001, after which brain research of such processes began to gain momentum; see Refs. [6,12]. Herein we review state-of-the-art behavioral and brain-imaging-based approaches that are used to measure spontaneous processes specifically underlying creative cognition, and we identify avenues for further development that might ultimately converge to a comprehensive, fine-grained understanding of these processes. Figure 1 presents a summary of the methods outlined in this review.

Mind-wandering-based methods

Mind-wandering (MW) refers to an individual's mental state when not engaged in an external task and is characterized by contents that are task-unrelated [13]. It can be defined as a form of spontaneous thought, in that it lacks constraints (e.g. it is less deliberately constrained than goal-directed thought, and less internally constrained than rumination) [9••]. Several studies have measured MW as a means of evaluating the amount of variance in creative performance that can be attributed to spontaneous thinking. This approach generally involves measuring participants' tendency for MW and creative performance separately, and then correlating the two scores.

Figure 1

Spontaneous processes	Relation to creative performance	Main means of measure	Recommendations for enhancing the capacity to capture spontaneous processes
Mind-Wandering (MW)	Correlating MW measures with scores on creativity tasks.	Self-report questionnaires, experience sampling or behavioral measures of deficits on non-creative tasks.	Taking into account characteristics of the MW that occurred (content, intentionality, awareness).
Unconscious processes during incubation	Participants work on a target creative task, switch to an incubation activity/control, and then return to the target task after the incubation. Scores on the creativity task are compared between the incubation group and control group.	Different incubation tasks (e.g., SART)	Using multiple variations of the incubation tasks; incorporating specific measurements to characterize MW that takes place during the incubation task
		Rest/passage of time	Not advised
		Sleep	Specifying the type of sleep, specifically REM.
Spontaneous processes related to the Default Mode Network (DMN)	Correlation of creative performance with measures of DMN structure, activity, and connectivity.	Resting state functional activity and connectivity, structural MRI.	Better understanding of the spontaneous processes that the DMN relates to, investigating sub-networks of DMN, investigating areas outside the DMN
Spontaneous processes related to divergent vs. convergent thinking or to improvisation	Participants complete creative tasks during brain imaging and the relevant brain underpinnings are identified.	Applying brain imaging paradigms that include at least 2 conditions, one with a creative (divergent/ improvisational) task and the other with a control task.	The creative task and the control task should be as similar as possible, differing only in the extent to which spontaneous processes are involved. Creating variations of the creative task and control task to control for potential confounds. Using before-after intervention designs.
Brain areas critical for spontaneous processes as defined by different tasks (e.g., spontaneous associations)	Correlating performance deficits on creativity tasks with the presence of different types of brain lesions.	Brain imaging coupled with administration of creative tasks	The more the specific cognitive processes necessary for each task are known to include spontaneous processes the better. It is preferable to compare across multiple participants with similar brain lesions in areas that are known to be relevant for creativity.
Associative spontaneous processes (e.g., unfolding of thoughts in memory, generation, shifting between concepts)	Comparing performance on tasks that involve associative processes to performance on creative tasks.	Associative tasks	It is preferable to use associative tasks whose relevance to spontaneous processes has been validated, e.g., using brain imaging.

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Methods used to isolate spontaneous cognitive processes involved in creative thinking.