On How Mind Wandering Facilitates Creative Incubation While Using Information Technology: A Research Agenda for Robust Triangulation

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Abstract. Our minds tend to frequently drift away from present technology-related situations and tasks. Against this background, we seek to provide a better understanding of mind-wandering episodes while using information technology and its link to decisive variables of Information Systems research, such as performance, creativity and flow. Since the academic literature still lacks reliable and validated measurements that can fully account for all facets of mind-wandering episodes while using information technology, our work addresses this gap by presenting a way to triangulate data in the context of a digital insight problem-solving task. This new approach enables researchers to further investigate the effects of spontaneous thought in technology-related settings and is a promising building block for the development of neuroadaptive systems.

Keywords: Technology use · Mind wandering · Creative incubation · Insight · Triangulation · Experience sampling · Behavioral markers · Neuroimaging

1 Introduction

Information Systems (IS) research studies how to reason or interact with information technology (IT). Building on that, Neuro-Information-Systems (NeuroIS) seeks to understand the development, use, and impact of IT by including neurophysiological knowledge [1]. The emphasis is set on understanding how humans interact with IT, e.g., for designing neuroergonomic or neuroadaptive systems. Studies test for externally-focused

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concentration and internally-directed attention, as cognition is not limited to the processing of events in the environment. While intrinsically-generated thoughts such as mind wandering (MW) become increasingly relevant, however, measuring them comes along with methodological challenges. As NeuroIS research successfully coped with similar obstacles (e.g., studying technostress; see [2–5]), the triangulation of neurophysiological data and self-reports seems a particularly promising avenue.

MW is described as a shift in attention away from a primary task and toward dynamic, unconstrained, spontaneous thoughts [6, 7] – or as the mind's capacity to drift away aimlessly from external events and toward internally directed thoughts [8]. The emphasis on attentional engagement in IS research follows the implicit assumption that our thoughts are continuously focused [9–11]. However, a growing body of knowledge suggests the opposite – namely, that our minds regularly tend to proceed in a seemingly haphazard manner. Therefore, neglecting MW leaves important IT phenomena largely unexplored. It is complex in nature and can have both negative and positive effects. For example, MW can be a necessary and useful cognitive phenomenon that offers potential for technology-mediated creativity (e.g., in webinars). In contrast, it can go along with various deficits in performance (e.g., IT management), disturbed team dynamics (e.g., trust), or weakened IT security (e.g., data management). Building on the findings of current research on digital stress (e.g., on information overload or interruptions), and based on the increasing demand for healthy breaks and distraction-free phases at work, we focus on the potential of wandering thoughts. Research in complex technology-related contexts can benefit from both a clear conceptualization of MW and comprehensive triangulation that adequately captures its characteristics. Against this background, our study is novel because it addresses measurement of intrinsically-generated thought while using technology. Without reliable and valid measurement, it is hardly possible to understand whether to expect negative or positive consequences; moreover, it is difficult to design systems that either increase or reduce MW episodes. Against this background, the research question of this work-in-progress paper is: Which procedure is most suitable for measuring MW while using IT? In order to answer this question, we will briefly introduce the theoretical background as well as the neurophysiological correlates of the relevant concepts, propose a procedure for triangulation, and close with an outlook on our next steps.

2 Theoretical Background

Solving complex problems is often associated with creativity, as the solution seems new and useful. Looking at the creative process [12], insight problem-solving is often associated with incubation. Incubation stands for taking a step back from the problem, and for allowing the mind to wander. In this phase, unconscious thought processes take over, e.g., while going for a walk, taking a shower, or in Newton's case, while sitting under a tree. This stage is followed by illumination (i.e., "Eureka!"), as well as verification (or implementation), where we build, test, analyze, and evaluate the idea. Considering incubation is central when dealing with internally-directed attention, because it helps understand whether and why past studies have shown that letting the mind wander in this phase can lead to greater creativity [13]. The benefits of incubation appear to be greater when being engaged in an undemanding task, where MW is found to be more frequent, than in a demanding task or no task at all (ibid.). Therefore, task difficulty can be used as a manipulation in our experiment.

According to Christoff et al. [14], MW is "(…) a mental state, or a sequence of mental states, that arises relatively freely due to an absence of strong constraints on the contents of each state and on the transitions from one mental state to another" (p. 719). It often occurs during tasks that do not require sustained attention [15]. Literature refers to it as unguided, unintentional, task-unrelated, or stimulus-independent thought [16]. Because empirical evidence expresses concern to describe MW as unguided [17], unintentional [18, 19], or stimulus-independent [20–22], we follow the family-resemblances perspective by Seli et al., which treats it as a heterogeneous construct [16]. Against this background, it becomes all the more important to clearly measure and describe the specific aspects of MW when investigating it in technology-related settings. Given that MW is considered to represent a failure of attention and control [23–27], their potential to yield beneficial outcomes has been widely neglected. Only in the last decade have studies highlighted its advantages, which include more-effective brain processing, pattern recognition, and associative thinking as well as increased creativity [13, 15, 20, 28, 29]. Recent IS research shows that MW relates to enjoyment [30, 31], creativity [13, 32] as well as performance and knowledge retention [20, 33, 34].

Evidence shows that deep absorption undermines creativity, whereas distraction can enhance it [13, 35]. This speaks in favor of taking breaks, appreciating boredom, and doing simple, monotonous things when agonizing. In this context, the benefit of incubation seems greatest when being engaged in an undemanding task, compared to a demanding task or no task at all [15]. Because undemanding tasks evidently open the door for MW as attentional demand reduces MW [36], we expect that the success of incubation (i.e., insight problem-solving while using IT) relates to the opportunity for MW.

3 Methodology

MW is studied mostly by using thought sampling and questionnaires [15]. Facing the potential shortcomings of subjective self-reports (e.g., common methods, social desirability, subjectivity [37] (p. 688)), we depict triangulation as a more promising strategy, in which one applies different methods, types of data, and perspectives to the same phenomenon to achieve a higher validity of the results and to reduce systematic errors. In specific, we will conduct an experiment, in which we will triangulate neurophysiological data and self-reports. Because literature introduces a number of different methods of estimating MW, we briefly summarize the overview by Martinon et al. [34].

Experience Sampling. The gold standard measure estimates thoughts and feelings as they occur. However, the data relies on subjective inquiry. There are three groups: First, online experience sampling gathers self-reports of the participants' ongoing experience 'in the moment' while they are completing other activities. Either the probe caught method (open/closed) requires participants to be intermittently interrupted, often while performing a task, and describe the content of their experience. The self-caught method asks them to spontaneously report their mental state (e.g., MW) as soon as they notice it, e.g., by pressing a button. This accounts for meta-awareness. Second, retrospective experience sampling gathers data immediately after a task has been completed. The reports can be biased, as they rely on memory. Third, the assessment of disposition encompasses multiple dimensions of experience and includes personality traits.

Behavioral Markers. Behavioral indices provide evidence of the nature of an ongoing thought at a specific moment of time or in a particular task. They deliver additional insight into the processes underlying different aspects of experience and are a less subjective measure of the observable consequences associated with performing dull, monotonous tasks. There are numerous potential tasks, such as the Sustained Attention Response task (SART), the Oddball task, reading (comprehension) tasks, breath counting tasks, the Complex Working Memory task (CWM), or the Instructed Mind Wandering task (IMW). Task complexity can be varied. However, in isolation, behavioral markers struggle to provide evidence on underlying causal mechanisms, being only a superficial description of the nature of experience.

Neurophysiological Tools. Neurophysiological measures allow for a more detailed picture of whether participants' attention is directed externally or internally, by illustrating the level of engagement during different stages of ongoing thought [38]. They show that during MW, attention shifts from the processing of sensory input (suppression of external stimuli by perceptual decoupling) to internally-directed processes [39]. The measures include, but are not limited to, electroencephalography (EEG), eye-tracking, and functional magnetic resonance imaging (fMRI). First, EEG is a recognized brain imaging tool, which assesses MW non-invasively without interfering with a task [40]. The event-related potential (ERP) ("a waveform complex resulting from an external stimulus" [41]), and EEG oscillations ("the manifestation of the activity of populations of neurons in the brain" (ibid.)) can be assessed. During MW, perceptual input is reduced, pointing at P1-N1, P2, and P3 as discriminative ERP-features. Studies observe an increased activity of lower oscillation frequencies, namely theta and delta, as well as a decrease of higher frequencies, namely alpha and beta [40]. Second, fMRI measures brain activity by detecting changes associated with blood flow. It controls for individual variation, e.g., in the Default Mode Network (DMN), but it is highly intrusive (for details on the concept of intrusiveness in NeuroIS research, see [42]), more expensive than EEG, time-consuming, and does not allow for temporal conclusions on the milliseconds level as EEG. Third, eye tracking operates as a reliable "time-sensitive indicator of internal attention demands" by capturing specific eye behavior changes [39]. These psychophysiological changes are divided into three ocular mechanisms: visual disengagement, perceptual decoupling, and internal coupling (ibid.). Since eye-tacking is non-invasive, relatively inexpensive and has already been widely applied, recent studies increasingly integrate this tool [43] (p. 22). In the future, all of the three presented techniques offer great potential, for example, when it comes to developing machine learning estimators for MW detection, for non-invasive brain stimulations, or for building neuroadaptive systems that adapt to the mental state of technology users in real-time (e.g., [44–48]).

To the best of our knowledge, few studies have directly assessed the occurrence of MW during incubation [13]. Our work uses the incubation paradigm and seeks to enhance the meaningfulness and reliability of the involved measurement. Our proposed experiment will be based on the Unusual Uses Task (UUT) [13], a classic and widely used measure of divergent thinking [49]. It requires participants to generate as many unusual uses as possible for a common object, such as a food can, in a given amount of time. The originality of the responses is taken as an index of creative thinking [13]. The experimental procedure will replicate the work by Baird et al. [13]. Based on our past research [30–34], we propose to add neurophysiological measures, namely EEG and eye-tracking, to experience samplings [20, 30, 50–52]. The combination of self-reported information with the detailed measures of neural function promises to shed critical light on aspects of spontaneous thought while using IT.

Participants will be randomly assigned to work on two digital UUT problems (5 min each). They will tell their responses to the investigator who types them into a text box on a computer. After completing the baseline UUT, participants will be assigned to one of three groups (demanding task, undemanding task, rest) using a between-subjects design. The aim is to have approximately the same number of participants in the respective groups. Participants in the demanding-task condition will perform a 3-back task, whereas those in the undemanding-task condition will perform a simpler task (1-back). In the rest condition, participants will be asked to sit quietly. This step will be followed by incubation (12 min). Next, all participants will answer a MW questionnaire [based on e.g., 20, 30, 50–52], and then work on the same two UUT again (5 min). Finally, they will be thanked, debriefed and receive financial compensation. At each point, the cognitive processes of the participants will be recorded with an EEG and eye tracking device. The tools' high temporal resolution (milliseconds level) will make it possible to determine thought patterns and to work out the typical course of a MW episode. The self-reports will serve to validate the findings. In addition, the assessment of creativity by two raters controls the behavioral correlate. The following research agenda is inspired by Dimoka et al. [53] (Fig. 1).

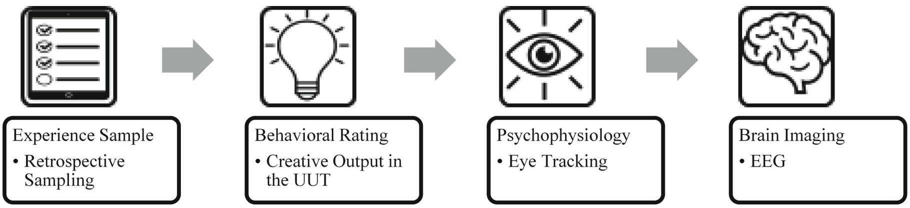

Fig. 1. Research agenda for robust triangulation

4 Outlook

Our work contributes to two crucial pillars of NeuroIS research [48], namely to designing information systems and developing neuroadaptive systems. First, we make a call for future research focusing on the relation between technology and creativity from various perspectives, e.g., on other phase of the creative process besides incubation. Future work can enhance our neuroscientific models of creativity while using IT, and further develop creativity-promoting tools. Moreover, we strongly believe that neuroadaptive systems offer significant potential, both from a theoretical and practical viewpoint. Although coming up with systems that adapt to the users' mental states in real time might sound utopic for mainstream IS and management researchers, efforts are already being made (not only in NeuroIS, but also in other fields that have been existing longer, such as affective computing, physiological computing, and brain-computer interfacing). Our work is a first step towards automatically observing and interpreting MW, which could help design human-computer interaction tasks and IT artifacts to increase the users' performance, productivity, and creativity. Note that the group of users explicitly also comprises programmers and software designer (because they are also users of computer systems). Creativity is a critical talent or skill in software development, and the potential of neuroscience for software engineering has been documented comprehensively in a recent review [54]. We see MW while using IT as a promising future research area based on the practical, methodological and theoretical values our project offers.

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