Cycle-Sensitive Knowledge Work? A NeuroIS Study Proposal for Improving Female Workers' Task Management

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Abstract. Hormone fluctuations due to the menstrual cycle can significantly impact women's physical and cognitive performance. While athletes already incorporate this in training plans to optimize training outcomes, it is still neglected in knowledge work. To address this gap, we review existing literature on hormone fluctuations and their impact on cognitive performance to design a cycle-sensitive task manager for knowledge workers (this paper). The proposed follow-up design science study should incorporate both the physiological menstrual cycle data as well as tagging tasks based on their required cognitive performance (future paper). The resulting app can then arrange the upcoming tasks in accordance with the cognitive performance strengths of the respective menstrual phase. This will enhance awareness among female employees while allowing an increase in task performance through cycle-sensitive work task management.

Keywords: knowledge worker • task performance • work productivity • menstrual cycle • hormone concentration

Introduction

Knowledge work performance goes beyond desk-bound tasks and is significantly impacted by the worker's emotional and physical state [1], well-being, and work practices [2, 3]. Therefore, organizations increasingly emphasize fostering employees' well-being and happiness at the workplace [4]. However, employees often face interruptions in their daily work that can be detrimental to their work performance [3]. Due to high digitalization in the field of knowledge work, information technology(IT)-related interruptions make up a significant part, potentially leading to technostress [5]. In response to this, several NeuroIS studies investigated the nature and impact of IT interruptions on task performance with fruitful insights into how and when these interruptions are stressors, and how workers habituate to them [e.g., 6, 7, 8]. Furthermore, first studies also offer solutions for how interruptions can be defined into the task management without hindering the workers' flow [9]. While existing findings are significantly advancing the field, most results generalize to knowledge workers and do not consider sex-related differences beyond the use of sex as a control variable. Yet, there are indications that women respond differently to stressors such as IT interruptions than men [5, 6, 10]. Going beyond sex comparisons, specifically women face additional challenges in the workplace that require more attention in research.

Drawing back to the importance of physical state and well-being of the employee, women's well-being is regularly affected due to the menstrual cycle (i.e., during menses) [11]. This has led to several researchers investigating the impact of the menstrual cycle on cognitive work performance, often with negative connotations of productivity loss [12]. Ponzo et al. [11] showed recently that the majority of surveyed women reported not receiving any support from their managers, though the greater share would desire it. The same study reveals how app-based self-tracking menstrual symptoms can already significantly contribute to reducing the self-perceived impact of the menstrual cycle on productivity [11]. This highlights the potential of menstrual cycle tracking to empower female knowledge workers in their everyday work. Furthermore, several studies have identified that cognitive performance is increased in some phases of the menstrual cycle, and variations in cognitive performance significantly depend on the type of task and the current menstrual phase [13-15]. Therefore, leveraging performance strengths of certain cycle phases may provide especially fruitful ground to improve female knowledge workers' task management and well-being. However, we could not yet identify literature that undertakes such endeavors. Therefore, this paper presents our first step toward designing a task management app that incorporates physiological tracking of the menstrual cycle and, accordingly, structuring work tasks along the cognitive performance variations throughout the cycle. For now, we will answer the following research question: *How does the cognitive performance on knowledge work tasks vary along the menstrual cycle (and how can this be incorporated in a knowledge work task management app)?*

In answering this question, we review literature regarding hormone fluctuations along the menstrual cycle and how these can be measured with wearables. After that, we summarize literature investigating the impact of the menstrual cycle on cognitive performance and map the key findings to the different cycle phases. Eventually, we propose a NeuroIS design science study [16-18] that takes the findings of this paper as a starting point and aims at developing an app that incorporates physiological cycle tracking, work task management, and the mapping of work tasks to the cycle phases in which highest productivity can be assumed.

The Menstrual Cycle and Cycle Prediction

The Menstrual Cycle. Women's physical state and well-being depend on the varying sex hormone concentrations that characterize the eumenorrheic menstrual cycle lasting on average 28 days [19]. Variations up to seven days of this 28-day cycle are still referred to as "normal" cycles [20]. The menstrual cycle starts with the first day of menses. It can be divided into the follicular and luteal phases (see Fig. 1). The follicular phase is characterized by increasing and peaking concentrations of estradiol, luteinizing hormone, and follicle stimulation hormone to mature the follicle for ovulation, which marks the beginning of the luteal phase [20]. Progesterone and estradiol concentrations peak during the luteal phase of the menstrual cycle, which cause the lining of the uterus to recede, menstruation to return, and a new cycle to begin if the follicle is not fertilized [20]. These varying hormone concentrations impact the cognitive performance of female knowledge workers.

While the varying hormone concentrations along the two phases occur in all eumenorrheic menstruation, the individual woman's hormone levels, duration of the phases, and accompanying symptoms (e.g., cramps, swelling, breast pain) vary greatly [21], affecting the physical and cognitive performance. Hormonal contraception (e.g., the pill) also influences the menstrual cycle to a large extent [22]. The impact on physical performance (e.g., in elite sports [19, 23]) is already well known and implemented; however, research on the effects of the menstrual cycle on cognitive performance in knowledge work is limited. Yet, there are several measures that can be used to track the menstrual cycle, and, therefore, would allow for a seamless consideration of menstrual cycle phases in the management of work tasks.

Methods for Menstrual Cycle Prediction. To accurately structure work tasks based on cognitive performance fluctuations, it is necessary to predict the individual cycle and its phases precisely. As invasive methods to measure hormone concentrations (e.g., blood tests) require significant effort, easy-to-use methods to assess menstrual cycle phases are increasingly available. Proposed methods are based on observing physiological signs and symptoms (e.g., calendar method and basal body temperature), and are discussed in the context of natural family planning (NFP) [24, 25]. In wearable technology, various NFP methods are included to offer cycle tracking and prediction [26]. Menstruation and fertility apps for smartwatches, for example, include calendar functions to track the days of the menses (e.g., the length and strength of the period bleeding), document menstruation-related symptoms and irregularities (e.g., cramps, swelling, breast pain), and receive notifications of the upcoming menses [27]. The apps allow the management and monitoring of women's physiological and psychological health data [28]. In addition to menstruation-related information, more general fitness apps track further physiological measures (e.g., heart rate [29], sleep quality [30]).

Among the physiological measures for menstrual cycle tracking, basal body temperature has shown to be the most accurate one. Basal body temperature is an essential indicator of the luteal phase, as it is constantly 0.5°C higher than in the follicular phase [20]. This relationship is being incorporated into a growing number of wearable technologies. For example, the Oura ring [31] and the cycle tracker "Trackle" [32] continuously measure body temperature via finger or vagina. With additional self-reported physical measures (e.g., cervical mucus), the wearables and smartphone apps (under perfect use) result in a high Pearl Index (0.3) for contraception, thereby being reliable predictors of the menstrual cycle phases [33]. With various wearable technology options, the menstrual cycle and its phases are easily measurable and trackable, allowing for analyzing indicators of fluctuating hormone concentrations and their impact on knowledge workers' cognitive performance.

Cognitive Performance Along the Menstrual Cycle

Several cognitive neuroscience studies have shown how significantly sex hormones impact brain functions and, potentially, cognitive performance [34, 35]. As a result, researchers started to systematically investigate how ovarian hormone (i.e., estrogen and progestogen) concentration changes may impact cognitive functions and brain

connectivity [34, 35] as well as cognitive and behavioral performance across a variety of tasks [13-15]. Interestingly, whereas some authors show how an estrogen peak may positively impact routine tasks while it potentially diminishes task performance on more perceptual tasks [e.g., 36], there are studies proclaiming that there are no objectively measurable differences in cognitive performance during the menstrual cycle [13, 37, 38]. Furthermore, research has shown that self-efficacy is higher during the follicular phase [22, 39]. However, the effects remain somewhat inconsistent between studies due to several methodological limitations of the studies [13, 14, 40]. As a result, researchers have called for more (rigorous) research on the matter [14].

To identify effects that are consistent across studies, we deliberately investigated structured literature reviews of original works that investigated performance fluctuations along the menstrual cycle [14, 40]. Key findings reveal increased performance levels in verbal tasks and lower performance in visuospatial tasks in the follicular phase when estrogen levels are at peak, but progestogen is low. In the luteal phase, where both estrogen and progestogen are high, studies found that performance in verbal tasks is increased. Furthermore, findings regarding emotion regulation are consistent across studies. They show that emotion regulation is decreased in the luteal phase, which is also evidenced by respective brain activity [15, 34, 41]. The identified effects of the menstrual cycle on cognitive performance are depicted at the bottom of Fig. 1.

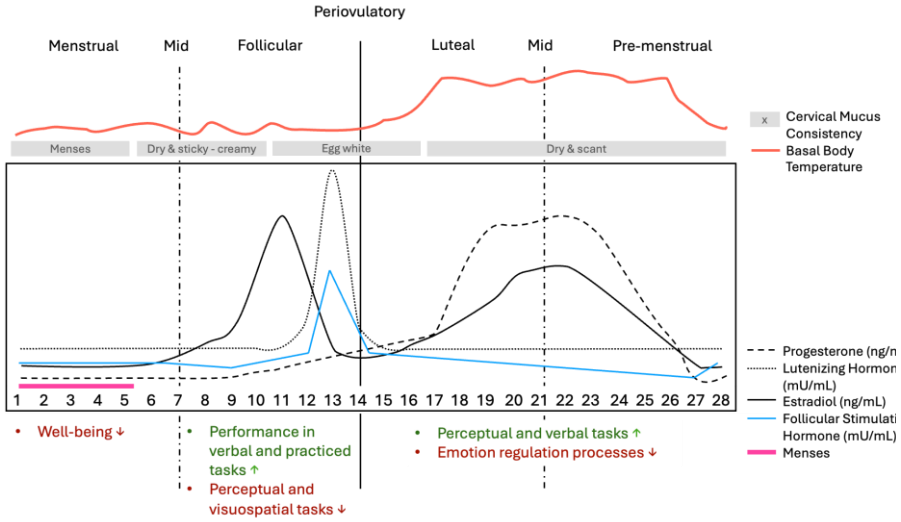

Fig. 1 Varying Task Performance Along the Menstrual Cycle

Next Steps: Using Wearables to Predict Cognitive Performance via the Menstrual Cycle

Based on the first findings presented in Fig. 1, we derive initial insights of how a cycle-sensitive work design could be realized in practice. For example, this could be realized by tagging the performance strengths to specific tasks in a task manager (see examplary in Fig. 2). Here, we show for the process "writing a NeuroIS paper" how the different tasks in the writing process could be distributed across the phases of the menstrual cycle. The phases could either be used as buckets to sort the tasks, or in case the buckets are required for a different categorization, they can be used based on the labels. To dive more into this, and to derive robust design guidelines for such a cycle-sensitive manager, we will conduct a design science study in our next steps [16, 17]. More precisely, we will design an app prototype that combines the results on cognitive performance with the various tasks of knowledge workers and, via wearable technology, tracked menstruation data. We aim to achieve this by considering the effects of fluctuating hormone concentrations during the (healthy and natural) menstrual cycle phase based on manual menstruation tracking and physiological data (e.g., basal body temperature). The app will then enable users to tag tasks with their respective types (e.g., communication tasks tagged with verbal or editing tasks tagged with visuospatial [42]), deadlines, and priorities. Based on the tagged tasks and the physiological information, the app will then automatically arrange the tasks along the cycle phases if the set deadline allows for it. This will empower female knowledge workers to match their cognitive performance to the tasks at hand, and it will allow seamless productivity increases in everyday work. The app prototype will be evaluated with a cohort of female knowledge workers over at least two to three menstrual cycle lengths in an experimental setting.

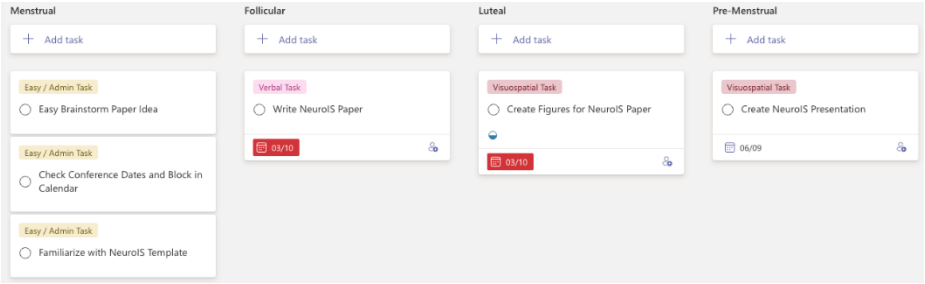

Fig. 2 Example for Incorporating Cycle-Sensitive Task Management

Discussion and Conclusion

Managing and matching tasks to phases of the menstrual cycle enables female knowledge workers to increase their self-perceived productivity. In the following, we discuss three challenges that we are aware of for our research project: (1) individual characteristics, (2) cycle-sensitive planning and dependency between tasks, and (3) environmental factors that influence female workers' cognitive performance.

Ad (1) individual characteristics. As Randolph and Moore Jackson [43] show, individual characteristics such as demographic traits, physiological traits, as well as prior experiences in certain domains significantly influence the use of nontraditional assistive technology. It is deduced how most of the individual traits can each have a different impact, making them important to consider in app design and the selection of neurophysiological measures. This is supported by previous research highlighting that app design, especially personalization opportunities of apps, positively influences the acceptance and use of apps [44, 45]. Our design science approach will thus take additional individual traits such as age or athleticism into account as an additional crucial part of the design guidelines to allow for more personalization.

Ad (2) cycle-sensitive planning and dependency between tasks. As shown above, in each menstrual phase, different tasks can be worked on and completed with more ease compared to other cycle phases. However, not all work tasks can, of course, be planned perfectly in the timing of the menstrual cycle (eumenorrheic 28 days), as digital work is characterized by an "integrated, interdisciplinary, participative and agile" [46] design with various dependencies between tasks. Therefore, it will not always be possible to match the tasks to the most appropriate cycle phase. However, each job position also includes several recurring tasks that can be well included in cycle-sensitive planning and extended with the planning of other tasks whenever possible. Either way, our app prototype contributes to female knowledge workers' awareness of their varying cognitive performance and the opportunities that a cycle-sensitive work design offers them. This may also allow female knowledge workers to be more self-forgiving in cases where a task must be completed in a phase that is detrimental to the respective task performance. So even if objective task performance may not be increased, this approach may lead to empowerment of female knowledge workers, furthering their job satisfaction and satisfaction with oneself.

Ad (3) environmental factors that influence female workers' cognitive performance. In addition to the effects of menstrual cycles on cognitive performance, environmental factors extending what we outlined previously also affect the female knowledge workers' productivity. Examples include high task fragmentation and work interruptions [3], sleep deprivation [30], and technostress [5, 47]. While these factors are relevant, they are also difficult to control. However, along the different phases of the menstrual cycle, the susceptibility to these interruptions and their influence on performance vary. We are aware that we can only take these factors into account to a certain extent, but the app prototype will allow us to track these other effects as well.

Overall, the proposed study greatly contributes to IS research in general and NeuroIS research in particular. First, we show how a cycle-sensitive approach can significantly benefit female knowledge workers in their work lives. Second, this generates awareness of female workers not only in relation to work but also for themselves and their own health because structured cycle tracking also allows them to identify potential diseases early on. Third, we answer the call for and guidelines provided by vom Brocke et al. [18] to incorporate neuroscience in design science research since only few studies exist that follow this call, and even fewer consider body temperature and hormone concentrations as physiological measures to complement the design.

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