Body Clock Awareness: Circadian Scheduling and Interventions

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Abstract
Sleep deprivation, stress, and resulting burnouts are a common struggle of today's knowledge workers. One major cause is disruptions in our sleep/wake regulation due to jam-packed schedules and an always-on mentality. Current technologies do little to help us manage our days more in alignment with our inner body clocks. In our research, we investigate cognition-aware systems capable of detecting circadian rhythms of alertness and cognitive performance, deriving strategies for smart schedules, and triggering interventions to align cognitive states with the requirements of tasks at hand. Interventions range from recommending a caffeinated drink to solving a puzzle, napping or taking a walk outside.

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cognition; cognition-aware systems; context-awareness; human memory; cognitive systems; recall;

Introduction
Our alertness, attention and vigilance is highly variable and subject to systematic changes across the day [9]. These fluctuations are in part caused by circadian rhythms and are

therefore roughly based on a 24h cycle, which follows our internal body clock. Peaks and lows during the day thereby impact our higher level cognitive functions, including perception, memory, and executive functions [3]. However, technologies barely take into account these variations of their users' cognitive capacities. Instead, their near-constant availability and increasingly mobile features allow (and at times pressure) users to work anytime and anywhere. Therefore, it becomes more and more difficult for knowledge workers to 'switch off' and recharge their mental capacities. Stress can be the result of chronically high levels of work load and can cause various health problems, such as depression or burnouts.

Research has shown how activities, such as taking a walk, exercise and being in nature have a positive effect on anxiety, depression, but can also foster creativity and focus [7, 10]. In this position paper we discuss our current investigation into technologies that detect circadian rhythms and proactively suggest interventions designed to align daily activities with the user's body clock. Technologies that are aware of their users' diurnal rhythms of cognitive performance are capable of scheduling a day's work to match complex tasks with cognitively high-performing phases, but also of recommending interventions, such as taking a walk in nature, designed to recharge cognitive capacities and alter cognitive states.

Circadian Computing

People's cognitive performance fluctuates throughout the day: at some times we are highly focused while at others we feel unable to concentrate. These fluctuations—in part caused by circadian rhythms—are deeply rooted in the body's inner clock and sleep/wake regulation. Variations in alertness and sleep propensity are generated by two underlying processes: sleep/wake homeostasis and a

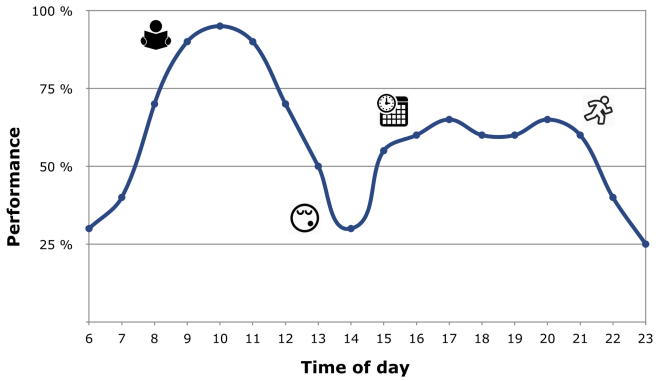

Figure 1: Illustrative depiction of the circadian rhythm of cognitive performance along with activity recommendations (reading, resting, route work, and going for a run) at times of different performance capacities.

circadian process [4]. The homeostatic process manifests itself as a gradual decrease in alertness during wake periods. The longer we are awake, the stronger becomes the need for sleep. Alertness is further modulated by a circadian biological clock with a period length of about 24h. Following a sinusoidal pattern, it determines hours of the day when we experience a particularly low or particularly strong sleep drive. For many people, the alerting capability of the circadian process peaks in the late afternoon, thus partially counterbalancing the accumulated sleep pressure from the homeostatic process. This is commonly experienced as heightened alertness towards the evening after a post-lunch dip in alertness and concentration. These rhythms can be slightly different from person to person, however they occur in individual, but distinct patterns. Figure 1 shows an illustrative graph with phases of high attention in the morning, a decline in the early and a performance recovery in the late afternoon. The circadian rhythm of alertness and cognitive performance depends on

a range of individual factors, such as sleep, nutrition, stress levels, and general health.

Traditional methods to assess the circadian rhythm include extensive lab experiments, which can take weeks of being in controlled environments. Other methods can be equally cumbersome or even unpleasant, such as sleep-wake protocols or physiological markers (e.g., dim light melatonin onset, rectal temperature monitoring, cortisol level measurements [9, 8]). A more recent investigation conducted by Abdullah *et al.* [2] related mobile phone usage to circadian rhythms of alertness, therefore allowing for unobtrusive measurement of performance variations across the day.

However, current technology rarely adapts to these variations in sleep/wake cycles and the related diurnal patterns of alertness and cognitive performance. Instead, systems generally assume a constant level of cognitive performance and rarely accommodate for fluctuations. We believe applications can highly profit from being aware of the user's rhythms and help schedule tasks, adjust UIs, and stage interventions to prevent health problems and foster productivity. In previous investigations we looked at equipping mobile phones with an awareness of the users' general receptiveness for incoming messages [6] and suggested contents in situations of detected boredom [11]. In our current research we focus on reconstructing users' more general attention patterns across the day and explore application use cases for cognition-aware systems, as well as exploring possible recommendations for state-inducing activities.

Cognition-Awareness and Invoking Alert States

With regard to application use cases of cognition-aware systems we envision technologies to be capable of supporting smart task scheduling, managing disruptions, increasing self-awareness, and triggering interventions for state changes (for an overview of the vision of building personal assistants based on cognition-awareness, also see [5]). In this position paper we would like to focus on discussing interventions in phases of low cognitive performance, *i.e.*, the local minima depicted in Figure 1.

Consumption of caffeine, for example, has been shown to—at least temporarily—enhance alertness and compensate for sleep deprivation [12]. Abdullah *et al.* [1] investigated the effects of blue light—both artificially induced and by taking a walk—on creative thinking abilities. Generally, outdoor activities exposing us to blue light and further stimulating our cardiovascular system are known to have activating effects. Also, short mental distractions in the form of games and puzzles can help us recharge our cognitive capacities. In our current research we use unobtrusive measures, such as phone usage or typing behavior, to collect information about the user's body clock. In phases of low activation, our system then recommends one out of a pool of stimulating activities, namely 1) drinking a caffeinated drink, 2) taking a walk outside, 3) solving a puzzle, and 4) taking a nap. Through triggering interventions in combination of experience sampling (subjective assessment and objective test measures) we investigate the effects of each intervention and their feasibility to be triggered throughout the day.

Conclusion

Our vision of cognition-aware systems entails learning about users' patterns and schedule a work day according to their innate body clocks. The resulting daily agenda entails appointments and completion of tasks, but also sleep, and outdoor activity tips, as well as temporary interventions to battle fatigue. To help users to be more effective at their

tasks and therefore increase overall productivity, such systems naturally blend into everyday life and propose recommendations throughout the day that help users to align their activities with their body clock. Alignment between inner states and our everyday tasks allows us to work more effectively and promotes overall well-being.

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