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Towards attention-aware adaptive notification on smart phones

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ABSTRACT

As the amount of information to users increases with the trends of an increasing numbers of devices, applications, and web services, the new bottleneck in computing is human attention. To minimize users attentional overload, we propose a novel middleware "Attelia" that detects breakpoints of user's mobile interactions to deliver notifications adaptively. Attelia detects such timings in real-time, using only users phones, without any external sensors, and without any modifications to applications. Our extensive evaluation proved Attelias effectiveness. In-the-wild user study with 30 participants for 16 days showed that, specifically for the users with greater sensitivity for interruptive notification timings, notification scheduling in Attelia's breakpoint timing reduced users frustration by 28% in users' real smart phone environments.

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1. Introduction

Since the introduction of the computer, users' attention has remained constant; however, the amount of information from computer systems, applications, and services has been growing. This trend has driven users to perform more multi-tasking and depend more on notifications for completing computing tasks on their devices. As a result, they face an increasing number of interruptions caused by the notifications. The number of connected computer devices, including a user's own mobile and wearable devices, as well as sensors, cameras, servers and other devices embedded in the environment (such as home, office or city space) have been increasing as well. Users possess, carry and utilize an increasing number of mobile and wearable devices, such as smart phones, smart watches or smart bands [1], sometimes interacting with multiple of them simultaneously [2]. Driven by several technological and market trends, such as the web and cloud platform technologies that enable agile development and deployment of applications and services (through channels like the "AppStore"), each of the user's devices is loaded with more applications and back-end services. Furthermore, users have been communicating more with their peers, as new types of communication channels on the web such as social networking or location-based networking, have emerged.

Focusing on this "information overload", human attention, rather than computation power or network bandwidth, is the new bottleneck in computing [3]. In this paper, we focus on the particular problem of "interruption overload", a type of distraction caused by an undue amount and inappropriate delivery of interruptive notifications from computer systems. Conventional notification systems that deliver notifications immediately after they are available, have negative

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impacts on users' work productivity [4–7]. One solution is to defer such notifications until the transition between a user's two contiguous activities is detected. This interval of time or transition in between activities is referred to as a "breakpoint" [8] in the psychology literature. This deferral can reduce the negative effect on users' cognitive load made by the interruption.

In this work we especially focus on the "mobile experience" of users on a smart phone while they are actively manipulating their devices and show how our system can detect breakpoints during such periods, and defer notifications to these breakpoints. This work is a first step towards "user-attention-aware" adaptation in notification systems. Our system, Attelia features (1) its ability to work well (as a lightweight background process) on smart phone devices, (2) applicability to any type of application installed on the devices, (3) real-time breakpoint detection in order to realize real-time adaptation, and (4) needing only the smart phone, and not any external psycho-physiological sensors such as an ECG or EEG monitor.

A controlled in-lab user study with 37 users validated that, for users who showed greater sensitivity for interruptive notification timings, notifications, along with an artificial interruptive task to answer a quiz question, delivered at the timing of breakpoints detected by Attelia resulted in 37% reduction in user's frustration score, compared with the notifications delivered at the conventional "random" timings. A further "in-the-wild" user study with 30 users for 16 days, conducted after the promising results of the in-lab user study, validated the effectiveness of Attelia in a real-world situation. For those who showed greater sensitivity for interruptive notification timings, notifications along with an artificial interruptive task delivered at the timing of breakpoints resulted in 28% lower frustration. Furthermore, response time of the users to the notifications (displayed in the breakpoint timings) was quicker by 13% than the notifications in the random timings.

The contributions of this paper are two-fold.

1. The design of Attelia, our novel mobile middleware on smart phones that detects user's breakpoint timing in real-time, without any external psycho-physiological sensors.
2. The results both from in-lab and in-the-wild user studies which validated the effectiveness of Attelia for reducing users' frustration.

The paper is structured as follows. Section 2 introduces the problem of interruption overload by notifications. Section 3 introduces several recent trends in notifications and specifies the requirements for the adaptive scheduling of notifications on smart phones. Section 4 shows our approach for designing Attelia, followed by Section 5 that describes its system architecture. We show the results from our controlled user study in Section 6, and the results from the in-the-wild user study in Section 7. Based on the analysis of the user studies, Section 8 discusses future research opportunities. Section 9 introduces related work. Finally, Section 10 concludes the paper.

2. Interruption overload

The excessive number and ill-timed delivery of interruptive notifications cause interruption overload, one piece of the larger information overload problem. For this problem, more research has been focusing on the topics of interruption and multitasking [9].

Notifications from computer systems are the main source of interruption in a user's computing environment. The concept of notification was originally for delivering information to users in a more speedy and timely manner, rather than requiring users to manually pull new information.

Although the notification system gives such merit to users, past researches have shown that excessive numbers of notifications or ill-timed delivery of notifications result in several types of negative impacts on user's work. These impacts include reduction in user's work productivity [4–7,10,11], including productivity of a user's primary work (work to be interrupted) or quality of decision making, negative effect on a user's emotional states and social attribution [4], and even negative effect on a user's psycho-physiological states [10].

Although a user, of course, can configure the notification system and can even disable the notification delivery, such operation negates the benefits of the notification system and cannot fulfill the needs of the users for the speedy and timely delivery of new information. Users prefer to keep notification systems on, even given the interruption costs, rather than simply disabling the system and check the new information manually, according to the previous research [12].

2.1. Existing research on mitigating the cost of notifications

Past research for the interruption overload problem can be categorized into two different approaches, (a) scheduling (deferring) notifications, and (b) mitigation of notifications.

A "breakpoint" is often used as a target timing of deferred notification to users, in the first "deferring" approach. Breakpoint [8] is a concept found in psychology field. A boundary between two contiguous discrete actions, when a human's perceptional system segments human activities into a series of hierarchically-structured actions, is called a breakpoint. Iqbal et al. [13] found that there are at least three different granularities of breakpoints (Fine, Medium, and Coarse), that users can reliably detect during interactive computing tasks. Other research [4,14,15] has also observed interruption cost, including resumption lag of the user's primary task and subjective frustration value, when notifications are deferred until the breakpoint timings.

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