Interruptibility Research: Opportunities for Future Flourishment

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Abstract
As users enjoy their computing with an increasing number of devices, applications and services, and connected other users, usersąÇ attention is getting the most precious resource in computing due to increasing information fragments provided proactively. Research on user's attention management and especially interruptibility have been accelerated in the recent years. After clarifying some recent background computing trends, this paper focuses on those researches areas, specifies several possible opportunities in the area, and proposes 3 key future opportunities that include being a layer and platform, communication with industries, and intersection with research areas. This paper aims to motivate active discussion on how we can make our research flourish in rather longer term.

Author Keywords
ubiquitous computing; attention; interruptibility; research community; opportunities

ACM Classification Keywords
H.3.4 [User profiles and alert services]: Systems and Software

Introduction
Ever since Herbert A. Simon firstly emphasized the preciousness of the limited amount of attention expected in

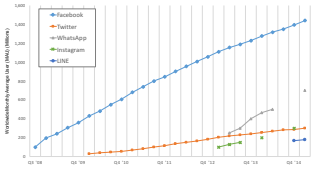

Figure 1: The Number of Worldwide Monthly Active Users (MAU) of the Major Social Media Services

(Source: Facebook, Inc., Twitter, Inc., LINE Corporation and Instagram, Inc.,)

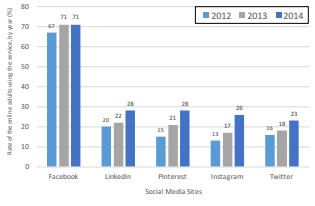

Figure 2: Online Adults using the Major Social Media Sites, 2012-2014

(Source: Social Media Update 2014 [17])

ubiquitous computing (using the words "information-rich world") in 1969 [19], a gap between the unchanged amount of available attention resources of a human user and the amount of resources demanded by the increasing amount of information has been becoming significant. Clearly, human's attention has been recognized as one of the most precious resource in computing in the recent ubiquitous computing research [5]. For many years, researchers have been working on user's interruptibility as one of relatively-easy-to-measure and concrete metrics of around human attention, firstly in static goal-oriented environments [7, 4, 8], in-lab controlled environments [9, 10], to user's own in-the-wild environments [16, 14, 15, 18].

In this paper, after we clarify some of the key trends around user's computing devices, communication, and notification occurring in the recent computing experience of users, we propose several opportunities for the future of interruptibility researches. The purpose of this paper is to motivate active discussion on how we (interruptibility researchers) can collaborate internally with each other as well as with other researchers and developers, towards further flourishment of the interruptibility and attention management research area.

Trends in People's Computing

In this section, we summarize some of distinctive current trends in the recent computing that are related to interruption and attention management research as their backgrounds.

Increasing Connected Devices

Firstly, the number of computing connected device has been (and will be) drastically growing. Due to emerging Internet of Things (IoT) devices in addition to the conventional mobile and wearable devices, the total number of devices (PCs, smartphones, tablets, IoTs, smart TVs, wearables) in use in the world is expected to be more than 18 billion in 2018 [1]. Thus, naturally in personal scale, the number of networked computing devices in a user's surrounding environment has been increasing [20]. The average number of devices that people are using to access the Internet has been increasing from 2.12 devices in 2011 to 2.78 in 2014. Another survey revealed that users tend to carry multiple devices and even use them simultaneously [6]. For example, 75% of the time when users are using a tablet, they are using another device (35%, a smartphone; and 44%, a television). In particular, the trend of watching TV with simultaneous Web access from a tablet or smartphone is called "second-displaying."

Increasing Applications and Services

On recent mobile devices, users are utilizing an increasing number of applications as the mobile application market, from which users can easily find and download new applications, grows drastically. Launched in 2008, Apple's App-Store is reported to have 1.7-million active applications as of June 2015. The competing Google Play store has 1.5-million applications. From these numerous applications on the market, Yahoo Aviate's research has shown that smartphone users on average install 95 applications on their phone and use 35 of them throughout the day [21]. Other research [3] has shown that users continuously download new applications. Even in one of the most mature app markets in the U.S.A., consumers have been continually downloading applications at the same rate since 2011 (8.9 apps per month in 2011 versus 8.8 apps per month in 2014).

Increasing Connected Others

The advent of social networking services, in addition to conventional communication channels (such as email and SMS), has increased the number of people that users communicate with on a daily basis. Figure 1 shows the number

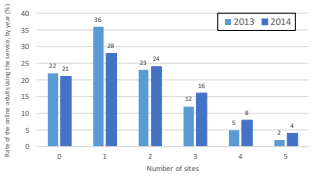

Figure 3: People's Use of Multiple Social Media Sites, 2013-2014
(Source: Social Media Update 2014 [17])

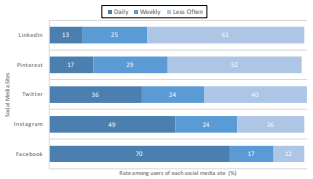

Figure 4: Frequency of Major Social Media Site Use
(Source: Social Media Update 2014 [17], September, 2014)

of monthly active users (MAU) of the major social media services worldwide from 2008 to 2014. The biggest social network, Facebook, has an MAU of 1.4 billion as of Q1 2015. This number is approximately 20% of the world's population. According to the results of a survey conducted on online users worldwide, all of the major social media sites have been receiving greater interest over the past recent years, as illustrated in Figure 2. In addition, the same survey showed that users have been using an increasing number of social media sites over time, as shown in Figure 3. More than 50% of Facebook users (in the U.S. market, 18 years or older, $n = 1,074$, as of September 2014) have more than 100 "Facebook friends", with the median number being 155. Furthermore, the frequency of access to each of the major social media sites by registered users is increasing (Figure 4). In particular, Facebook has far more than 50% of users who access the site every day. A combined estimation from the numbers described here tells us that approximately 1 billion people around the world accesses Facebook daily.

User's All-Day Long Computing Experience
Finally, user's computing is becoming an all-day long experience. The duration of typical user's computing used to be 8 hours a day in the era of office computing. However, in the age of ubiquitous computing, the duration is reaching close to 24 hours a day, meaning that a user's computing experience (such as sleep monitoring with a smart wristband [2, 11]) sometimes takes place even while in bed.

Explosion of Push Notifications

Driven by the key trends introduced above, what we are starting experiencing is "explosion of push notifications" in the advancing ubiquitous computing.

- **Increasing Notifications from Versatile Sources**
  We are receiving more notifications from an increasing number of applications installed and running on a computer. Furthermore, behind such applications are versatile Web services on the net, and an increasing number of other users connected to the network. Due to the recent proactive interaction capabilities of such applications, more notifications are being delivered to users.

- **Multiple Mobile Devices as Targets**
  Users have been carrying and using an increasing number of devices. Very often, users receive notifications on each device individually. Furthermore, a user may often install the same application, which can be viewed as a front-end of a Web service, into their multiple devices. This may lead to a situation with multiple duplicated notifications with the same content delivered to multiple devices.

- **Increasing Length of Notification Experiences**
  As mentioned, user's computing has been changing to an all-day long experience, with users surrounded by multiple mobile and wearable devices with a long battery life and various types of ubiquitous computing applications that support the users' lives comprehensively. Under this situation, the notification experience is also becoming an all-day long affair.

Opportunities

Given mentioned key background trends and the situations around notifications, here we propose 3 distinctive research directions towards further flourishment of interruptibility research area, as follows.

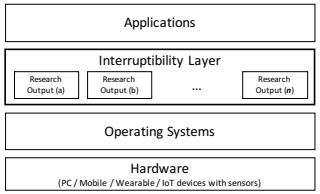

Figure 5: Concept of Interruptibility Layer (Client Side)

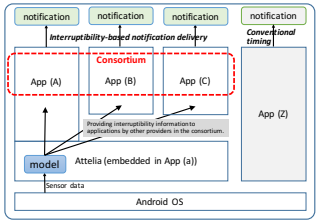

Figure 6: Application-layer Interruptibility Sharing between Applications from Consortium Members

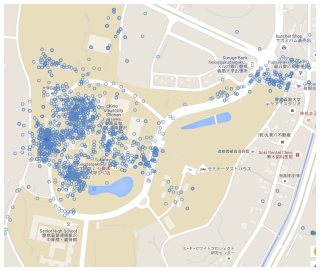

Figure 7: Breakpoint Map

Be a Layer! Be a Platform!
The first opportunity is to provide the series research output (implementation of the research proposition) in this field to other researchers and developers by a means of "layering". Although there have been lots of interruptibility researches conducted in the mobile, wearable, and ubiquitous computing fields (and although there will be even more emerging field, such as "multi-device" and "IoT"), very few works [16, 14, 15] have been implemented as a platform software (such as middleware that exports "interruptibility API"). This means that (1) interruptibility researchers have difficulty to compare research outputs each other, and also (2) potential users of those interruptibility research outputs need burden to evaluate and utlize those outputs.

Possible opportunity is building "Interruptibility Layer" by the researchers towards higher reusability of the research outputs and broader use by versatile applications. Figure 5 shows a conceptual figure of Interruptibility Layer particularly in the mobile client side. (Although some works actually implement their interruptibility detection mechanisms at server side, for sake of simplicity we use the client side example here.) Preparing a common interruptibility sensing platform as middleware on top of the mobile operating system, and placing our individual research output as a module inside the middleware would bear several beneficial outcomes both for the interruptibility researchers ourselves and much larger community of potential users of interruptibility research.

Communication with Industries
Further extensive flourishment of this research area naturally includes communication and collaboration between research community and industry. Building the interruptibility platform layer will involve in the major operating systems players, such as Apple (iOS) and Google (Android). We interruptibility researchers have been discussing possibility of collaboration between our research community and those OSs, but there is no open platform built up-to now. On iOS and Android OS, researchers (including broader "mobile sensing" researchers) are continuously trying to catch up those "moving target" OSs that changes their specifications release by release.

Possible alternative scheme of building an open platform between multiple players are "just build it on the current moving target OS". Figure 6 shows a conceptual scheme of an cooperative behavior between multiple applications with a "consortium" in a single device. Currently, we are jointly integrating Attelia [15] middleware inside an commercial Android application (App (A)) as a research project. If we can initiate a multi-player consortium with other application developers (B) and (C), breakpoint [12]-based interruptibility information can be shared among multiple applications by all consortium members so that all of those apps can issue notifications in "appropriate" timings of the user. Although the Android OS is still the "moving target" from the middleware, pure application-layer middleware is possible and cost for catching up the OS update can be afforded by the larger-scale multi-player consortium.

Intersection with Other Research Areas
Collaboration with other research areas of ubiquitous computing and computer science beyond Human Computer Interaction will bring up another huge research opportunities. For example, we are currently pursuing an ongoing collaboration between interruptibility research with smart city research. Figure 7 is a map of multiple user's detected physical-activity breakpoints [13] in a university campus. Knowing where people are experiencing breakpoints, the timings considered to be an appropriate timings for notifications, notifications delivery can be adapted with respect to

the user's current location inside the smart city. Also, this is another example of "being as a platform layer" of interruptibility research outputs.

Conclusion

Towards realization of human attention management in ubiquitous computing, this paper proposed 3 possible opportunities for the current interruptibility research. After clarifying some of the key trends around user's computing devices, communication, and notification occurring in the recent user computing experience, we specified the important aspects in "explosion of push notification". Lots of interruptibility research have been done for many years. Now is the timing for us to be a layer and a platform in order to realize expansion of this research area. Although collaboration with major OS players in industries are very important, the application-layer player can do certain degree of multi-player collaboration through a application-layer consortium. Versatile types of collaborative research between interruptibility researchers and other computer science researchers are expected to bring flourishment to this research area.

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REFERENCES

1. BI Intelligence. 2014. Here Comes The Internet Of Things. https://intelligence.businessinsider.com/the-internet-of-things-2013-10. (Aug. 2014).
2. Fitbit Inc. 2014. Fitbit Trackers. http://www.fitbit.com/. (2014).
3. Flurry. 2014. App Install Addiction Shows No Signs of Stopping. http://flurrymobile.tumblr.com/post/115194583975/app-install-addiction-shows-no-signs-of-stopping. (Dec. 2014).
4. James Fogarty, Scott E. Hudson, Christopher G. Atkeson, Daniel Avrahami, Jodi Forlizzi, Sara Kiesler, Johnny C. Lee, and Jie Yang. 2005. Predicting Human Interruptibility with Sensors. *ACM Transactions on Computer-Human Interaction* 12, 1 (March 2005), 119–146. DOI: http://dx.doi.org/10.1145/1057237.1057243
5. D. Garlan, D.P. Siewiorek, A. Smailagic, and P. Steenkiste. 2002. Project Aura: toward distraction-free pervasive computing. *Pervasive Computing, IEEE* 1, 2 (april-june 2002), 22 –31. DOI: http://dx.doi.org/10.1109/MPRV.2002.1012334
6. Google Inc. 2012. The New Multi-Screen World | Think with Google. http://www.google.com/think/research-studies/the-new-multi-screen-world-study.html. (Aug. 2012).
7. Eric Horvitz and Johnson Apacible. 2003. Learning and Reasoning About Interruption. In *Proceedings of the 5th International Conference on Multimodal Interfaces (ICMI '03)*. ACM, New York, NY, USA, 20–27. DOI: http://dx.doi.org/10.1145/958432.958440
8. Shamsi T. Iqbal and Brian P. Bailey. 2006. Leveraging Characteristics of Task Structure to Predict the Cost of Interruption. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '06)*. ACM, New York, NY, USA, 741–750. DOI: http://dx.doi.org/10.1145/1124772.1124882
9. Shamsi T. Iqbal and Brian P. Bailey. 2007. Understanding and Developing Models for Detecting

and Differentiating Breakpoints During Interactive Tasks. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '07)*. ACM, New York, NY, USA, 697–706. DOI: http://dx.doi.org/10.1145/1240624.1240732

10. Shamsi T. Iqbal and Brian P. Bailey. 2010. Oasis: A Framework for Linking Notification Delivery to the Perceptual Structure of Goal-directed Tasks. *ACM Transactions on Computer-Human Interaction* 17, 4, Article 15 (Dec. 2010), 28 pages. DOI: http://dx.doi.org/10.1145/1879831.1879833
11. Jawbone. 2014. Jawbone UP. http://www.jawbone.com/. (2014).
12. Darren Newtson and Gretchen Engquist. 1976. The perceptual organization of ongoing behavior. *Journal of Experimental Social Psychology* 12, 5 (1976), 436–450.
13. Mikio Obuchi, Wataru Sasaki, Tadashi Okoshi, Jin Nakazawa, and Hideyuki Tokuda. 2016. Investigating Interruptibility at Activity Breakpoints using Smartphone Activity Recognition API. In *Adjunct Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing - UbiTtention Workshop 2016*.
14. Tadashi Okoshi, Julian Ramos, Hiroki Nozaki, Jin Nakazawa, Anind K. Dey, and Hideyuki Tokuda. 2015a. Attelia: Reducing User's Cognitive Load due to Interruptive Notifications on Smart Phones. In *Proceedings of IEEE International Conference on Pervasive Computing and Communications 2015 (PerCom '15)*.
15. Tadashi Okoshi, Julian Ramos, Hiroki Nozaki, Jin Nakazawa, Anind K. Dey, and Hideyuki Tokuda. 2015b. Reducing Users' Perceived Mental Effort Due to Interruptive Notifications in Multi-device Mobile Environments. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '15)*. 475–486.
16. Veljko Pejovic and Mirco Musolesi. 2014. InterruptMe : Designing Intelligent Prompting Mechanisms for Pervasive Applications. In *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '14)*. ACM, New York, NY, USA, 395–906. DOI: http://dx.doi.org/10.1145/2493432.2493445
17. Pew Research Center. 2015. Social Media Update 2014. http://www.pewinternet.org/2015/01/09/social-media-update-2014/. (Jan. 2015).
18. Martin Pielot, Tilman Dingler, Jose San Pedro, and Nuria Oliver. 2015. When Attention is Not Scarce - Detecting Boredom from Mobile Phone Usage. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '15)*. 825–836.
19. Herbert A Simon. 1971. Designing organizations for an information-rich world. *Computers, communication, and the public interest* 37 (1971), 40–41.
20. Trendstream Limited. 2015. Multi-Device Owners - GWI TRENDS Q1 2015. https://app.globalwebindex.net/products/report/multi-device-owners-q1-2015. (2015).
21. Yahoo Aviate. 2014. How Android Users Interact with Their Phones. http://yahooaviate.tumblr.com/image/95795838933. (Aug. 2014).