Pseudo-Ambience: Filling the Gap Between Notifications and Continuous Information Displays

Jeffrey R. Blum
Shared Reality Lab
Dept. Electrical & Computer Eng.
McGill University
Montreal, Canada
jeffrey.blum@mail.mcgill.ca

Jeremy R. Cooperstock
Shared Reality Lab
Dept. Electrical & Computer Eng.
McGill University
Montreal, Canada
jer@cim.mcgill.ca

Jessica Cauchard
IDC Herzliya
Herzliya, Israel
jcauchard@idc.ac.il

UbiComp/ISWC'18 Adjunct, October 8–12, 2018, Singapore, Singapore
ACM 978-1-4503-5966-5/18/10.
https://doi.org/10.1145/3267305.3274111

Abstract
A hallmark of ambient displays is their constant presence in the periphery of the user's attention, such as the Ambient Orb[1] that changes color based on the outdoor weather. Users of such a device can explicitly turn their attention to the device if they are curious about the current weather conditions, and also be notified of a change by noticing the light changing abruptly, e.g., as a thunderstorm suddenly begins. However, especially in a mobile context, it can be difficult to have truly continuous indicators that are not fatiguing, annoying, or consuming considerable power. We propose "pseudo-ambient" displays that are not continuous, yet are nearly always accessible since they are triggered at regular intervals. Our contention is that such displays can potentially provide most of the benefits of a fully continuous ambient display, with limited drawbacks. In this work we focus on haptic pseudo-ambient displays. Yet, we believe the same approach can apply to other modalities, such as visual and audio.

Author Keywords
Haptics, Ambient displays, Tactons, Notifications.

ACM Classification Keywords
H.5.2 [User Interfaces]: Haptic I/O

[1] http://www.ambientdevices.com/about/consumer-devices

Introduction & Background

Many people receive a large number of notifications on a daily basis, from their computers, watches, phones [12], and even home appliances such as refrigerators[2]. Receiving all of these notifications can impose costs such as delaying completion of tasks [6], and can cause users to self report symptoms of Attention Deficit Hyperactive Disorder (ADHD) [5]. While some notifications are indeed critical to receive immediately, such as an important phone call or calendar alert, considerable effort has been applied to better manage this torrent of notifications, such as finding more opportune moments in which to deliver them [10, 11].

Another proposed solution is the use of "ambient displays" that provide ongoing, background references to information. Many examples are reviewed by Pousman and Stasko, who organize them around four axes, such as their information capacity and aesthetic emphasis [14]. To provide a flavor of one such system, the "Dangling String" [16] spins faster the more traffic there is on an office computer network. Anyone seeing the string or hearing the motor has a visceral sense of the current network load, and abrupt changes serve as a gentle indicator that something is taking place. However, systems relying on a fixed physical device in the environment have limited potential in a mobile context.

Similarly, audio ambient displays can use a signal such as a beep, where the timing of the sound, as well as the tone, provides information. For example, a pulse oximeter can be set to beep each time a medical patient's heart beats, providing rate and regularity information. In addition, the tone of the beep can change depending on the patient's blood oxygenation (SpO2) rising or falling, which is crucial information during surgery [4]. Although technically periodic, this can effectively be treated as a continuous ambient signal for all practical purposes, since the heart normally beats more than once a second.

Although mobile augmented reality (AR) headsets and wireless audio AR headphones[3] hold out the eventual promise of being able to render ambient information via vision [2] or sound through wearable technology, these are not yet widely deployed. Fortunately, with the advent of smartwatches and fitness trackers, being able to render haptic vibration patterns at any time is now a relatively common use case. In the paper, "Putting Haptics into the Ambience", MacLean argues that the haptic modality is particularly well-suited to delivering ambient, background information [8]. She outlines several key aspects of an ambient display, including, "Ambience lets us follow up. We become gradually aware of a developing situation and can access extra information as needed – possibly because we already have its context." These represent two key features of an ambient display. First, the ongoing indicator we can pay attention to on demand to get current status, and second, the constant signal that our brains can process in the background and alert us when an important event takes place.

There are mixed results with continuous haptic feedback being used for ongoing ambient displays that meet these two goals. Pielot and Oliveira conducted a study showing that a near-threshold ongoing vibration could effectively fade into the background, where participants would notice its absense relatively quickly, yet report that the ongoing vibration was not annoying [13]. However, such a near-threshold vibration is likely of limited use for conveying meaningful information. Nagel et al. created a haptic belt with 13 motors around the waist, with the vibration motor closest to North always vibrating [9]. Four participants

[2] https://www.samsung.com/au/support/home-appliances/i-heard-a-musical-tone-from-my-refrigerator-is-it-normal/

[3] https://developer.bose.com/content/tuning-augmented-reality

wore the belt for six weeks. Although two of the four participants had a change in perception after wearing the belt, the other two did not, and, “the vibration was even perceived as disturbing at times.” The feelabuzz system by Tünnermann et al. directly linked two mobile phones such that the more one was moving, the more intensely the other vibrated, giving two partners an ongoing haptic sense of each-other’s motion [15]. However, this system was not evaluated outside of short-term laboratory studies, so it is unclear whether the ongoing vibration would be acceptable in actual, continuous use.

Ambient systems take advantage of our ability to process continuous information in the background. In contrast, typical notifications rely on a computer algorithm to decide when something “interesting” has occurred, such that the user’s device must interrupt them to let them know they should pay attention. Thus, the notifications and information are pre-filtered before they even reach us. This is not how our senses typically function. In the real world, our senses instead receive constant, unfiltered stimuli, and we rely on our perceptual processing system to sort out when to pay attention. For example, our ears constantly receive the sound around us, but we largely tune it out unless our brain decides that something interesting has occurred (bottom-up integration), or we purposely turn our attention to it based on our conscious goals (top-down integration) [7]. Both bottom-up and top-down integration contribute to the effectiveness of ambient systems.

Given these results and constraints, we are encouraged to explore ambient information display techniques that do not require continuous haptic actuation. Based on preliminary results, we anticipate that achieving both a background visceral awareness as well as the ability to explicitly focus our attention to find out what is happening, can be accomplished without a continuous indicator.

Pseudo-Ambient Displays

Instead of rendering a continuous signal, as with most ambient displays, we instead propose using periodic summaries at frequent, regular intervals. We refer to this approach as “pseudo-ambient” since it does not provide the continuous feedback that a pure ambient system would typically use, yet has the potential to deliver the key benefits of a fully ambient interface. We hypothesize that bottom-up integration does not require a fully continuous signal, and these regular, non-continuous stimuli will be sufficient to trigger attention to informative events. In addition to bottom-up awareness, we expect that a certain level of top-down integration is also possible, albeit with some latency depending on how often the information is rendered. For example, with summaries 10 seconds apart, a user would only have to wait 5 seconds, on average, after turning their attention to the signal, before perceiving a value.

For example, instead of a string continuously twitching based on network activity [16], a user might feel a vibration every 10 seconds where the vibration intensity would represent the network activity level over the previous 10 second interval. Such a system has several potential advantages:

1. Silent periods where there is no vibration, potentially reducing annoyance or distraction, and possibly reducing habituation.
2. The ability to convey multiple parameters in a single message, by rendering multi-part tactons.
3. For a haptic motor, reduced power use since actuation is not continuous.

Compared to a fully ambient system, the pseudo-ambient approach also has several limitations, which could make it unsuitable for particular applications:

1. One cannot “tune in” to the signal at an arbitrary time, but instead must wait for the next iteration.
2. There may be some loss of sensitivity to changes in the signal, since users need to remember the first stimulus, and compare it to the second, which might be rendered significantly after the first. Since memory is flawed, the difference likely needs to be greater than if the change occurred within a continuous signal, in order to be detected.
3. Since the information is summarized, changes that occur within the interval between stimuli will be masked.

A designer will need to choose whether the advantages and disadvantages make sense for their specific application. However, note that by shortening the interval between stimuli, a pseudo-ambient display can more closely approach the real-time nature of a continuously ambient system.

Pseudo-Ambient Display Example

Blum and Cooperstock reported initial results from SenseProxy, a mobile app that uses a Pebble smartwatch to give regular vibrations linked to a partner’s activity [3]. In the initial implementation, the more your partner’s leg moves, the longer a periodic vibration you feel. These small haptic summaries are rendered multiple times each minute, so are frequent, but not continuous. Initial pilot results from daily Likert-scale questionnaires indicate that after a few days of getting used to the system, it is no longer reported as “annoying” or “distracting”, and participants report changing their behaviour based on the signal, demonstrating that it is not simply being ignored.

It is illustrative to contrast this approach with CoupleVibe, created by Bales et al. [1], which used geofencing to give custom vibration patterns whenever a partner entered or departed one of a pre-selected geographic regions (e.g., home, work). In this case, since the events are triggered only when one’s partner enters or leaves a given location, it is a background notification rather than an ambient display. This is certainly an improvement over having to text one’s partner or look at a shared map location to get their location, as the notification cue itself contains valuable information about the location transition. However, if one misses a CoupleVibe cue, then the partner’s current location cannot be divined by orienting one’s attention, since there is no “signal” to which one can tune in. In contrast, waiting a brief period for the next periodic motion summary from an application such as SenseProxy is a minor downside compared to having to get out one’s phone, and it appears that such periodic indicators may effectively fade into the background.

Discussion & Conclusion

Ambient display of information, especially in a mobile context, holds considerable promise for mitigating demands for attention from “smart” phones. However, continuous indicators have the drawback of being potentially annoying themselves, or consuming considerable power, especially for a haptic device. We propose using periodic indicators to provide key ambient benefits including the ability to “tune in” to the signal even though it is not continuous.

Although pilot experiments are promising, current studies underway must be completed to determine if a pseudo-ambient display can indeed succeed at conveying useful

information, yet still fade into the background during long-term, real-world, and mobile use.

Additional work remains to determine how the periodic summaries should be ideally spaced, which likely depends on the particular application.

Last, although we focused on the haptic channel, we see no reason that a pseudo-ambient approach would not be potentially useful with audio or visual ambient systems, although the power-saving benefit may not be as relevant.

Acknowledgements

The authors gratefully acknowledge funding from NSERC, a Mitacs Globalink Research Award, and a McGill Graduate Mobility Award.

REFERENCES

1. Elizabeth Bales, Kevin A Li, and William Griwsold. 2011. CoupleVIBE: Mobile Implicit Communication to Improve Awareness for (Long-Distance) Couples. In *Proc ACM conf Computer supported cooperative work - CSCW '11*. ACM Press, 65. DOI: **http://dx.doi.org/10.1145/1958824.1958835**
2. Mark Billinghurst, Raphaël Grasset, Hartmut Seichter, and Andreas Dünser. 2009. Towards ambient augmented reality with tangible interfaces. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* 5612 LNCS, PART 3 (2009), 387–396. DOI:**http://dx.doi.org/10.1007/978-3-642-02580-8_42**
3. Jeffrey R Blum and Jeremy R Cooperstock. 2016. Expressing Human State via Parameterized Haptic Feedback for Mobile Remote Implicit Communication. In *Proc 7th Augmented Human Intl Conf 2016*. ACM, New York, USA, 41:1—-41:2. DOI: **http://dx.doi.org/10.1145/2875194.2875225**
4. Julian M. Goldman and Frederick A. Robertson. 2004. Pulse-OX Tone Conveys Vital Information. *APSF Newsletter* 19, 2 (2004), 20–23.
5. Kostadin Kushlev, Jason Proulx, and Elizabeth W Dunn. 2016. "Silence Your Phones": Smartphone Notifications Increase Inattention and Hyperactivity Symptoms. In *CHI '16 Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. ACM, 1011–1020. DOI: **http://dx.doi.org/10.1145/2858036.2858359**
6. Luis Leiva, Matthias Bohmer, Sven Gehring, and Antonio Kruger. 2012. Back to the App : The Costs of Mobile Application Interruptions. In *Proceedings of the 14th International Conference on Human-computer Interaction with Mobile Devices and Services*. ACM Press, New York, NY, USA, 291–294. DOI: **http://dx.doi.org/10.1145/2371574.2371617**
7. Emiliano Macaluso, Uta Noppeney, Durk Talsma, and Tiziana Vercillo. 2016. The Curious Incident of Attention in Multisensory Integration : Bottom-up vs . Top-down. (2016), 1–27. DOI:**http://dx.doi.org/10.1163/22134808-00002528**
8. Karon E. Maclean. 2009. Putting Haptics into the Ambience. *IEEE Transactions on Haptics* 2, 3 (jul 2009), 123–135. DOI: **http://dx.doi.org/10.1109/TOH.2009.33**
9. Saskia K Nagel, Christine Carl, Tobias Kringe, Robert Märtin, and Peter König. 2005. Beyond sensory substitution–learning the sixth sense. *Journal of neural engineering* 2, 4 (dec 2005), R13–26. DOI:**http://dx.doi.org/10.1088/1741-2560/2/4/R02**

10. Tadashi Okoshi, Kota Tsubouchi, Masaya Taji, Takanori Ichikawa, and Hideyuki Tokuda. 2017. Attention and engagement-awareness in the wild: A large-scale study with adaptive notifications. *2017 IEEE International Conference on Pervasive Computing and Communications, PerCom 2017* (2017), 100–110. DOI:**http://dx.doi.org/10.1109/PERCOM.2017.7917856**

11. Martin Pielot. 2017. Beyond Interruptibility: Predicting Opportune Moments to Engage Mobile Phone Users. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol. Article* 1, 3 (2017), 1–25. DOI:**http://dx.doi.org/10.1145/3130956**

12. Martin Pielot, Karen Church, and Rodrigo de Oliveira. 2014. An in-situ study of mobile phone notifications. *Proceedings of the 16th international conference on Human-computer interaction with mobile devices & services - MobileHCI '14* (2014), 233–242. DOI:**http://dx.doi.org/10.1145/2628363.2628364**

13. Martin Pielot and Rodrigo de Oliveira. 2013. Peripheral Vibro-Tactile Displays. *Proceedings of the 15th International Conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI'13)* (2013), 1–10. DOI:**http://dx.doi.org/10.1145/2493190.2493197**

14. Zachary Pousman and John Stasko. 2006. A Taxonomy of Ambient Information Systems : Four Patterns of Design. In *Proceedings of the working conference on Advanced visual interfaces*. ACM, 67–74. DOI:**http://dx.doi.org/10.1145/1133265.1133277**

15. René Tünnermann, Christian Leichsenring, and Thomas Hermann. 2014. Direct Tactile Coupling of Mobile Phones with the feelabuzz System. In *Mobile Social Signal Processing*. 74–83. DOI:**http://dx.doi.org/10.1007/978-3-642-54325-8_8**

16. Mark Weiser and John Seely Brown. 1995. Designing Calm Technology. *Powergrid Journal* (1995). **http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.135.9788**