The initial vision of pervasive computing was for it to be 'transparent' to the user. However, the evolution of portable devices has led to a dependency to mobile information and notifications. What should be the balance between transparency and interruptibility?

Introduction

Time; an abstract term to determine one's life, everyone is running from it and some fall victims of its wasting. As Benjamin Franklin once said, "Time is money", given one requires time to produce, to give and to get back, to achieve. That is exactly why companies pay their employees; for their precious time. But are companies getting what they are paying for, or rather a portion of that. With technology ever squeezing its way into our everyday lives, camouflaged in the form of convenient smart devices, bombarding us with information irrelevant to the tasks currently on going, grabbing our attention, breaking our train of thought, and all of this with the aid of notifications; our time has finally been wasted. By 2020, a projection on the number of mobile devices suggests that it will surpass 9.7 billion, which translates to about 8 devices per person, (Bulling, 2016). That means that the number of notifications will only increase in the coming years, with more distractions, therefore more of our time wasted, more money lost. This information suggests that pervasive computing has strayed from the path of transparency and instead moved along the lines of interruptibility and obstruction. People are endlessly trying to avoid wasting their time by multitasking, but mostly fail to deliver on every interruption, and Thomas Friedman accounted this change in behaviour when he claimed that we entered the Age of Interruption, where anyone could be a victim of "interruption overload", (Friedman, 2017). Notifications and interruptions are not all bad, on the other hand. It is always useful to know information as soon as it is published and act accordingly, but the catch here is whether that information is directly connected to the task at hand, or to someone that is dear to us, such as a family member or a close friend. The following sections will walk the reader through the concept of transparency in pervasive computing, the effect of information passing through notifications as well as suggested methods and on-going software developing ideas to control the notion of interruptions when a user is trying hard to concentrate on a given task. Human Computer Interaction (HCI) experts play a protagonist role in the unrolling of further technology, as they design the future of how machines are to communicate with users while making sure that the user is still the main concern.

The transparency dream

Transparent computing was envisioned even before the age of smart devices. In fact, HCI pioneer Mark Weiser and his colleagues at the Palo Alto Research Centre (PARC), discovered the terms ubiquitous and pervasive computing back in 1991, where they describe what the world of computing for the 21st century would look like, with the use of embedded processors and mobile devices, (Weiser, 1991) (Dillon, 2006). They simply refer to the ability of computers to extract and process information, without the need for user interaction to do so, and without showing the user the complexity of calculations and hardware underneath the required task. The term transparent computing has been reprocessed and fine-grained in most recent years, to mean a synonym to cloud computing. Specifically, Zhang et al. suggest that devices will be freed from owning a single interface, and instead make use of any operating system and software immediately available by a cloud service, (Zhang et al., 2017). This entails that devices will not be supplied with massive internal storage to facilitate operating systems or other applications, with current examples such as the Chromebook, which has low storage capacity and uses its network capabilities to "stream" such software, thus hiding what happens in the background from the user. Nonetheless, the notion of transparency seems a valuable asset to decrease distractions and interruptions, and even though ubiquitous computing tries to stay in track, pervasive computing has developed in a way that makes notifications and information passing important to users around the globe.

The effect of notifications

Recently, BBC published various articles on how social media and marketers found a way to keep users on their smartphones continuously. In fact, they called this effect the "attention economy". People responded with serious issues concerning this new economy such as receiving a notification while crossing the street where users naturally tended to their smartphone. Experts in the field stated their concern on this matter as life-threatening both in a physical and a psychological way. Social media applications are feeding off of this behaviour by users and enjoy such situations since they profit from them. That constitutes exactly on how transparency in pervasive technology is absent. BBC named the video they produced "How technology tries to hack our brain", and while watching this video, viewers can directly relate to interviewees' opinions and statements, (BBC, 2017). In summary, companies are targeting the vulnerability of users through attention seeking behaviours, which they have discovered while focusing on the human psychology on rewards.

Various sources of research have shown that companies lose significant amounts of money, given interruptions and distractions of employees in the workplace, which in turn causes a drop in productivity. Based on the words of Silverman, distractions in the workplace have started increasing years ago, and looking at the statistics proving this increase, Figure 1, one can acknowledge that this got out of hand, (Silverman, 2012).

Figure 1: Wall Street Journal interview with Rachel Emma Silverman, (Silverman, 2012).

Of course, the distractions stated in this article involve other workplace distractions such as interruptions from colleagues, other than the effect of notifications. Alternatively, one might even think that this was 7 years earlier; the number of mobile devices was considerably less at that time. Additionally, during another research performed by the Microsoft Research group, results show that it takes 25 minutes for an individual to refocus and regain a train thought, to resume with the task paused by a notification, (Iqbal and Horvitz, 2007). In the same paper, Iqbal and Horvitz, discovered that when distracted by notifications, users did not immediately return to the work they had to attend, but instead continued this procrastination period by launching applications that had nothing to do with the notification that caused this distraction in the first place. This also applies to students, given the amount of available displays in front of them, the amount of work done by them corresponds to just a portion of the time they spent "studying". Following the previous concern, yet another study was found, this one stating how notifications can break the immersion while an individual is watching

a movie, (Rigby et al., 2017). Rigby et al. have proven this hypothesis via experiments conducted with groups of participants. This does not only entail that notifications are a distraction during work or studying, but also a distraction during relaxation, which could potentially harm the mental health of mobile users.

Mental health is a more crucial concern than money, and notifications have the ability to disrupt the psychological state of a human being, without acknowledging the context of the notification itself. Bernazzani, a journalist, compared notifications with the likes of a drug, an addictive substance that one finds difficult to rehabilitate from, (Bernazzani, 2017). She explains that notifications have the same effect, by stimulating the release of dopamine, which is "a neurotransmitter associated with reward-seeking behaviours and addiction", and like drugs, recipients feel great when receiving notifications but exhibit "negative feelings of withdrawal", otherwise. Moreover, she refers to another study including 2000 workers in the UK, which necessitates that push notifications are causing "toxic levels of stress".

Based on the information gathered and mentioned above, notifications are responsible for wasting time, money and impair users' mental state. On the plus side, notifications have the ability to provide necessary and urgent information to recipients, even from senders abroad, information that could potentially lighten up the mood of the recipient and enhance their psychological state. Therefore, a way to filter incoming notifications would produce minimal harm when considering the productivity of individuals. HCI experts are consistently trying to provide mechanisms that would decide the nature of the notification and apply intelligence that would make the nature of the notification to be more acceptable and less distracting.

Controlling the "urge" of notifications

A plethora of notification types exist, each with a separate semantic meaning and each with a different enclosed context. Notifications are triggered on a smart device when new information or a reminder of a schedule arrive to the connected device. They vary from messages from relatives, friends or even strangers, to advertisements from various applications, to emails from work or other advertising agents or to notifications produced by game applications, luring consumers to microtransactions of digital goods. One might wonder who is to blame for the vast amount of notifications received per person per day, or what could be done to avoid the effects of such notifications. A query online will yield numerous articles on how to increase productivity by controlling when to allow notifications to be received. Following are some of the ways advised by experts in the field, for controlling distractions and increase productivity from the point of view of the users. Example articles include "The Age of Interruption Overload" by Ami Ben David, (David, 2017), and "Are Notifications Driving Us Crazy" by Sophia Bernazzani, (Bernazzani, 2017). Both articles, as many others, suggest methods such as disabling notifications while at work, or shutting the device off when the user wants to concentrate so that interruptions from notifications can be avoided without the risk of getting the user's attention. These ways portray the wrong approach towards the main issue; interruption and attention seeking from notifications. They suggest occluding users from their privacy by avoiding the use of their devices; notifications or phone calls from family members or close friends asking for help could be missed, which could potentially endanger the sender. A twist in this research sector was pointed out by a journalist in collaboration with psychologist Dr. Eyal Peer, (Thompson, 2017). They discovered that a group of participants that were on high-alert of receiving notifications during a task, interpreted the imminent arrival of notifications as a deadline. This made the On-high alert group be more productive by adapting their brain so as to be ready to be distracted. Alternatively, a subtler technique could, eventually, hide certain notifications depending on the user's current activity and/or preferences. Here is where HCI experts and mobile application developers are dependent upon, to construct a mechanism that would control the delivery of notifications.

Learning the users

Users should not be forced to adapt to receiving notifications, but instead the applications sending the notifications or information should account for the users' needs and preferences. The parameters

a developer must thoroughly examine when producing an application that uses push notifications should be where, when and why to send a notification. A valid example of a good notification would be: "A user wakes up and looks at the clock. The user must attend a lecture at a certain time. While on the bus to the University campus, a notification pops up informing the user that the lecture will start in 10 minutes, so the user is satisfied with this information based on location (bus) and time (before lecture)". Receiving the same notification during the lecture while in the theatre would be the case of a bad notification as it would be produced untimely (during lecture) and at the wrong location (in lecture theatre), causing unwanted disruption to the user and fellow colleagues.

An on-going research, studies the way notification recipients behave at the time of notification arrival, as well as given the notification alert, thus the application source of the notification, how they tend to it or sense its context, (Chang et al., 2017). Chang et al. further implicates the significance of the psychology sector when deciding on the frequency and scheduling of notification sending by developers and/or marketers. Moreover, a method usually used to assess such experiments, consisting of human behaviour and studying their daily routines, feelings and actions, is called the Experience Sampling Method (ESM), (Larson and Csikszentmihalyi, 2014). Using ESM, Chen et al., constructed an experiment to further understand how participants react during interruption from their mobile device based on who triggered the interruption in the first place, (Chen et al., 2017). The study is yet to finalise, but their initial hypothesis based on the information they have by now, shows that users are more receptive to notifications from relatives through Computer Mediated Communication (CMC), while measuring the interpersonal relationship strength between receiver and sender, through the use of questionnaires and interaction logs.

The "where" and "when" aspect of notification arrival could be examined by various ways. An efficient way for capturing the perfect timing and place was suggested by Lovett et al., even though their research had nothing to do with notifications, (Lovett and O'Neill, 2012). Their research stemmed upon the information retrieval from mobile devices using Global Positioning System (GPS), of certain users. They used this information to record the users' semantically meaningful places and the transition between such places, therefore indicating a way to allow for preference mining of users' data for applications to send notifications in the right place at the right time.

Controlling notifications: Finding the balance between transparency and interruptibility

Coupling the knowledge gained from the papers mentioned above and the power of machine learning and Artificial Intelligence (AI), notification sending applications, or the device itself, can be utilised to better understand the preferences of the users, gathering data on their daily routines, work schedule and calendar entries, thus achieving a good balance between transparency and interruptibility. Fortunately, several developers have, already, revised their mechanisms and adjusted it appropriately. Nonetheless, we still get bombarded with numerous of unpleasant notifications daily. With the aid of the papers to follow, two software solutions will be proposed that essentially capture the users' needs and define a layout that provides the desired balance.

Firstly, the introduction of the PrefMiner application is imminent. Mehrotra et al. came up with a solution that is not only completely efficient, but also gives full control to users when it comes to notifications, (Mehrotra, Hendley and Musolesi, 2016). They explored the various data mining techniques such with criteria such as the ones mentioned in the previous section to produce an application that has the capabilities to configure a set of rules which are made "transparent to users so that they can check their appropriateness". In other words, PrefMiner records the activity of the users, then proceeds with mining for consistencies in the data, such as ignoring certain notifications which are uninteresting or not tapping on the notification because of its untimely manner, for a training period. Once this period is over, the application devises a set of rules on when, where and for how long a notification is to be shown. The rules are to be accepted by the user, and based on these rules, the notification pattern will match the user's preferences. This application is currently available through the Google Play Store and screenshots of the application can be seen in Figure 2.
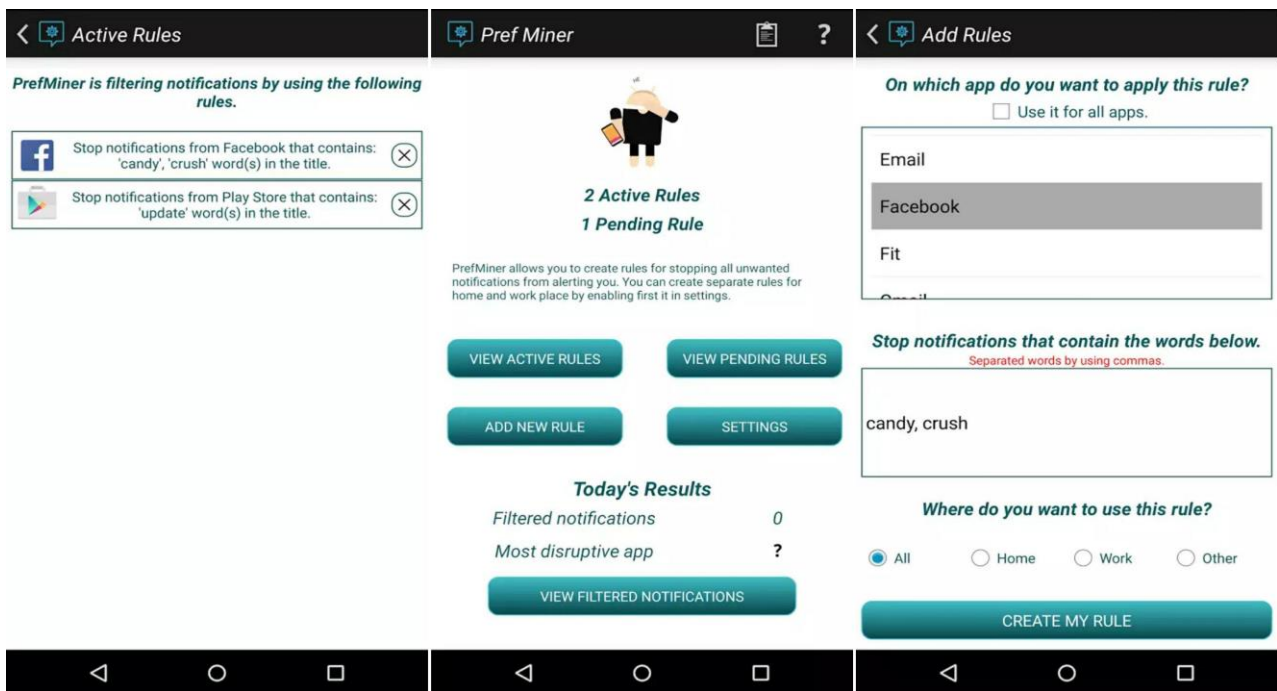
Figure 2: Screenshots showing the various capabilities offered by PrefMiner application, (Mehrotra, Hendley and Musolesi, 2016).

On the other hand, a different method for controlling, not the actual notification but, the appearance of notification to capture a certain degree of attention was proposed, (McCrickard and Chewar, 2003). Even though this method is regarding notifications in the workplace computers while the user is concentrating on a task, this could be extended to work for mobile devices as well. McCrickard and Chewar explored how different attention-centric notifications contribute towards interruption in the workplace based on the notification's size, colour and animation, thus propose a way to adapt information delivery to avoid overloading the user. It makes sense when one thinks about this scenario. The distraction from a smaller size notification would be less as the user would know that it is not relevant at the time. Additionally, the operating system could be embedded with an extra layer that could check the eye-gaze of the user, where on the screen the user is currently looking. With this information, the device could pop a notification away from where the user is gazing to avoid unnecessary distraction.

Conclusion

The dream of transparency might have been postponed due to the Age of Interruption, but researchers are working consistently to avoid having issues such as the various examples mentioned previously, with the most important being time wasting and mental health related. In order for developers to come up with a technique to make pervasive computing transparent, they must examine the numerous mechanisms there exist that could potentially extract enough data to learn from the users' preferences on when, where and why they would be shown a notification. Certain currently existing solutions exist that aid to the chase of this transparency dream such as PrefMiner, but they still depend largely on recording data by users that could eventually lead to the rising of other security and privacy issues. Nonetheless, people are aware of this lack of transparency and are continuously trying to construct efficient applications and software to save the fate of the future.

"The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it. "

- Mark Weiser, 1991

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