Contextual Experience Sampling of Mobile Application Micro-Usage

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ABSTRACT
Research suggests smartphone users face "application overload", but literature lacks an in-depth investigation of how users manage their time on smartphones. In a 3-week study we collected smartphone application usage patterns from 21 participants to study how they manage their time interacting with the device. We identified events we term *application micro-usage*: brief bursts of interaction with applications. While this practice has been reported before, it has not been investigated in terms of the context in which it occurs (*e.g.*, location, time, trigger and social context). In a 2-week follow-up study with 15 participants, we captured participants' context while micro-using, with a mobile experience sampling method (ESM) and weekly interviews. Our results show that about approximately 40% of application launches last less than 15 seconds and happen most frequently when the user is at home and alone. We further discuss the context, taxonomy and implications of application micro-usage in our field. We conclude with a brief reflection on the relevance of short-term interaction observations for other domains beyond mobile phones.

Author Keywords
Context-Awareness; Mobile Automated Logging; Design Implications.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Mobile phones have evolved from simple communication devices into multifunctional information and communication devices [4]. Today, application stores allow for the ad-hoc installation of applications, extending and customizing mobile phones' functionality with games, navigation, social networking, news and music among others [13]. With the increase in functionality and diversity of use, applications on mobile phones are accessed frequently: constantly checking for updates on social networks and email has become a part of our daily routine. As continuous updates from several sources can be disruptive, mobile operating systems offer several techniques to keep the user updated without disturbing their mobile usage flow and mitigating information overload [24]. For example, Android and iOS use background notifications to alert the user of application events and messages. Android also provides application status widgets for glanceable information as a secondary interface.

Yan *et al*. [29] reported that a lot of mobile device usage is brief and competes for human attention with the real world. They found that 50% of mobile phone engagement (the time period between the user unlocking and relocking the device) lasts less than 30 seconds. With more granularity, here we explore whether individual mobile applications are also used for short periods of time, from application launch to exit (*i.e.*, application session). We want to uncover the taxonomy of the applications that encourage brief bursts of usage (henceforth *micro-usage*) and the context in which micro-usage is more likely to take place. We approach mobile phone usage as a particular manifestation of HCI in daily life [2].

Our key contributions then, lie not within prescribing design guidelines for the seamless integration of technologies into daily life, but instead by describing daily life with mobile technologies as a fragmented type of interaction. By exploring the situations around this practice and uncovering possible reasons why some applications are used so briefly, we aim to contribute to a broader understanding of mobile phone usage practices that in turn will inform the design of mobile applications and mobile technologies in the future.

RELATED WORK
The existence of brief bursts of application usage on smartphones has been reported in previous literature, but typically as a secondary or inadvertent finding. Falaki *et al*.'s [12] study on diversity in smartphone battery usage reported finding short-term application usage (10-250 seconds) among their participants. Similarly, Böhmer *et al*.'s [4] large-scale study on mobile application usage revealed that mobile phone owners use their device for an average of 59 minutes daily, with the average application session lasting 72 seconds.

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Considering routine and focusing on mobile phone users' habits, Oulasvirta *et al*. [24] suggest that mobile phones are "habit-forming" devices. Particularly closely related to our work is the "checking habit: brief, repetitive inspection of dynamic content quickly accessible on the device." This habit was found to comprise a large part of mobile phone usage. We believe that the checking habit is one of the behavioral characteristics that leads to mobile application micro-usage, and that it is manifested as short bursts of interaction with applications.

Interestingly, micro-use of applications is not exclusively mobile; multitasking and the management of multiple tasks occur on desktop computers as well [8, 15]. These studies found that desktop users were focused on goals but within these goals they embedded a set of secondary goals that were completed through multitasking. This observation led to the technical advances within multitasking and the options that almost all multipurpose technical devices support: being able to seamlessly switch from one application (and often from one task) to another.

Multitasking is not without consequences for use practices and users' overall wellbeing. For example, Mark *et al*. [21] reported that while workers compensate for interruptions to their work, these interruptions also mean users experience "a higher workload, more stress, higher frustration, more time pressure, and effort." Much of this literature, however, focuses on external interruption, but many interruptions within workflows are in fact "self-inflicted" [16], which multitasking also alludes to.

Here we argue that multitasking is an inherent characteristic of technology use practices and that micro-usage is yet another consequence of our mobile multitasking devices being available throughout the day. But where desktop use often takes place over longer stretches of time (hours, often full work days), mobile phone use is intermittent. So albeit related, we seek to extend the work on interruptions and multitasking to mobile phone use. Here we address micro-usage of mobile phone applications by exploring its characteristics and discussing implications of this practice.

We conducted two field studies to explore micro-usage. Study 1 sought to understand how users spend time interacting with their mobile phones. Subsequently, we wanted to unobtrusively gain enough understanding in order to design and build a mobile Experience Sampling Method (ESM) tool to collect *in situ* real-time qualitative data on application micro-usage while minimizing user burden and annoyance. In Study 2 we deployed the tool on participants' phones to understand the situational factors (*e.g.,* place, with whom) and motivations for mobile application micro-usage. We recruited participants by affixing posters, advertising on a local mailing list and through Facebook. We took extra care in selecting participants with diverse backgrounds as to reduce the risk of selection bias and for a more reliable representation of a wider population.

STUDY 1: MOBILE APPLICATION USAGE

We recruited 21 participants (17 male, 4 female), aged between 22 and 40, with a range of technical skills and professions, and owning an Android mobile phone (Android 2.3+). The study lasted for 3 weeks and participants were compensated with two movie tickets. We conducted a semi-structured interview prior to the study to collect their perception of their application usage behavior.

We designed a logging tool using AWARE [1], deployed on participants' own devices as a background application. Both the Android operating system and AWARE are event-driven so collecting data did not have a noticeable impact on device usability or battery usage. Our logging tool collected:

- *Application session*: when, for how long and which applications were active and visible to the user.
- *Screen usage*: current screen status (on/off) and for how long it was on/off.

The application session listens to events about changes in which applications are active, provided by the Accessibility Services APIs, thus capturing interaction with the applications. The screen usage captures every time the users interact with the mobile phone, by listening to screen on/off events sent by the operating system.

Participants' Perceptions of Mobile Application Usage

In our first interview before deploying the logging tool, we discussed with participants which applications they use the most, and when during the day and week. Not surprising, all participants used their mobile phones for *more* than just calls and messages, mentioning using email, navigation (*e.g.*, Google Maps), browser, games and social applications (*e.g.,* Facebook) *intermittently* throughout the day. More interestingly, some revealed following some *routine*: they would use mobile applications more often *indoors* than outdoors, more *during the day* than evening. However, the use of mobile applications "would depend" on *where* and *with whom* they were at a *given time*.

Elusive Nature of Micro-Usage

Our interviews emphasized the challenge in collecting reliable data on application micro-usage. Particularly, they highlight the need to *capture micro-usage as it happens*, to understand the context in which it occurs. Our first step towards gaining this understanding was to establish an empirical time frame for exploring micro-usage. This is a temporal threshold, below which we choose to flag an application session as micro-usage, based on our data analysis. An *application session* begins when an application is launched, and ends *when the screen is turned off* or the user *exits the application*. Figure 1 shows a probability distribution function of application usage in Study 1. Specifically it shows the duration of sessions for "All apps" across all participants, in relationship with the top-10 most used applications. We used Jenks optimization method [18] to determine the best arrangement of our data values into two clusters. We found a natural break in the data at approximately the 15-second mark indicated with the

dashed vertical line, dividing the application sessions' probability into two categories: *micro-used* below the 15 seconds time frame (41.5% cumulative probability) and not micro-used when above (58.5%).

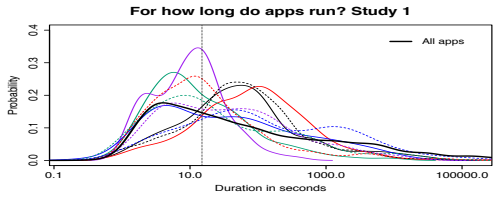


Figure 1: Probability of application session length in Study 1, across all users, regarding the top-10 applications (15-second threshold for micro-usage - dashed vertical line).

Yan *et al.* [29] had a similar number of participants (25) as our Study 1, and their application analysis of these participants reported that 50% of application usage is under 30 seconds and 90% under 4 minutes. Our results were 61% and 78%, respectively. Böhmer *et al.* [4] with a larger sample further shortens the application sessions: 49.9% of all recorded application sessions were *under* 5 seconds, while the average application session lasted about 70 seconds.

To contextualize *micro-usage* behavior in terms of mobile application usage, we conducted a follow-up interview. Participants indicated that checking notifications for email or other notifications took them less than "a minute". They noted that if the notifications were not interesting or if the emails were not urgent, they would quickly dismiss the application. This analysis led us to adopt *15 seconds as an upper threshold to further investigate micro-usage*: it is brief, yet accounts for 41.5% of the application sessions we observed for our participants in Study 1.

Note that 15 seconds is not a definite threshold but an approximate boundary within which we decided to explore micro-usage behavior. Therefore, we are interested in investigating application usage that lasts *up to* 15 seconds, including for example application sessions that last just 1, 5 or 10 seconds.

Usage or Micro-Usage

The most frequently used applications across all users in Study 1 were Facebook, Google Mail and the browser. More interestingly, we note that *micro-usage does not occur equally* with all the applications (*e.g.*, Facebook (22.4%); Google Mail (52.0%) micro-used), in Figure 2.

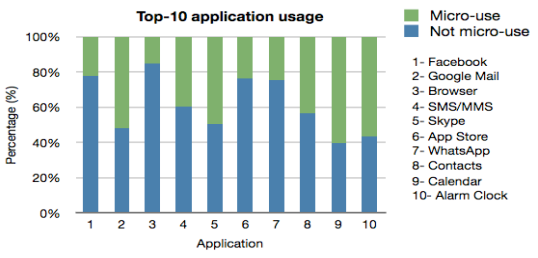


Figure 2: The 10 most frequently used applications in Study 1.

The fact that all applications may at some point be micro-used is not surprising because mobile phones are increasingly used to fill an *undetermined* amount of time. Various applications were used between scheduled activities such as traveling from work to home, "killing time" on games [10] or very briefly while waiting for the elevator or for someone.

Summary of results from Study 1

Our results indicate a cumulative probability of 41.5% of application micro-usage across all participants and applications. However, how much micro-usage occurs *depends on the application*; of the most frequently used applications, some were micro-used as low as 15% (*e.g.*, Browser) while others were as high as 60% (*e.g.*, Calendar) (see Figure 2). As the participants could use *any application* at any given *time* and at any given *location*, our next step was to gain an understanding of the situations in which application micro-usage occurs.

Since we are most interested in instances when our participants interact with their devices for brief periods of time, our critical requirement was to develop a reliable data-collection mechanism that allowed participants to respond quickly. The interview feedback regarding application usage helped inform our data collection strategy for the follow-up study and deciding what questions to ask. From our initial interviews on Study 1, participants revealed that using mobile applications "would depend" on *where* and *with whom* they were at a *given time*. This motivated us to include *location* and *social* context into our micro-usage probe. We discuss this next.

STUDY 2: UNDERSTANDING MICRO-USAGE

We conducted a 2-week follow-up study with a *different* set of 15 participants (gender: 9 male, 6 female; age: 23-50), with varied professions and technical skills, to understand the context of use and the intentions of the user when micro-usage takes place. Previous studies have used diaries [6, 24, 28] and mobile ESM [7, 14] to capture qualitative data on mobile phone usage. Micro-usage is extremely brief and frequent, and thus any reliance on recall methods is likely to be subject to response bias or unreliable recall. Asking participants to reflect on a brief event that happened a few hours or days in the past is likely to result in unreliable data. Therefore, we used mobile ESM to capture *intermittent* micro-usage as it occurs on the device, wherever the user is.

We extended Study 1's software to display a short ESM questionnaire:

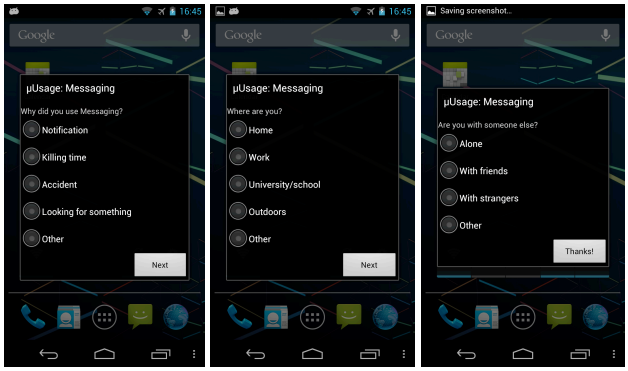
- *Micro-Usage ESM dialog*: automatically captured *what* application was micro-used and *when*; asked the user *what* triggered the micro-usage; *where* was the user; and *who* was with the user.

We identified instances of micro-usage by measuring the duration of application sessions in runtime. If an application session lasted *less than* 15 seconds, a micro-usage ESM

dialog was scheduled (See Mobile ESM Scheduling section for details).

Mobile ESM Design

The software adopts a 3-step approach in the design of the ESM task for reporting on different context categories for micro-usage. Dey *et al.*'s [10] context categories were used to aggregate the questions we asked (*i.e.*, *Location* (where), *Identity* (who), *Activity* (what), *Time* (when)), and the *Trigger* (why) for the particular micro-usage instance. More importantly, we explicitly chose to minimize the amount of free-text typing required of participants, to minimize their burden (Figure 3). We used the results from our Study 1 interviews to specify the answers to questions, as follows:



a) **b)** **c)**

Figure 3: Mobile ESM shown when micro-usage is detected.

- Step 1 (Figure 3a) *Activity*, *Time* and *Trigger* contexts: A group of radio-buttons displayed: "Notification"; "Killing time"; "Accident"; "Looking for something"; and "Other." These categories reflect Study 1 participants' feedback on perceived mobile phone application usage. "Killing time" refers to instances in which participants used the phone as an entertainment device. "Looking for something" refers to when the participants used the devices to search for information, such as navigation instructions or the Internet, and "Notifications" to instances when the device indicates new information is available (*e.g.*, new email has arrived). Lastly, we included "Accident" for cases where participants launched an application by mistake, and "Other" for other reasons we could not foresee but still wished to capture. The "Other" option would create a modal textbox above the first question, asking the user to be more specific. The current time and application name is automatically captured by the ESMs.
- Step 2 (Figure 3b) *Location* context: A group of radio-buttons displayed: "Home"; "Work"; "University/ School"; "Outdoors"; and "Other." The participants provided the most common locations in which they used mobile phone applications. We clustered the locations into categories that summarize participants' answers.
- Step 3 (Figure 3c) *Identity* context: A group of radio-buttons displayed: "Alone"; "With friends"; "With strangers"; and "Other." Once again, we included "Other" to capture other social contexts.

Further design decisions pertain to the quality of the data:

- The tool should only ask about the *most recent* detected instance of micro-usage, not queue up a series of ESM requests, particularly in the case of bursts of short application sessions.
- The ESM request is only relevant at a specific time, for a specific instance of micro-usage. If the user does not respond within 3 minutes, the ESM is automatically dismissed.
- The user should be able to dismiss an ESM request, by explicitly closing the ESM questionnaire (*e.g.*, pressing the "Back" or the "Home" button on Android devices).
- If the user micro-used an application but immediately turned the screen off, the ESM tool would *vibrate* the mobile phone to prompt the user to answer the ESM.
- The ESM questions did not have default answers to reduce response bias.

Mobile ESM Scheduling

An important issue to consider is the frequency of issuing ESMs. In their work, Consolvo & Walker used randomly triggered ESMs spaced equally during the day [7]. They suggest issuing up to 10 ESMs per day to each participant to keep participant burden manageable. They also advise that proper scheduling requires a flexible and adaptive approach to issuing ESMs, otherwise there is a high risk of missing important events.

We conducted a simulation using Study 1's data and found that if we issued an ESM every time micro-usage took place, participants would have to complete more than 20 ESMs per day, posing a high burden on participants in Study 2. As a compromise, we set a cap of 10 daily ESMs as recommended by [7], and the system considered triggering ESMs only if an application was used for 15 seconds or less. To ensure that the maximum of 10 ESMs per day were distributed throughout the day, as opposed to all being issued successively in the morning and none in the evening, we decided to space out the ESMs by introducing a timeout after each time an ESM was answered. We set this timeout to 15 minutes, such that no two ESMs would be issued within 15 minutes of each other. This value was chosen after analyzing how participants in Study 1 locked and unlocked their phone using a cumulative probability function (CDF) on our screen usage data. Specifically, we looked at how long the screen remains off once it has been turned off (Figure 4).

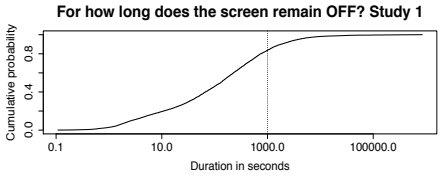


Figure 4: Cumulative probability of screen off duration.

If the screen is on, it is very likely the user is using the mobile phone. Therefore, it makes sense to consider the instances of time when the screen is off to infer periods of inactivity from the user. Using the Jenks optimization [18] we identified a natural break in the data at the 1000-second mark (vertical line), which is approximately 15 minutes, and simulation using Study 1's data confirmed that the cap of 10 ESMs per day was not crossed. This means that participants were relatively more likely to turn their screen on after 15 minutes of inactivity, and therefore this posed as a good threshold for issuing a new ESM if micro-usage occurred.

Recording Micro-usage

Our examination of the results from Study 2 confirmed that the micro-usage followed a similar pattern to Study 1, despite the different set of participants. We analyzed our data to identify any potential links between demographics (*e.g.*, age, gender, profession) and micro-usage: we found no significant effect of age (χ^2=0.78, df=2, p=0.677) or gender (χ^2=0.18, df=1, p=0.672) on micro-usage frequency, for each study independently (Table 1).

Study 1					Study 2				
#	Gender	Age	Profession	Micro-usage (%)	#	Gender	Age	Profession	Micro-usage (%)
1	male	27	Student	20,66	1	male	34	Researcher	60,15
2	male	30	Unemployed	53,29	2	male	28	Student	16,15
3	male	40	Senior Researcher	56,09	3	male	30	Researcher	44,79
4	male	37	Senior Researcher	66,26	4	female	50	Development Manager	12,80
5	male	34	Researcher	25,09	5	male	32	Student / Waiter	44,40
6	male	29	Researcher	24,23	6	male	49	Project manager	55,5
7	female	28	Secretary	49,79	7	male	27	Designer	25,83
8	female	37	Secretary	64,48	8	male	30	Student	66,00
9	male	26	Networks Researcher	31,68	9	male	37	HW & SW Engineer	25,93
10	male	28	Networks Researcher	59,64	10	female	23	Student	52,50
11	male	27	Networks Researcher	40,84	11	female	34	Biologist	48,36
12	male	25	Student	19,66	12	male	27	Student	65,63
13	male	24	Civil Engineer	40,64	13	female	31	Chemist	22,45
14	female	25	Accountant	35,06	14	female	28	Student	40,23
15	male	23	Student	20,61	15	female	42	Researcher	27,1
16	male	29	Student	46,58					
17	female	22	Biology Researcher	42,89					
18	male	32	Robotics Researcher	26,07					
19	male	36	Researcher	65,25					
20	male	30	Researcher	27,35					
21	male	29	Researcher	55,32					

Table 1: Participants' demographic information for both studies. Highlighted in grey are the selected participants for interview in Study 2.

Similarly to Study 1, the cumulative probability of micro-usage for all application instances across all participants is 36% at the 15-second threshold, and we found that certain applications exhibit a higher likelihood of micro-usage than others. Application micro-use also varied between participants, with an average of 41.5% (min=19.7%; max=66.3%; SD=16.1%).

Our mobile ESM was able to capture micro-usage reliably throughout the day (with a maximum limit of 10 ESM per day, per participant)(Figure 5). In total, we detected 14,229 micro-use instances. The logging tool scheduled 762 ESMs questionnaires and recorded 642 complete ESM responses over the 14 days from our 15 participants. We did not consider incomplete, dismissed and expired ESMs in our data analysis. 642 ESM responses correspond to an average of 3 complete ESM answers per participant, per day, and a 76% response rate.

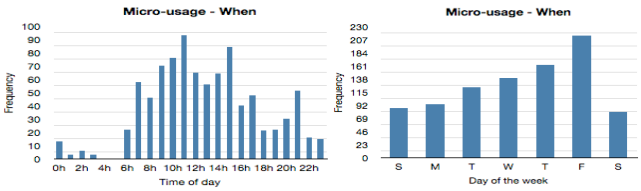


Figure 5: Distribution of time context for micro-usage.

Micro-Usage Context

The most micro-used application categories in Study 2 were Email (40%), instant messaging (*i.e.,* Google Talk, Skype, WhatsApp) (21%) and text messaging (16%)(Figure 6, top left).

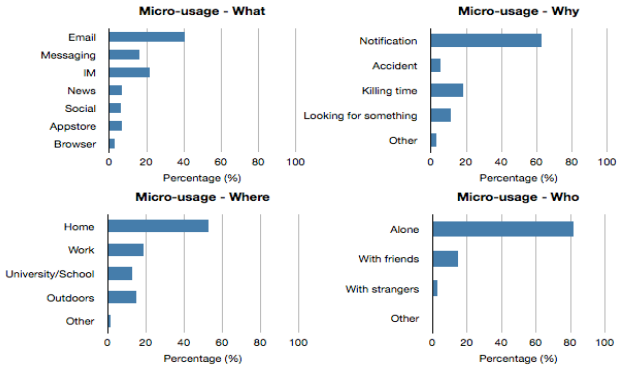


Figure 6: Micro-usage incidence depending on different contexts.

The most frequent triggers for micro-usage were notifications (62%), "Killing time" (18%) and "Looking for something" (11%). Participants micro-used applications by accident 6% of the time. When denoting the "Other" category, 2 participants indicated using their mobile phone for making a translation and writing a message (3%)(Figure 6, top right).

We did not capture location automatically (*e.g.*, using GPS or network triangulation) with our software, to minimize power consumption on the mobile phone. Instead, we asked participants to indicate a coarse-grained category of location. Mobile phones spend more time at home than anywhere else, including time during the night [25], and not surprisingly, our results indicate that micro-usage happens more at home than in other locations (53% *vs*. 47%, respectively)(Figure 6, bottom left). Similar to [11], our participants reported that, when at home, they quickly check their devices for new emails, calls, or messages, regardless of notifications. The results show that micro-usage is most likely to take place when the user is alone (82%). We also found that it happens least often amongst strangers (Figure 6, bottom right).

A chi-squared analysis showed that there was a significant relationship between the trigger of micro-usage (why) and the location where this happened (where) (χ^2=107.8, df=16, p<0.001)(Figure 7).

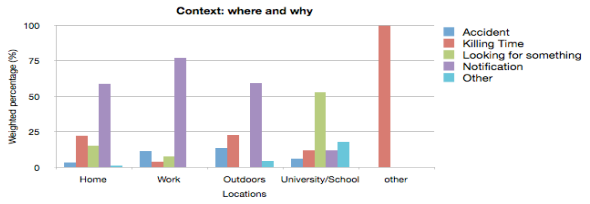


Figure 7: Weighted percentages of micro-usage context by trigger and location context.

Specifically, we found that *system-initiated* micro-usage takes place at home, work or outdoors, mostly due to notifications, whereas *user-initiated* micro-usage happens more frequently at the university, school and other locations. We also found a significant relationship between the location where micro-usage took place (where) and the social context (who) (χ^2=114.2, df=12, p<0.001) (Figure 8).

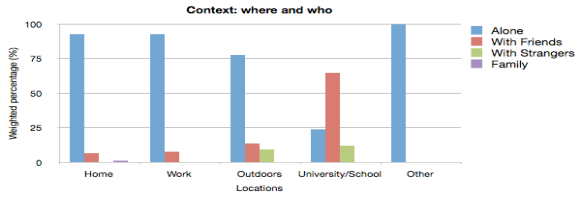


Figure 8: Weighted percentages of micro-usage context by location and social context.

Despite micro-use happening more often at home (Figure 6, bottom left), Figure 8 suggests that application micro-use happens in other locations too, especially when the user is alone. Our participants often reported using their devices to "spend time" or reach out to others, while commuting and at random locations. Less frequently however, micro-use happens too with friends and co-workers. Participants reported showcasing emails, pictures and game high-scores on the phone to each other. We also found a significant relationship between the triggers for micro-usage (why) and the social context (who) (χ^2=30.9, df=12, p=0.002) (Figure 9).

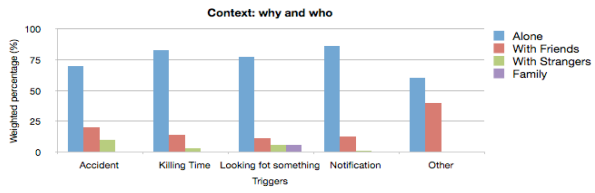


Figure 9: Weighted percentages of micro-usage context by trigger and social context.

Figure 9 further iterates that *user-initiated* micro-use is often to "kill time", while *system-initiated* micro-use is triggered by a notification, especially if the user is alone.

"Other" Context

Please note that the ESM allowed users to input text when an appropriate choice was not provided. We have combined this input text into an "Other" category.) As seen in Figure 6, there were few instances where text input was used. We can only hypothesize about whether our participants purposefully avoided entering time-consuming answers [7], or whether the provided answer-choices were sufficient to capture their micro-usage context. However, as the number of "other" instances is so small, it is *not* statistically significant context, and has not been included in our discussion and conclusions.

Participant Views on Micro-Usage

At the end of Study 2, we interviewed 9 of our Study 2 participants, all those who had exhibited above 40% (min=40.2%; max=66.0%; mean=53.1%; SD=9.4%) of application micro-usage (Table 1 – highlighted in grey). In other words, these participants closed an application within 15 seconds of launching it for at least 4 out of 10 times they used it.

Since we had purposely omitted the true nature of our study to our participants, as an application usage study, we began by introducing micro-usage. Participants were presented with a data analysis on their micro-usage behavior (as in Figure 2). We started the discussion with whether they were aware of such behavior and if they had any thoughts about it. All participants reported that they *never* recognized their micro-usage behavior before. We further inquired about their thoughts on micro-usage happening most often when they are alone, except when with friends at University/School. All participants acknowledged that they often used their mobile phone when alone, as the device is theirs.

"Mostly alone, yes. It is my phone. People check for something, new email, Facebook, then they don't find anything and then they jump to another application." – P5

Also using their device while with others is regarded as normal, especially when the device is used for *information retrieval*.

"The world changed… people before got together and discussed and now they use their phones, on the table or in front of them all the time. Maybe to text or just to show something to others…" – P6

Participants attributed their micro-usage to *system-initiated* triggers (*i.e.,* notifications) or *user-initiated* (*i.e.*, opening an application by mistake, quickly checking email for something new or the calendar, or spending time). In the majority of cases however, participants believed that micro-usage happened simply because *15 seconds was enough* for them to get the information they required.

"I use the phone to control what I need to do and I check it regularly. Also when waiting for my kids, I use my phone to browse the web and play a game or video…" – P8

Interestingly, 4 out of the 9 participants noted that they frequently and swiftly checked specific applications throughout the day, most often those social in nature (*e.g.,* Facebook, Google+, Twitter or email).

"Google+… I don't contribute there much. I go browse what the notification was and close it. I use Facebook more." – P8

We questioned if notifications were the reason why they used an application and what they thought about them.

Participants had split opinions regarding notifications, with 5 out of the 9 participants considering them as an essential or important feature, while others saw notifications as a nuisance.

"I use it [Facebook] on Chrome. I don't like the application because it keeps buzzing" – P5

"I check the notification bar […] I check the email, calendar, and messages. I don't spend time there." – P8

Participants did not associate notifications with the reason for using a particular application, but regarded it as a part of an application, *i.e.*, participants *expect* notifications from specific applications, such as a notification from a message, or an update in Facebook.

"I send a text there [Google Talk] and they reply when they can. It's not urgent but it's like saying Hi!" – P8

Surprisingly, 2 participants associated not having notifications as distressing or an indicator of connectivity malfunction.

"They [notifications] should be there. If there is nothing there, I would assume something is wrong with my connection." – P8

We concluded the interview with the participants' thoughts on how they felt about their mobile phone usage in the context of micro-usage. Participants repetitively used "to check" their phones as an explanation for their micro-usage behavior, thus confirming our initial belief that the previously reported "checking habit" [24] is often manifested as micro-usage.

"I can't imagine not being able to check… […], I can't know what is happening, it's not good…" – P6

ANALYSIS & DISCUSSION

The purpose of this paper is to highlight mobile application micro-usage as an important practice, and to investigate the context in which it occurs in order to suggest why it occurs and to identify what consequences it has. Our work also relates to the more general topic of multitasking and interruptions. Previous investigations of mobile application usage [4, 12, 24, 29] reported that the bulk of our interactions are brief, but have not further investigated the reasons *why* this is the case, *how probable it is* and the *context* in which it manifests.

In Study 1, we captured micro-usage behavior as reliably as possible without intervention as to better study this phenomenon. In Study 2, we intervened with ESMs. Our ESMs did not affect *detecting* the *context* of application micro-usage, allowing us to better understand it.

Micro-Usage Timescale

Our findings indicate that micro-usage is indeed a prevalent practice with mobile phones. In line with previous studies [29], we showed that a lot of application launches are either terminated or dismissed *within* 15 seconds (Figure 1) (cumulative probability of 41.5% and 36%, in Study 1 and 2 respectively). The probability of micro-usage is different between our studies due to different application usage patterns and participant samples.

The heavily skewed distribution in our data encouraged us to consider micro-usage as "individual application use that lasts *up to* 15 seconds" for our micro-usage software and our data analysis. Please note *micro-usage should not be treated as having a rigid time frame of 15 seconds*, but for our participants and study, this threshold provided a lens for investigating micro-usage behavior. An application usage session depends on several performance factors that are challenging to consider beforehand:

- *Device*: time to load the application (*e.g.*, CPU, memory, operating system);
- *Network*: time to load network content (*e.g.*, Facebook, browser);
- *User*: time spent on the keyboard, clicking, reading content.

More importantly, our studies and interviews are evidence that *15 seconds is enough for many uses of an application*, such as checking and dismissing a notification, quickly responding to a message or searching for something in the mobile phone browser. As such, our work provides the first study to specifically study *micro-usage in-situ and in real-time.* The exact figure of 15 seconds is defined based on our collected data, and future studies will likely broaden or narrow it. In our own study, this time frame allowed us to identify micro-usage, characterize it and understand it.

Context of Micro-Usage

Our results from Study 2 provide evidence regarding the context in which micro-usage occurs. The most important question is *why* does micro-usage occur, in other words, what triggers micro-usage. Micro-usage triggers are *system-initiated* for application usage sessions initiated by notifications, otherwise as *user-initiated*, *i.e.*, due to users' natural application usage. It is apparent that a substantial amount of micro-usage was not *user-initiated* but *system-initiated*: participants attributed 62% of micro-usage instances to notifications (Figure 6, top right). This raises a further question regarding micro-usage: is it a 'naturally-occurring' behavior or is it mainly system driven? Since most applications, such as Facebook and email, let the user configure notification alerts, it is notable that the users in these cases had not specifically turned notifications off, and on some level found them useful.

Our interviews provide insight into *user-initiated* micro-use. Mobile phone use has changed and we use them as replacements for watches, cameras, game consoles, just to name a few. Mobile phones are 'companions' in moments of potential 'boredom' and fill in the gaps when waiting or on a bus, for example. By far the most popular place where micro-usage occurred was at "home" (Figure 6, bottom left) and "alone" (Figure 6, bottom right). User-initiated micro-use is *unique* to the user and is *diverse*, as expected. However, a distinct characteristic of our data was that the top-10 most frequently used and micro-used applications, for both studies, were for people's *social connections* (See Figure 2 and Figure 6 - top left).

This finding suggests that applications designed to help us remain connected and "keep in touch" are most likely to be used and also micro-used. "Keeping in touch" is a vital social lifeline, essential to human social, psychological and even physical wellbeing [9]. As one participant expressed about her routine: "*It is pleasant, […] when I go home, certain things always happen. I eat and then I sit on the sofa, I see what is on the telly and at the same time I check [Facebook]. And during weekend it happens many times, I go there and I check.*"

Other previous research [3] has highlighted how smart phone users would 'control' their own use of communication by checking email and other communication on their smart phone and wait to reply until they could get to a larger device such as their laptop. This way *they would only spend minimal time checking if anything was in need of immediate attention* but specifically not reply on the device itself. This resonates well with our participants' micro-use of social applications; they were often used for brief checking.

Yet, these social applications rely on new information and updates (providing or consuming) that are being *pushed* to or *pulled* from the device. It is therefore likely that they are popular because they lend themselves well to micro-usage. Just like a telephone ringing in a home 20 years ago prompted immediate answer by the nearest family member, the notifications may trigger our innate need for social interaction [26].

Furthermore, our participants perceived mobile notifications as an integral part of using a mobile application, especially social applications, and as an indicator of contact; therefore their existence has a reassuring effect on users. Similarly, in the context of desktop application usage [21], responding fast and often to notifications, was perceived not as a nuisance but instead alerts were seen as a useful awareness mechanism.

Considering the participants' description of place where *system-initiated* micro-usage took place, interestingly, few instances took place outdoors (16%) but more than half of the notification-prompted micro-usage took place at home (52%). Although there is a slight bias in our data collection method that could influence the answer (perhaps people are more likely to answer the EMS following micro-use at home, than, for example, outdoors), it indicates that people are more open towards interruptions at home, compared to the university and work where only 4% and 28% of the micro-use was prompted by notifications, respectively.

Applications with micro-usage behavior in mind

Applications are very likely to be used very briefly (41.5% under 15 seconds) but also for substantial durations (58.5% above). Mobile phone screen real estate is limited to displaying one application at a time on almost all phones, and these devices do not truly support multi-tasking in comparison to desktop computers. According to our analysis, *15 seconds is often enough to use an application* and switch to another. How should this attention time frame affect application interface design?

We provide evidence that not all applications are micro-used to the same extent (Figure 2). We identified four categories of applications regarding micro-use probability: *focused, social, information seeking* and *leisure* applications:

- *Most likely* to be micro-used are *focused applications*, applications with limited functionalities or that are task-oriented, such as Alarm Clock, Calendar; and *social applications*, applications that rely on frequent notifications to update the user, such as Facebook, email. Of the top four micro-used applications in Study 1, three are communication applications (Facebook can arguably also be used as such with the built-in messaging system), similarly to what Iqbal & Horvitz [16] found with desktop use. They found that the vast majority of diversions took place in the users' email applications.
- *Least likely* to be micro-used are *information seeking applications*, applications that the user uses for information retrieval, such as Google Maps, browsers, news readers; and *leisure applications*, applications meant to entertain the user for longer periods of time, such as sports trackers, games and multimedia.

The applications' purpose of use is a concern that designers address at the *interface* level (*e.g.,* simple or complex interface), developers at the *implementation* level (*e.g.,* widget, notification, full application), and architects at the *system* level (*e.g.*, power consumption, resource management, caching, *etc.*). Similar to multitasking with desktop applications [16], fundamentally mobile application micro-usage emphasizes *fragmented and brief* application usage, that is, switching to, and resuming from another application very quickly. In addition to traditional HCI usability heuristics [23], we further provide micro-usage application interface recommendations, motivated by our studies:

- Allow transitioning between streamlined and full interface; default to the streamlined interface for those applications that are most likely to be micro-used (*e.g.*, focused and social applications), and to the full interface otherwise (*e.g.*, information seeking and leisure applications);
- Support intermittent application usage and transparent resume (*e.g.*, automatically save and resume from changes, provide visual cues for incomplete tasks [20]) to tackle multi-tasking and fast application switching;
- Support brief (*e.g.*, quick reply to new content without launching the application) and long application sessions (*e.g.*, review previous content, exploring new content).

The existence of micro-usage is not a sign of bad design. On the contrary, our studies and interviews indicate that micro-usage is a form of *experiencing* a mobile application and some applications do support it very well (*e.g.*, Gmail – Figure 10), allowing the user to quickly interact with an

application (*e.g.*, quickly archive, delete or reply to an email) without launching the application itself.

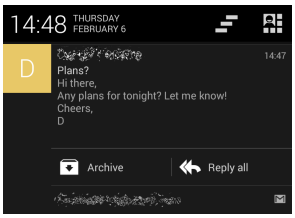


Figure 10: Example of Gmail micro-usage support.

Moreover, we show that notification functions are an important trigger for application usage and micro-usage and application designers should explicitly support these different behaviors. Should the user be presented with all her emails when opening a notification for new emails? What if the interface only displayed what is new for faster readability? The high-level question is, what information should be *emphasized* if the user interface will only remain *visible* for a few seconds?

As the time between phone usage instances is about 15 minutes (Figure 4), and since notifications are the main trigger for micro-usage, phones can optimally pull information from social applications, rather than pushing notifications to the user on every single update. In return, phones can ultimately reduce the nuisance of notifications reported in our interviews yet maintain the perception that applications are working properly. Moreover, when at home, users keep their devices 83% of the time in the same room [11]. As micro-usage is more frequent at home and when the user is alone, applications should take advantage of peripheral notifications, *i.e.*, no sound or vibration, by using device's LEDs or display for feedback and alerts.

From a systems perspective, the FALCON application manager [29] improved the loading times of applications by preemptively loading applications with high probability of use, thereby improving resource management and power efficiency. In considering the impact of micro-use, we could extend the predictions to the allocation and recovery of memory and other resources. We extend the micro-usage application recommendations to include recommendations developers:

- Provide succinct notifications with relevant up-to-date information, at approximately 15 minutes of inactivity, since the users are more likely to use their device again then (see Figure 4);
- If not time-critical, use peripheral notifications, especially if the user is at home (Figure 5 – bottom left);
- Unobtrusive and preemptive loading of newer content, so users do not have to wait for this content, nor search manually for it, for more likely micro-used applications (*e.g.*, social applications);
- For applications that are likely to be micro-used, have the OS make short-term resource optimizations for allocating memory, CPU, *etc.*, since the resources will only be needed for a very short time.

We must emphasize that micro-use is *not just* a mobile phone phenomenon. For example, while reporting on their analysis of 1 billion search queries and search sessions, Silverstein *et al.* note: "*[…]most of them are very short. […] 63.7% of all sessions consist of only one request.*"[27:8]. Users' propensity to disproportionately exhibit short bursts of inquiry are closely reflected by users' website visiting patterns, where about 50% of visits to a website typically involve visiting just a single page [17]. Similarly, for TV channel-watching behavior, 60% of channel holding times are shorter than 10 seconds [5].

As a ubiquitously available media solution, mobile phones naturally compete against other information sources for users' attention. It is not a surprise that, in both of our studies, Facebook and Google Mail are ranked as the most-frequently-used mobile services. Frequent interaction with the mobile phones, such as checking notifications, gave our participants a sense of gratification, and these activities increase in frequency when the cost to perform these activities decreases. We expect increased micro-usage to follow advances in computing devices such as wearable [17], as the effort required for interaction is increasingly minimized. The phenomenon of micro-usage is far from confined to smartphones; rather it is an instance of a broader human mechanism in how we allocate time to activities and how we regulate the rate of our activities.

Contributions

Our work has provided the following contributions: 1) we highlight a temporal dichotomy in application usage: *micro-use* (vs. non-micro use) and describe the distinct characteristics related to the brief spurs of application use that is found to be very common with mobile devices; 2) we identify a close relationship between notification-driven micro-use and how social applications in particular are being used in this way, and finally, 3) we emphasize how micro-use is an important phenomenon across platforms. This manifestation in a variety of domains makes micro-use relevant for the design of future applications and services, and we highlight implications for design and guidelines.

Limitations

Despite our best efforts, we must acknowledge the limitations of studying micro-usage with a sample of 36 participants and that our findings might not be indicative of the behavior of a larger sample. We did not find any potential link between participants' demographics and micro-usage behavior, but we must acknowledge that this might be due to our sample diversity. Despite our effort in designing the ESM to capture as much context as possible, the answer-choices could have limited users' micro-usage context [22]. Nonetheless, through our studies, we were able for the first time to *specifically* investigate micro-usage and the context in which it occurs.

CONCLUSION

The purpose of this paper is to highlight mobile application micro-usage as a distinct phenomenon, and to investigate

the context in which it occurs. Our findings suggest that micro-usage is a frequently occurring phenomenon that is most likely to happen when users are alone. Our results provide further evidence that location and purpose are likely to affect the occurrence of micro-usage behavior.

Our results have also raised a number of issues regarding micro-usage that remains to be addressed. Specifically, it is not clear whether micro-usage is in fact wanted at times, or becomes a nuisance due to the existence of system notifications that alert users. Furthermore, our findings suggest a dichotomy in how mobile applications are used, and therefore we argue that designers and developers should consider how this affects their applications' usability and users' experience.

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