Slide to X: Unlocking the Potential of Smartphone Unlocking

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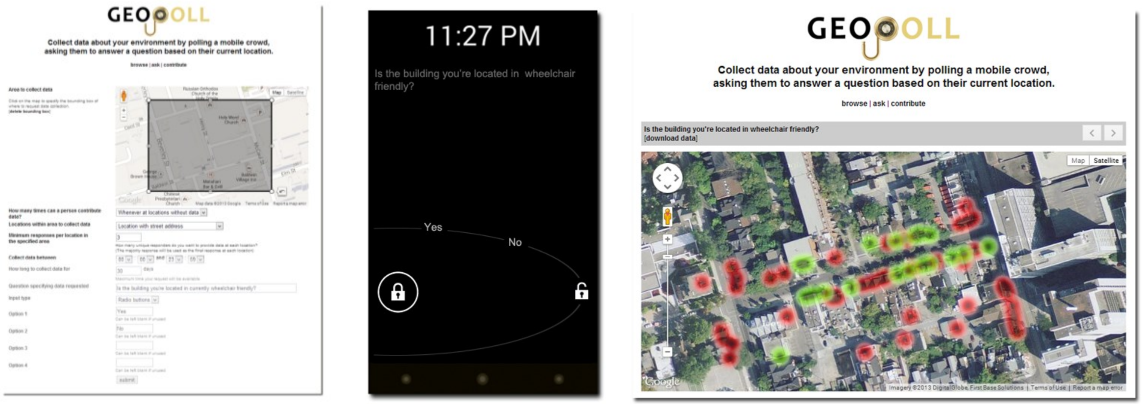

(a) (b) (c)

Figure 1. A Slide to X application—Slide to GeoPoll. (a) Interface for creating a Slide to Geopoll task (b) Slide to GeoPoll screen unlock interface, and (c) the GeoPoll webpage for viewing and downloading the content collected by mobile phone users

ABSTRACT
Unlock gestures are performed by billions of users across the world multiple times a day. Beyond preventing accidental input on mobile devices, they currently serve little to no other purpose. In this paper, we explore how replacing the regular unlock screen with one that asks the user to perform a simple, optional task, can benefit a wealth of application domains, including data collection, personal-health metrics collection, and human intelligence tasks. We evaluate this concept, which we refer to as Slide to X. Further, we show that people are willing to perform microtasks presented through this interface and continue to do so throughout the day while they visit different locations as part of their daily routines. We then discuss how to implement this concept and demonstrate three applications.

Author Keywords
Dual-purpose interaction; microtasks; phone unlock.

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INTRODUCTION
According to Gartner, by the end 2013, there will be 1.3 billion smartphones in active use worldwide [17]. Largely to reduce accidental input, most touchscreen-based phones and tablets require that a gesture be performed in order to unlock the device (*e.g.,* [6, 30]). Previous work has found that, on average, adult users unlock their phone between 10-200 times per day. This suggests that, worldwide, at least 13 billion unlock gestures are performed on a daily basis. Given a measured 3cm per unlock gesture performed in an average time of 1.72 seconds (found in our study), we estimate that humanity is spending 6.2 million man-hours sliding fingers approximately 390,000 km (roughly the distance to the moon) – every day – all for the sake of reassuring our phones that we are, in fact, acting intentionally.

To be sure, preventing accidental inputs is important. However, we see this as a tremendous opportunity to harvest that time and physical activity to other aims. We believe that these unlocking gestures, instead of simply acting as wasted movements, could be redirected to far greater effect. In this paper, we examine replacing the regular unlock screen with a dual-purpose one asking the user to perform a simple, optional task while unlocking. We demonstrate this concept, which we refer to as Slide to X, can enhance geo-location data, assist in biometric data collection, and provide sustenance for those in need – while preserving the use of a gesture to reduce accidental input. Each of these applications share a common workflow: the user or a third party defines a set of questions which can be easily and quickly answered with a single gesture. Those questions are presented to the user in place of the traditional 'unlock' UI for their phone. The user can then to choose to answer the question, or bypass it by performing a traditional unlock. The answers which are provided are then shared back to the party specifying the question, along with any necessary contextual information (such as, geo-location).

While Slide to X applications holds promise, it is clear serious questions must be answered about their viability, as each relies on particular usage patterns of the phone, as well as users' willingness to answer Slide to X questions. We sought to understand these issues through a deployment study, in which participants were presented with abstract tasks in place of their unlock screen over a two-week period. In this paper, we thus make three contributions:

1. *The use of micro-tasks as a replacement for traditional phone unlocking.*
2. *A study of regular unlocking patterns and of users' willingness to perform micro-tasks in that context.*
3. *A set of three example applications which demonstrate the Slide to X concept.*

We begin by reviewing related work, before describing our study and our applications in more detail.

RELATED WORK

In this section, we review previous studies and findings which lay the foundation for our research and the Slide to X concept. We first present previous research which has examined smartphone usage patterns; we discuss how their findings suggest that users will interact with the phone's unlock screen an ample number of times per day, and thus the unlock screen can potentially be augmented and harnessed to complete a large amount of work. We then discuss research projects which have explored using mobile phone users to complete human-intelligent tasks and collect data. Finally, we describe prior research of dual-purpose interactions, focusing specifically on applications for mobile devices.

Smartphone Usage Patterns

Researchers have conducted studies to examine how often people use their phones on a daily basis [12] and the reasons why [20, 24]. Falaki *et al.* [12] have shown that users interact with their phones on average 10-200 times a day. A recent study by Lookout Mobile Security [25] found that 58% of adult smartphone users do not go an hour without checking their phone. Khang *et al.* [24] have identified compulsive anxiety as a factor in mobile phone addiction, while Ha *et al.* [20] have shown that Korean adolescents who report excessive cellular phone use expressed more depressive symptoms, higher interpersonal anxiety, and lower self-esteem than people who use their phones at a lower frequency. Oulasvirta *et al.* [34] showed that 18-35% of the time, users interact with their phone only briefly out of their habit of checking dynamic content. Finally, Verkasalo [39] showed that, on average, over 50% of the time spent on mobile devices is at home, over 25% is on the move, and the remainder is at work.

Although past research suggests that people use their phones a large number of times per day at different locations, because the user can customize how soon the phone's lock screen becomes active after it sleeps, the actual frequency of presentation of the unlock screen is not known. Thus, one of the questions that we attempt to answer in our study is how often users see the unlock screen, and actually proceed to unlock the phone.

Mobile CrowdSourcing & In-Situ Data Collection

Patel *et al.* [35] and Dey *et al.* [10] have shown that on average the mobile phone is on the user's body or within-arm's reach more than 75% of the time. Thus, not surprisingly, mobile phones have been used for *in situ* data collection purposes, such as experience sampling [15,25] and life-logging [22, 31]. Klasnja *et al.* [25] studied how mobile phones can be used for in-situ experience sampling via regular (hourly, daily, *etc.*) cellphone surveys. A key issue they identify with such a method is identifying opportune times to pose surveys and avoid disruption.

There are also many potential applications that could be developed if the billions of mobile phone users across the world can be leveraged as a potential source of workers for performing data collection and human-intelligence tasks. Examples of such commercial and research applications include crowdsourcing work that needs to be completed for companies and developers [1,11,18] (including testing of mobile apps in the wild [40]), to providing up-to-date traffic information [1], and participating in citizen science [28] and community activism [36].

Many of the crowdsourcing applications described above envision that users will complete requested tasks for free or small payments. However, it is unclear whether small payments or none at all could attract mobile phone users in all parts of the world and keep them motivated to continue to complete work (*e.g.,* beyond the initial month in which people may use applications because of their novelty factor). For example, Alt *et al.* [1] developed and evaluated whether a mobile application could be used for location-based crowdsourcing. In their study, nine participants completed only 30 total tasks over the course of 2 weeks. This demonstrates that people are willing to work; however, further research must explore how to motivate continued participation. Later in this paper, we propose a different way to motivate participation in mobile crowdsourcing.

Dual-Purpose Interactions with Mobile Devices

The concept of performing a single interaction with a mobile device to complete two actions has been explored previously in a number of contexts. Lyons *et al.* [29] have shown that speech which is "socially appropriate in the context of human-to-human conversations" can also be used to provide instructions to a mobile computer, such as to navigate and interact with the user's calendar. The UbiFit Garden [8], ShutEye [4] and MONARCA 2.0 [16] systems demonstrate that the background screens on mobile devices can be used to convey health information; as the user uses her phone, she would also see information which would support self-reflection about specific aspects of her health. Dearman and Truong showed that a Vocabulary Wallpaper [9] could display place-specific phrases and translations to help the user develop vocabulary in a second language through implicit learning which occurs while she uses the phone for other explicit reasons. Because the interface for ShutEye [4] and MONARCA 2.0 [16], and Vocabulary WallPaper [9] were all implemented as live wallpapers for the Android OS, they were displayed on the lock screen as well as on the home screen. Thus, even when the user turns on the phone to glance at the time or unlocks the screen to use the phone, she may gain information from those actions.

When interacting with the Slide to X interface on the lock screen, the user can both unlock the screen while also producing input to complete an additional task. This concept has been proposed in a number of similar applications: Lock Screen Query [33] and Twitch [38]. Applications of supported by these interfaces overlap with one another, not surprisingly, because many of them have been previously explored by the research community (*e.g.,* crowdsourcing and collection of geo-tagged information about the environment). Thus, what is introduced in Swipe to X, Lock Screen Query [33] and Twitch [38] is the augmentation of the lock screen as a way to get users to perform tasks while they unlock their phones. This concept itself is a next step that extends prior work; *i.e.,* now the lock screen is not only altered to display useful information (as done in previous work such as Vocabulary Wallpaper [9] and ShutEye [4]) but also designed to receive input to complete a task while also unlocking the screen. Our contribution, as shown in this paper, is to answer research questions which will help to inform the design of applications which use such a dual-purpose unlock screen interface to collect data. For example, it is important to know how long on average the phone stays asleep before it is unlocked so that tasks can be selected and assigned to users without the assignment expiring before the user has a chance to complete the task.

STUDY

The success or failure of a Slide to X application hinges on two factors. First and foremost, the user must be willing to answer simple questions when unlocking their phones. Second, some applications require broad or particular context coverage (either temporal or spatial) from unlocking actions throughout a user's day, and thus would require that users unlock regularly, or at particular locations. To shed light on these two issues, we conduct a study to answer four questions, the first two of which relate to context coverage:

1. *How often, throughout the day, do users unlock their phones?* (*i.e.,* what is our temporal coverage?)
2. *What is the distribution of phone unlocks across the places the user visits during the day?* (*i.e.,* what is our geolocation coverage?)

These issues of coverage are of critical importance to many applications. In our Slide to QuantifySelf application, for example, collecting information at the appropriate time is essential (*e.g.,* determining users' coffee consumption by asking "have you had a coffee in the last hour?"). In our Slide to Geopoll application, location coverage is also critical (*e.g.,* mapping wheel chair accessibility by asking people about their current building). In general, it is our goal to understand if Slide to X microtasks could replace the use of location or time-based alerts for many applications.

In addition to our questions about coverage, we also sought to understand users' willingness to perform microtasks as a part of the unlocking action. In particular, we wished to begin to find answers to these questions:

3. *How often are users willing to perform Slide to X unlocking?*
4. *How intensive a question are users willing to answer when unlocking?*

We conducted a study in which experimental software was installed on participants' own phones to track their usage. Our software replaced their phone's unlock screen, allowing us to modulate the presentation of information at unlock time. In addition to answering the above research questions, we took the opportunity to collect additional information about our participants' phone unlocking habits.

Participants

We recruited 10 paid ($20) participants between the ages of 19-23 (3 female) from the local community using online advertising. Participants were selected for our two-week study based on their phone's compatibility with our apparatus (any version of Android 2.3 or later was allowed, with a preference for newer phones given the battery usage needs of our tracking software).

Apparatus

Software

We developed and installed experimental software on each participant's handset. The software was written in Java with a minimum Android API level of 10. Android was targeted as the distribution platform, because it exposes APIs for overriding the phone's unlock screen. The software was forked off on an open-source project called LinguaLock under the Apache 2.0 License. The software stored data locally on the phone's SD card in a CSV file format; thus, no internet connectivity or backend server was required,

The apparatus was instrumented to perform three fundamental tasks: collect position data, collect usage data, and present the participant with various types of unlock screens:

1. <u>*Position data:*</u> Every 10 minutes, the user's geospatial position was recorded using the Android location APIs (whether the phone's screen was on or off). The APIs ensure that the most accurate means available is employed. Tracking participants allowed us to assess the 'spatial coverage' of their unlocking gestures.

2. <u>*Usage data:*</u> Further, every time the phone's screen was turned on, the event was recorded, as was the time and location of each unlocking activity.
3. <u>*Slide to X functionality:*</u> When a participant unlocked her phone, she was presented with one of several possible unlock screens: (a) a traditional, Android unlock screen, (b) a simple mathematical question, meant to abstract cognitive load and provide a question with ground-truth to test participant effort, (c) an introspective questions about health (*e.g., "how happy have you felt in the past hour"*), meant to understand if users are able to meaningfully sample their experiences during the time it takes to unlock their phone; or questions about recent activities (*e.g., "in the last hour, have you had any coffee"*), meant to test if users are willing to quickly perform recall when unlocking their phone.

The answers provided to each question were recorded, as was the time spent between screen power-on and the eventual completion of the unlock action.

To ensure sufficient data collection, participants were not given the choice to override the Slide to X functionality. While we advocate for a design in which a traditional unlock gesture is always available, we believe this compromise in external validity allowed us to enhance our collection of both quantitative data and post-task feedback.

Procedure

We instructed the 10 participants to use their phones as per usual but with our experimental apparatus running on their phones for two weeks. We asked participants to return to the lab for a follow-up interview and post task questionnaire at the end of the two weeks. Due to scheduling difficulties, time in the field varied from 14 to 20 days. All data are included in our analysis.

Because all input to our apparatus is participant-initiated, the lower bound on the number of data points per participant was not controlled. The software was configured so that Slide to X questions were presented only occasionally. The rate of presentation was set as follows: at the beginning of each day, a pseudo-random value p was computed with a uniform distribution in the range of (0.25, 0.75). Each time the phone was activated, the apparatus would either display a question (probability of p), or a traditional unlock screen (probability of $1-p$). This distribution was chosen based on early testing, which found that asking a question on every unlock was too onerous. The range was set to allow us to collect feedback about the reasonableness of a given frequency. Questions were posed using a random without-replacement method.

RESULTS

Over the course of the study, the ten participants unlocked their phones a total of 16,398 times. Of these, a question was posed 8,118 times, and a simple unlock screen displayed a total of 8,280 times.

The average number of daily unlocks was highly variable across participants: the minimum mean was 4.82 (std dev=8.75) per day (participant P8), the maximum mean was 105.24 (std dev=35.11) by P1. P8 was an outlier in this respect – the next lowest was 20.07 (std dev=18.97) by P3. The average number of Slide to X questions answered per day, per participant, was 49.83 (std dev=28.95).

All but 1 participant reported in the post-task questionnaire that they checked their phone immediately after waking up and immediately prior to going to sleep each night. We therefore used unlocking activity as a proxy for the beginning and end of each user's day when computing various descriptive statistics.

Participants were asked in the post task questionnaire if they would be willing to continue the study for another period of the same length for the same compensation ($20) – all but one volunteered. This suggests that the compensation was sufficient for the task. Given the average of 772 questions per participant, this resulted in a rate of pay of $0.026 per question.

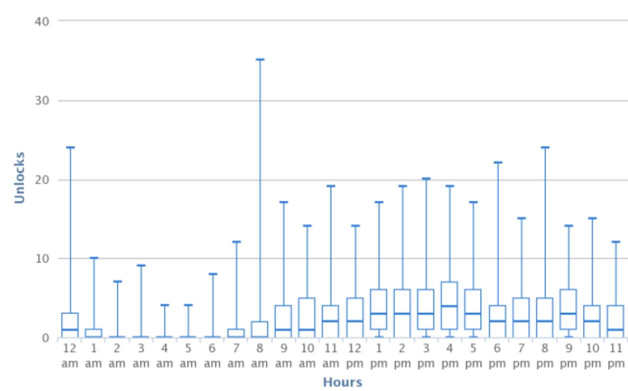

Figure 2. Hourly distribution of unlocking actions.

Unlocking Distribution & Frequency

As mentioned above, 9 out of 10 participants indicated that they checked their phone immediately upon waking up and immediately before going to sleep each night. Phone usage typically tapered off during meal times (12pm-1pm and 6pm-8pm), and peaked in early afternoon (3pm-5pm) and late evening (8pm-10pm). On average, participants unlocked their phones 4.3 times per waking hour. Unlocks happen on average 25.8 minutes apart (std dev=150.7).

Participants were asked in the post task questionnaire whether the frequency of Slide to X questions was *too low*, *too high*, or *just right*. 8 of 10 participants reported the current frequency of questions was reasonable, while 2 reported that they were too frequent. None of the participants noted a difference in frequency on days with a lower p value than on days with higher values. Seven of the 10 participants noted that, while the overall frequency of being asked a question was reasonable, greater variety in the questions and less redundancy (*i.e.,* seeing the same question less frequently) was desired.

Participants were asked in the post-task questionnaire to list situations where the Slide to X behavior was problematic. All reported that activities requiring frequent unlocking were sometimes frustrating (*e.g.,* carrying on a conversation via SMS). They also indicated the occasional need to find information quickly (*e.g.,* time of arrival of the next bus). For this reason, we advocate for a design in which a traditional unlock gesture is always available—allowing the user to bypass a task when she is unable or unwilling to complete it.

Location Distribution

Using our persistently recorded GPS data, we analyzed the coverage of 'locations visited' in unlocking actions. To eliminate noise from the GPS readings and to cluster movements that might happen within buildings, we defined a *visit* location as one where 3 or more consecutive recorded locations were within a 500m radius. These thresholds were set *post hoc*, after interviewing participants and presenting them with their location data.

We found that participants visited an average of 2.58 locations per day (std dev = 1.02). Although this seems low, it is consistent with what is commonly reported in the literature as the number of places a person visits on a daily basis. We note it is because the location data is collected once every 10 minutes, and a visit is denoted only if 3 consecutive readings fall within an area of 500 m radius. This means that the participant has been inside of an area for at least 30 minutes. We also found that, participants unlocked their phone at least once during 90% of their visits to any given location (std dev=0.18).

Overall, 45% of the unlocking actions took place in the visited locations, and 55% happened while the participants were on the move. That 55% of unlocking actions which took place on the move is important because they happened in locations that are not the places where the user stays for very long and suggests that unlocking has broad spatial coverage.

In the post-task questionnaire, participants were asked to describe the situations in which they did not choose to unlock their phones, and whether the Slide to X functionality impacted those decisions. 4 of 10 participants indicated that they were always less likely to unlock their phone in certain social contexts, such as small gatherings or meetings. 3 of 10 participants indicated that, because of the increased unlocking time, Slide to X further decreased the probability that they would unlock their phone in those contexts. We leave it to the reader to decide whether this is a positive or negative impact of our framework.

Ground Truth

We did not allow users the option of skipping questions, so we aimed to understand if and when users would intentionally answer a question incorrectly (or without looking at the answers) in order to unlock their phone.

9 out of 10 participants reported occasionally 'skipping' questions in this manner and of those, 7 said they primarily answered questions incorrectly due to time constraints and not based on the type of questions answered.

Thus to study our ground truth we included a class of questions with definite answers that all participants were able to answer correctly, specifically simple math questions (*e.g.,* 'What is 4×8?'). We found that 81% (std dev = 0.19) of the math questions were answered correctly with 4 participants answering the questions correctly at least 95% of the time.

Unlocking Performance

To determine the difficulty added through a Slide to X interface, we recorded the time required between screen activation and successful unlock of the phone, differentiated by whether a regular unlock screen or Slide to X question was displayed.

The mean time across all participants for a 'regular' unlock was 2.15 seconds (std dev=0.75). In contrast, across all Slide to X question types, the mean time was 3.22 seconds (std dev=1.67), with math questions requiring 3.27 seconds (std dev=1.5), health related questions requiring 3.31 seconds (std dev=1.83), and recall questions requiring 3.14 seconds (std dev=1.58). Questions which participants felt were difficult were those which left them unsure of their response or those which needed extra time to perform a deep recall in order to answer.

"I didn't know how to rate how busy or alert I was, either I was doing work or I wasn't." –P8

"The questions that took the longest were the ones that I needed to look back on and remember like 'how many conversations have you had in the past hour'. Things like 'Have you had water in the past hour' were easy." –P9

DISCUSSION

We now discuss how the results validate the viability of Slide to X as a method that can facilitate in the completion of wealth of tasks which require human intelligence and effort. First, we discuss the context coverage of unlocking actions. Then we discuss participants' willingness to perform Swipe to X gestures.

Coverage

In our study, participant unlocked their phones between 4.82-105.25 times a day on average (20.07-105.25 times if we remove a participant who unlocked his phone much fewer than the next least participant). While participants were surprised by how often they used their phones, this matches with previous the findings from research by Falaki *et al.* [12]. Participants found that the plots of their phone usage over time correlated very well with their daily patterns. As a result, their unlocking pattern is a possible proxy for their daily routines. Our results showed that almost all participants unlocked their phones immediately after they wake up and before they go to sleep. Participants checked their phones regularly throughout the day while they are awake, and this tapers off during their meal times and peaks twice—once in the afternoon and once at night. We also learned that participants check their phones at least once at 90% of the locations they visit. On average, participants visit 2.58 places a day, and 45% of their unlocks happen in those places where they stayed for 30 minutes or longer, while the remaining 55% happens on the move.

In all, our findings show that the unlocking action has broad temporal and spatial coverage. It happens at a high frequency, on average 4.33 times per waking hour. Unlocks happen on average 25.8 minutes apart (std dev=150.7). 77.6% the unlocks that happened during our study happened within 15 minutes or sooner of the previous unlock. These findings demonstrate that unlocks happen very frequently and validate that augmenting the unlock screen is a potentially effective way to get tasks completed by users promptly, and if it requires broad context coverage (*e.g.,* experience sampling or in-place data collection).

Willingness

We found that overall participants thought the frequency at which they were presented with questions was reasonable. Answering the questions required an additional 1.64 seconds to their unlocking action. On the whole, however, participants did not find the interface to be disruptive to daily use. On a Likert scale from 1-5, with 1 being not disruptive at all and 5 being highly disruptive, participants rated their experience answering questions as a part of the unlocking action an average of 2.4 (std dev=1.17). However, the interface did impact 3 of our participants in that the increased unlocking time influenced their decision to unlock their phone or not in different contexts.

In all, the findings suggest that participants were willing to answer questions, but that questions could be disruptive. It is important for a design to include a mechanism which would allow the users to simply unlock the phone as they normally would without requiring them to answer the question. Additionally, the interface must conform with the phone's operating system settings users have applied for when a screen lock should occur. In this manner, users can turn on or off their phone and perform quick tasks (such as texting) without being slowed down by the augmented unlock screen. Finally, it is important to consider (1) how to determine the questions that are of interest to the user or ones that they want to ignore and (2) to adjust the tasks that they are asked to perform based on this information.

Motivation

Motivation for answering questions can come from either internal (self-interest) or external (monetary) sources.

In regards to self-interest, participants found that the novelty and personal relevance of the questions made them appealing to answer. For example, P8 remarked that she had no interest in tracking her exercise and would find such questions annoying, but questions about food and calorie consumptions would be more interesting to her.

Other question types may require compensation as motivation. We used math questions as an example of a question type with no intrinsic internal motivation. We found that participants were generally truthful in their responses, with 81% (std dev 0.19) correct answer rate. Furthermore, at least 4 participants answered the questions almost every time (95% correct or greater).

When asked if they would continue with the study at the same compensation rate of $20 for two weeks, all but one of the participants volunteered. This suggests that users were willing to complete tasks at a very small rate of pay ($0.026 per question). It is important to note, however, that users in this study were incentivized at a flat rate, not on a per question basis, so future research should examine how a per-question payout may impact motivations.

SLIDE TO X INTERFACE AND APPLICATIONS

In this section, we present Slide to X, our interface designed to provide users with an optional task that they can perform while unlocking their phones. Then we will discuss three potential applications of the Slide to X interface. Motivated by some of the real world problems recently explored by the HCI community: crowd-sourced generation of map data about the accessibility of the physical environment [19, 21], quantified self [27], and computing for social good [7], we demonstrate how to leverage mobile phone users' ability and desire to complete a short optional task as a potential way to:

- **Slide to GeoPoll –** produce context data for a specified geographical area;
- **Slide to QuantifySelf -** help users more easily collect information about themselves; and
- **Slide to Cure – offer users** work to receive payment that is donated to a charity.

Slide to X Interface

Slide to X is a software library which forked off an open-source project called LinguaLock under the Apache 2.0 License. The software was written in Java with a minimum Android API level of 10. Again, we targeted Android as the distribution platform, because it exposed APIs for overriding the phone's unlock screen. The interface performs three steps automatically when it is installed on a phone: first, it creates a unique user ID based on the device's default user profile; second, it subscribes for screen on and off actions from the operating system; and third, it subscribes for periodic location updates. When the screen is turned off, the software generates a packet composed of the user ID, the most recent location information, and a future time value (which takes into consideration how much time must pass after the screen has been turned off before the unlock screen can be shown again to the user). This packet is dispatched to a task managing service, which then responds with a microtask that will be presented to the user when the screen is next turned back on.

The time value is used by the task managing service to filter for tasks which will not expire before the unlock screen may next appear. The software obtains this task at screen turn-off time instead of turn-on in order to ensure that the screen is shown immediately to the user (instead of needing to wait for it to communicate with the task managing service which searches its database for a task that can be assigned to the user and then transferred that back to the interface).

The augmented lock screen itself has three parts:

1. a clock, which allows users who only want to check the time to be able to do so easily;
2. a question, which may include a picture; and
3. the slide to unlock widget, which includes the possible answers.

The slide to unlock widget can either display radio options (or multiple choice answers), a Likert scale, or a rating slider. To select a particular answer, the user simply touches the lock icon on the left side of the widget, drags it to the answer she wants to select and releases. An unlock icon is always present on the right side of the widget. This allows for the user to always be able to unlock the screen quickly using the same motion without needing to consider the question or the answers.

Once the user has completed a sliding action, the answer is reported back to the task managing service so that it can release the task assignment (if no answer was provided) or record the answer and close the assignment (if an answer was provided).

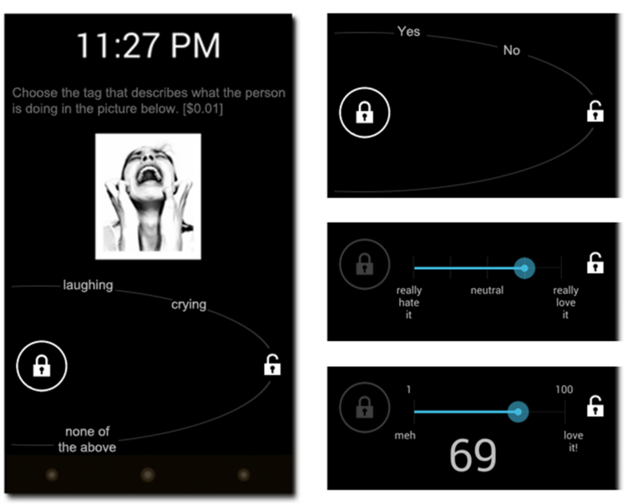

Figure 3. The Slide to X interface. Left shows the three parts to the unlock screen: a clock, the question with an optional image, and a slide to unlock widget. Right shows three possible variations of the slide to unlock widget: multiple choice answers, a Likert scale, and a rating bar.

The task managing service can either be online or on the same device. An online version of the task managing service is developed in PhP and can be accessed through web requests. It consists of a library for inserting, editing, deleting tasks, assigning and removing tasks, and to store and retrieve completed work/responses submitted by the user. Because it is a PhP library, an application developer simply installs it on a Website and directs the Android application they develop to that URL. The interface for creating questions online can be customized without needing to write additional PhP code. Alternatively, if the application being developed is for personal use, an Android version of the task managing service is also available to be imported and used by the application. More information about how the task managing service works will be described in the applications described below.

Slide to GeoPoll Application

We now discuss the first application of the Slide to X interface—using it to collect information about the environment.

Much information about the world still does not exist in an easy to access database. For example, information about how accessible streets and intersections are to the visually or motor impaired are not readily available and need to be collected. Prior researchers have asked online crowds to label previously captured StreetView images as a way to produce this information. However, these images may not always be up-to-date and occlusions can prevent online crowds from providing accurate judgments about the accessibility of streets and intersections for others. Motivated by these challenges, we developed Slide to GeoPoll, a system which leverages a mobile crowd to provide in-place data about the physical environment. Because the mobile phone user is asked to provide information about the place she is currently located at, this enables map information to be collected more accurately and furthermore for information beyond what can be extracted from Google StreetView to also be gathered.

For example, an extension of work by Hara *et al.* [21] is to determine whether different buildings in an environment are wheelchair friendly or not (that is, can a person in a wheelchair not only enter the building, but also navigate throughout the space and access different stories in that building). This information would be difficult for an online worker to judge simply from Google StreetView images and is best provided by someone who has visited and is located in the building. Additionally, if one wanted to map how noisy people think different parts of the city are, this information is both subjective and non-visual.

We have developed a website to allow anyone to request mobile phone users to help collect specific information within a specified geographic area when they unlock their phones. The requester simply specifies (a) the geographic area in which she wants context information to be collected (b) the question and possible responses to be asked of mobile phone users, and (c) additional parameters for the request, such as how long the request is active, the minimum number of responses needed per location within the specified area, and what constitutes a location for that request (see Figure 1a).

After a user installs the Slide to GeoPoll application on her Android phone, it replaces the normal keyguard mechanism setup on the phone. Each time the user turns off the phone, the application queries a task managing service on the GeoPoll website for a list of possible requests that the user can potentially help to produce a response for; this list is determined based on the user's location and whether or not the request has been previously responded to by the user at that or nearby locations. The application selects a random request from the list of possible requests and presents that request as an optional task on the mobile phone's unlock screen. When the user next turns on the phone, she can perform the task before performing a slide to unlock gesture to use the phone; alternatively, she can ignore the task if she is too busy to, does not want to, or is not in a position to be able to answer the question, and simply unlock the screen (see Figure 1b). That task will continue to remain as a possible request of the user until she has ignored it more than three times.

The Slide to GeoPoll application will submit user responses to the GeoPoll website. Because the user's location when she unlocks the phone may differ from when she last turned off the phone prior to that unlock, the server must check to confirm that the location at which the response was made satisfies the criteria and parameters of the data collection request. If it does not, it is simply discarded. However, if it matches the criteria and parameters of the request, then that information is stored to a database. Because the intent of the service is to produce a collection of public datasets, all requests can be browsed—and the respective datasets can be viewed and downloaded—from the GeoPoll website (see Figure 1c).

Slide to QuantifySelf Application

Our second application is Slide to QuantifySelf. This application allows users to enhance existing practices in personal health data collection, in order to better track and refine their personal habits. Questions include *"have you eaten lunch yet"* and *"are you happy right now?"* This information is, at present, collected solely for the information of the user, but could ultimately be provided to a healthcare professional monitoring the health of the user. This application builds on a growing trend of personal health and fitness datametrics, which has given rise to wearable sensors (*e.g.,* Fitbit [13], Jawbone Up [23]), personal tracking applications (*e.g.,* MoodPanda [32], Momento [31]), and social media applications (*e.g.,* Fitocracy [14]).

Li *et al.* [27] argued that personal informatics and self-reflection can help a person to improve his or her own quality of life. In a few instances, a simple sensor can be used to collect this information over time (*e.g.,* an accelerometer to measure how many steps a person has walked and a scale to measure how much a person weighs). However, there is an abundance of other information which cannot be collected automatically (*e.g.,* how a person feels emotionally) that the user would need help to collect. Often times, the burden of remembering and being prepared to manually capture this information is high [37] and thus it is a challenge to have a useful and detailed enough set of data needed for review and self-reflection.

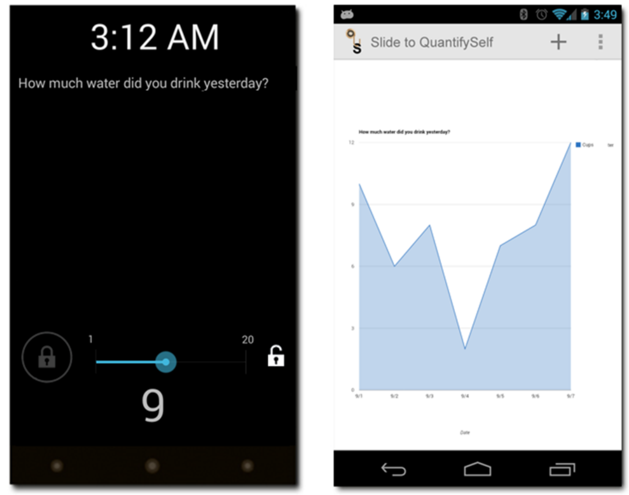

Figure 4. Slide to QuantifySelf application.

Slide to QuantifySelf allows the user to track information about herself each time she unlocks her phone (see Figure 5). The application allows the user to specify the set of information to ask herself about throughout the day and the conditions for which to collect any specific piece of information (*i.e.,* when and how often to ask the user particular questions). The application stores this information as time-series data for the user. When the user wants to review her life patterns, the application graphs the information on timelines to support self-reflection.

Slide to Cure

Amazon's Mechanical Turk [3] has popularized the concept of using an online crowd as workers who can complete tasks which require human intelligence (or HITs) at a relatively low cost to companies and developers who need the work completed. The low pay for completing tasks reduces the likelihood that the available online set of workers is a sufficiently broad workforce capable of attacking any problem. Furthermore, the time it takes for tasks to get completed largely depends on the set of workers who are online who can perform the specific work at any given time and how much compensation is provided for completing the work. Although researchers have previously shown that a plausible approach to using the Mechanical Turk for completing human intelligent tasks in a timely manner is to keep the crowd actively engaged on fake tasks until a real one arises. The scalability of this approach as a long term

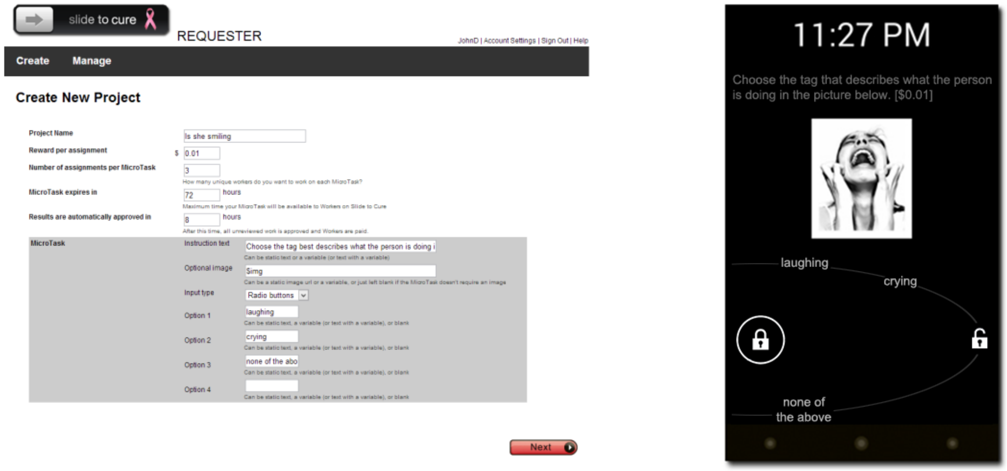

Figure 5. Slide to Cure application.

solution, however, has not been evaluated for tasks which require immediate responses but may not arise all the time (such as to help provide answers for visually impaired users [5]). Is having to pay a crowd to complete fake tasks until a real task is needed by a visually impaired user a cost that can be afforded?—the amount might seem low to the general population but not to users with visual impairments.

We have developed a website called Slide to Cure to allow people who need work done to create and deploy microtasks that can be performed by mobile phone users when they unlock their devices (see Figure 5). Similar to the application described above, after a user installs the Slide to Cure application on his Android phone, it replaces the normal keyguard mechanism setup on the phone (see Figure 5). Each time the user turns off the phone, the application connects to the Slide to Cure database and receives a random microtask which still requires work. When the user turns on his phone, the microtask is displayed as an optional task on the unlock screen, which the user can complete if he is able to and interested in doing so. Tasks which the user ignores more than three times are automatically removed from the list of possible ones to show again to that user in the future.

Our system allows for work to be completed differently from the Mechanical Turk in that work could, in theory, be pushed to an available mobile workforce of more than 1.3 billion people. The significantly larger workforce means that work can get accomplished quickly. We believe that benevolent motivations such as contributing their pay to donate to a non-profit/charity will keep the crowd motivated to complete microtasks. Although that aspect of the demonstration app is not developed, we can require requesters to register a PayPal or Amazon Payments account with their profile when they use the Slide to Cure website. As with the Mechanical Turk, microtasks are not available to the crowd until the funds needed to pay for the work have been transferred to the Slide to Cure website.

When each microtask is approved, the payment is added to the larger collection of money donated monthly to a charity. Although we suspect that the worldwide market for HITs is not yet large enough to support this many users, it is nonetheless worth considering that, were we to harness only 1% of daily unlocks (from our study, on average 52.8 per user, per day), the work capacity worldwide would be 686.4 million unlocks. Paid at $0.01 per HIT, this would represent $6,864,000 generated, per day, for charity.

CONCLUSION AND FUTURE WORK

As the project continues, we will seek out additional uses for the sorts of microtasks we have described. We will also seek to implement our platform on a wider array of devices. We will also explore other sorts of activities at the unlock screen. For example: if users were presented with two unlock widgets, one that is the 'normal' unlock, and one which would cause $0.01 to be donated to charity, which would they choose, when, and why? Along with this, we will seek to understand the relative mental difficulties of the various tasks and the effects of modulating difficulty on the cell phone usage and answer accuracy.

We will also seek to integrate microtasks into a wider array of circumstances and devices. Tablet unlocking, computer, indeed, all portable electronics, offer the potential for microtasks at login time. Further, other moments, such as idle, interruptible moments of use, might provide an opportunity for the completion of additional microtasks.

In this paper, we have described the concept of Slide to X, replacing the unlock screen of mobile phones with a screen that allows users to perform optional microtasks. We also describe our deployment study, in which 10 participants performed thousands of such microtasks over the course of two weeks. We demonstrated that users unlock their phones with high regularity, and at the vast majority of locations visited, indicating that unlock screens could potentially serve as a replacement for prompted alerts in all manner of ubiquitous computing applications. We also described our applications, which hold the potential to unlock the potential of smart phone unlocking to better support data collection, personal metrics, and HIT task completion.

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