"It's Like Being Gone For A Second"

Using Subjective Evidence-Based Ethnography to Understand Locked Smartphone Use Among Young Adults

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ABSTRACT

Smartphone use usually refers to what happens after users unlock their devices. But a large number of smartphone interactions actually take place on the lock screen of the phone. This paper presents evidence from a mixed-methods study using a situated video-ethnography technique (SEBE) and a dataset of over 200h of first-person and interview recordings with 221 unique lock screen checks (n=41). We find eight categories contextual antecedents to locked smartphone use that influence the nature and the content of the subsequent smartphone interaction. Overall, locked smartphone use emerges as a means to structure the flow of daily activities and to balance between not getting too distracted and not experiencing *fomo* (the fear of missing out). It also appears as highly habitualised, which can cause over-use and disruption. Based on this analysis, we provide recommendations on how intervention and design approaches can leverage differences in context and purpose of locked smartphone use to improve user experience.

CCS CONCEPTS

• **Human-centered computing** → Human computer interaction (HCI); Empirical studies in HCI; Ubiquitous and mobile computing; Ubiquitous and mobile devices; Smartphones; Ubiquitous and mobile computing; Empirical studies in ubiquitous and mobile computing.

KEYWORDS

Smartphone, Lock screen, Notifications, Video analysis

ACM Reference Format:
Maxi Heitmayer. 2021. "It's Like Being Gone For A Second": Using Subjective Evidence-Based Ethnography to Understand Locked Smartphone Use Among Young Adults. In *Proceedings of the 23rd International Conference on Mobile Human-Computer Interaction (MobileHCI '21), September 27–October 01, 2021, Toulouse & Virtual, France.* ACM, New York, NY, USA, 17 pages. https://doi.org/10.1145/3447526.3472026

1 INTRODUCTION

For many people around the globe, the smartphone has become one of the objects, if not the object, they interact with the most every day. Previous studies find that users interact with their phones between 10 and 200 times on average every day [26]. Crucially, when users interact with their phones, two types of interactions can be observed; locked use and unlocked use [40, 41]. Unlocked use is what is seen as the normal case where users lift the access restrictions to their device and use its full capabilities. Locked use, on the other hand, only gives users access to the 'lock screen' usually displaying time and date, notifications, and other widgets.

While unlocked use, naturally, has been studied from many angles and with a variety of methods, the investigation of locked use has been mainly focused on understanding user preferences for, and improving different authentication methods. Several studies show, however, that users check their phones only briefly in 18-35% of cases [61], and that users interact with their phones in a locked state more than half of the time [40]. Moreover, short interactions often appear to be automatic and unconscious [21, 38, 39, 61], leading users to interact with their phones more than they intend to, and even notice. It is, therefore, important to understand locked smartphone use in more detail. The relevant questions are: In which contexts and settings do users engage in locked use? How do they perceive and manage their use of the lock screen?

To address these questions and provide a better general understanding of locked smartphone use, we have conducted an *in vivo* study using Subjective Evidence-Based Ethnography (SEBE) [47], resulting in a dataset of over 200 hours of video with 894 unique smartphone use sessions, of which 221 constituted locked smartphone interactions. In this paper, we present evidence from first-person, audio-visual footage of user behaviour in naturally occurring contexts, in-depth interviews with participants based on the first-person footage, and a subsequent qualitative and quantitative analysis of the material to confirm and contrast findings from the literature and arising from the data. We find that locked smartphone use serves an important function for users to manage how they engage with their device and how they consume information. Overall, lock screen checks often occur in moments where users are focused on another activity, but wish to remain aware of the potentially relevant information that arrives on their phone. Locked use also serves as a displacement activity, and sometimes appears to occur automatically, raising questions around habitual usage patterns and problematic smartphone use. Based on our findings, we provide a categorisation of different contexts from which locked smartphone use arises and point to implications for the design of lock screens, as well as potential ways for interventions and data collection to leverage how users engage with the lock screens of their devices.

MobileHCI '21, September 27–October 01, 2021, Toulouse & Virtual, France

ACM ISBN 978-1-4503-8328-8/21/09…$15.00
https://doi.org/10.1145/3447526.3472026

2 RELATED WORK

Unlocking one's phone is a routine activity users perform many times a day to be able to fully interact with their phones. While the specific activity required to unlock a phone varies due to hardware and software differences and user preferences, the most common forms of entering a PIN, drawing a pattern, or using a biometric input all share one thing when it comes to users performing them: Unlocking happens automatically without much thought going into the process; it is a means to an end when accessing the phone, and a necessary inconvenience to protect the data stored within the phone, as well as prevent accidental inputs. The scale and magnitude of unlocking the phone is, thus, understandably easily overlooked. An estimation based on data from 2014 suggests that at least 13 billion unlock gestures are performed every day, taking up 6.2 million man-hours of sliding fingers over a distance roughly equal to the distance between the earth and the moon [72]. Without having to point out that current figures are likely to be significantly higher, it is clear that this *interaction before the interaction* is all but trivial in terms of time and effort spent, and therefore worth examining more closely.

Previous work around the unlocking of smartphones has focused on measuring frequencies and context of smartphone unlocking, describing different ways to unlock the device and differences between users, and some design work has investigated how the lock screen and the act of unlocking the device could be leveraged for increased productivity and well-being.

2.1 Measuring Smartphone Unlocking

Most studies on phone unlocking provide general 'metrics' of unlocking that allow to understand and categorise users and behaviours better. An early study found that users interact with their phones between 10 and 200 times a day on average [26]. Another study observed that the number of interactions ranged between 3 and 46 across participants with an average of 20. Usage time ranged between 9 minutes and 4.5 hours for an average total of 73 minutes of phone interactions spent per day [69]. Reporting 46 phone interactions on average per day as well, a third study showed that participants who were using some form of authentication-based protection interacted with their phones significantly more often than those who did not have any access protection (51 vs. 41 instances per day on average, respectively) [52]. A fourth study, finally, found a large variance in the average daily number of unlocks between participants, ranging between roughly 20 and 105 unlocks [72]. On average, they found that users unlock their phones 4.3 times every waking hour, with unlocks being roughly 26 minutes apart [72]. They further found that 55% of unlocks occur while participants were 'on the move' between locations, i.e., when they were in places where they do not spend larger amounts of time regularly [72].

Studies have also distinguished between locked smartphone use and actual phone unlocks. In one sample, participants activated their phones 83.3 times and unlocked them 47.8 times per day on average, translating into 5.2 interactions per waking hour of which 3 were unlocked [37]. Another paper reports that users interacted with their phones 57 times a day spending a total of 117 minutes on their devices while, importantly, only unlocking their devices in 43% of instances [40]. This suggests that participants use their phones in a locked state in many instances, underlining the importance of understanding these interactions in more detail. Initial basic numbers for locked screen use indicate that half of participants performed 9 or more lock screen checks per day on average, with the top 10% of the sample performing 52 lock screen checks per day on average [75], and that interactions with the lock screen lasted around 13.5 seconds [5]. The general uniformity of these patterns is also put into evidence by experimental software that can predict the next unlocking of the smartphone with reasonable accuracy [51].

2.2 Differences in Smartphone Unlocking

Research has also attempted to understand the differences in locked smartphone use between and within users, and what in the process users like and dislike. Research in this area developed from studies that investigated different unlocking methods primarily to address issues like *shoulder-surfing* or *smudge attacks* to improve the privacy and security of users [79–81]. Firstly, there seem to be significant age and gender differences in unlocking, with younger users more likely to use fingerprint authentication than older users [65]. Older users also interacted with their devices less frequently, which may explain why the use of a 'slower' authentication process is not perceived as an issue. Moreover, older users were more likely to be still as compared to moving when unlocking their phones. Finally, participants' gender correlated with total daily usage, session length, and choice of authentication method [65].

Research also shows that while the 'time cost' of unlocking only represented between 2-3% of the duration of longer interactions, it could take up to 80% of the time of shorter interactions, and that participants using pattern unlock spent 1.7s on average to unlock their devices, while password and PIN users took 4.1s on average [52]. Producing a similar result in terms of time use [35, 37], other studies find that PIN users were much less likely to make mistakes while attempting to unlock their devices (3.1% failed attempts for PIN vs. 12.1% for patterns) [35]. Moreover, even when users proceed to unlock their devices, they spend a certain amount of "preparation time" between activating the device's screen and beginning the authentication process to unlock the device. The mean preparation time before participants unlocked their devices was 22.7s with the majority of instances being less than 4s. In case participants did not unlock their device following a screen activation, the mean interaction time was 71.5s, with the majority of interactions lasting less than 39s [35].

Another study therefore suggested classifying smartphone sessions into three different types, i.e. *glance*, *review*, and *engage*. During glance sessions, users only wake the device to look at the lock or home screen of the phone with no other interaction. During review sessions, users interacted with their phones for 60s or less; everything beyond that was characterised as engage sessions [5]. In their sample, roughly half of interactions were glance sessions, with review and engage sessions each making up about a quarter. Interestingly, median duration of locked screen time during interactions was shorter for review and engage sessions (2s) than for glance sessions (5s), suggesting that users had already decided to go beyond a glance session when they picked up the phone, or that the made that decision almost instantaneously. Moreover, a

notification was almost twice as likely to be followed by a glance session than a review or engage session in their sample [5].

These findings are in line with the notion of smartphones as "habit forming devices", as users develop automatic and dynamic checking habits with their smartphones [61]. Further studies confirmed that users tend to spend less time on their phones when they respond to a prompt by a notification as compared to when they proactively pick them up [38, 39]. However, a detailed study on the gaps between smartphone sessions revealed that a common sense interpretation assuming a 'unity' of the nature of brief lock screen checks or glance sessions is not adequate in many cases [8]. Short activations can vary massively depending on whether they are individual interactions or are sandwiched between brief "usage gaps". Therefore, looking at the variety in locked smartphone use and the surrounding context is going to be crucial.

Following from this, the inverse question why people lock their phones, and more generally, why some users add authentication barriers to their phones and others do not has received some attention. Research indicates that about 35% of users do not add security barriers to their phones [13]. Reasons users give for not access-protecting the phone range from not caring about it or not having considered it, as well as thinking that there is nothing that needs to be protected, to worrying about the phone not being usable in an accident or in case it got lost, which would complicate returning it to the owner. More practical considerations also included ease of access and sharing the device with other users [22, 35–37].

2.3 Designing for Smartphone Unlocking

Thirdly, turning towards the application of the findings reported in the previous sections, several studies investigate how the overall usability of the phone can be improved by making use of the otherwise 'wasted' time and effort of smartphone unlocking, mostly for data collection, self-tracking, and behavioural interventions. One straightforward suggestion is to harness the unlocking action of participants for data collection, especially for brief experience-sampling methods (ESM), but also to complete large-scale human intelligence tasks or to collect personal health metrics. Different software packages include *Slide to X* [72], *Twitch Crowdsourcing* [74], and *I-Corps Lock Screen Query* [1].

These approaches aim to leverage the time and effort participants spend on swiping motions or fingerprint authentication when unlocking their phones by presenting them with a task or prompt, ranging from simple "right or wrong" questions to more introspective self-report measures that can be completed in a similar way to drawing an unlocking pattern or entering a PIN code. Moreover, the unlocking gesture can also be used for participants to indicate their willingness to participate in a slightly longer task, directly opening the application used for data collection with the unlock gesture [30, 72, 82]. Overall, these software packages were received very positively by users and resulted in a significantly higher frequency of responses and increased timely completion, while lowering perceived intrusiveness of the questions [30, 82]. This technology is not only useful to improve the quality of such data, but also holds the opportunity to generate small income streams for users and even large amounts of money for charity [72].

Figure 1: A researcher modelling the Subcam. The camera weighs only 7 grams and can be mounted on a pair of research glasses or the wearer's own (here). It has about 3 hours of autonomy with the internal, and several days with an external battery.

Finally, in line with the prevalence of lock screen checks, several studies also suggested using the lock screen as a "glanceable display" to relay health-related information or positively influence user habits. Early work used a simple, visual representation of "weekly goal attainment status, physical activity behavior, and a subtle but persistent reminder of commitment to physical activity" that was placed as the wallpaper of the phone [15, 16]. Other work has since used the phone's lock screen or background image to encourage healthy sleep habits [7], provide insights into personal health [31], or help with the acquisition of a second language [19]. In a more recent application, a Slide to X approach was used to record servings of vegetables users had eaten in combination with a glanceable representation on the lock screen [43]. The glanceable display approach was generally received positively by participants and described as a reminder to keep the "eyes on the prize" [15].

3 METHODS

Several studies report difficulties with noise in the data due to technical issues such as a distortion of usage time caused by different display timeout settings, or differences in user habits, such as switching off the phone after use versus letting the device timeout automatically [26, 40]. In this paper, we therefore propose using SEBE, a video-based, *in vivo* technique that combines qualitative and quantitative methods to study locked smartphone use in more detail [47, 48]. SEBE is especially valuable for explorative studies aiming to investigate user behaviour while it occurs, as it provides rich, contextual user data, and incorporates 'checks and balances' that avoid misremembering by participants and misinterpretation by researchers. The SEBE protocol consists of three phases: First, participants are given unobtrusive, miniature cameras worn at eye-level (*Subcams*, see Figure 1) to gather first-person video material (*Subfilms*). This enables participants to go about their lives naturally, without being disrupted or distracted, while gathering complete data on their daily experiences (first-person perspective, wide angle, stereo sound recordings). In the second step, the Replay-interview, participant and researcher watch the Subfilms together and discuss salient moments in the tapes. Here, participants can explain and reflect on what is happening in the tape, and they can object to

interpretations by the researcher and suggest alternatives as they relive their experiences. Crucially, these interviews usually unearth things that go unnoticed by participants in the course of the action as the videos can be rewound, slowed down, and stopped. Most importantly, reviewing one's own first-person perspective recording elicits accurate remembrance of actions, intentions, and emotions – similar to re-enactment or an access to episodic memory [73]. Finally, the researcher is left with many hours of situated first-person videos and a set of interviews, which can be analysed with different quantitative and qualitative techniques.

Similar to ethno-mining approaches (e.g. [2, 3]), SEBE is particularly relevant for the study of device use as it allows, unlike stand-alone interviews or any type of server- or smartphone-log method, to document the interaction of the physical and the digital environments users find themselves in, as well as both their online and offline behaviours. In the field, wearable video has been shown to provide initial insightful accounts of the use of smartphones [11, 12, 49] and smartwatches [58, 64]. Moreover, supporting interviews with logging and trace data has proven to be effective in supporting recall [28] and in contextualizing usage behaviours in "wider webs of activities" [3, 67]. The Replay-interview presents a useful addition to these approaches as the rich, first-person audio-visual material participants record leverage multimodal episodic memory in the interviews and enable participants to give detailed accounts of their activity, the context surrounding it, and their cognitive and emotional experience (see [47] and [32] for a detailed discussion).

4 DATA COLLECTION

The SEBE protocol includes stringent ethical guidelines ensuring participants' full control over the data all the way they were followed (the protocol received ethical approval from the Ethics Board at the LSE). We approach informed consent as an ongoing process as pre-formatted checklists filled out prior to data collection neither enable researchers to react adequately to issues arising while the research is being conducted, nor do they enable to update and change their consent during the research process [17, 33]. Participants were encouraged to review the material and blur or delete anything they wished, or abandon parts or all of the recordings altogether, and they were also offered technical assistance to do so if needed. Participants were also explicitly, and repeatedly, reminded about this option prior to data collection, after data collection, prior to the Replay-interview and after the Replay-interview, and consent to continue their participation was sough at each of these steps, so that the participants could rightly feel completely safe and in full control of their data. No participant made use of this option in our sample. Video recordings were then anonymised using pseudonyms and transferred to an encrypted hard disk drive to ensure confidentiality (see [23] for a detailed discussion).

Data collection took place in the UK in 2018 and 2019 with the majority of participants being residents of the Greater London area, generating an international, but mainly European sample of n=41 participants.[1] Participants were recruited through mailing lists at the LSE and through snowball-sampling. Two thirds of participants were university students, and one third (14) were working. The age of participants ranged from 21 to 29 years with 46% being female. The majority of our participants used Apple iOS devices (78%), six used Android on Samsung devices (15%), with one participant each using a Sony, Motorola, or Huawei device running Android.

Participants have been asked to wear their subcam on at least three consecutive days, collecting at least 5 h of video material. Participants have furthermore been instructed to only wear the camera in situations in which they felt comfortable and could forget about wearing it. Allowing participants to self-select when to wear the Subcam results in more natural behaviours, while also protecting their privacy, and it gives each individual the opportunity to document the parts of their lives they deem the most relevant. This has generated a data corpus spanning a breadth of activities and locations like commuting, working in the office, attending lectures at university, going to the supermarket or the museum, or spending time with friends and family (see Figure 2). Throughout we observe a rather even spread of Subfilms recorded at home, at work, and outside.

Replay-interviews lasted between 50 and 90 minutes and were conducted no more than two weeks after participants collected the subfilm material. In the interviews, we looked at every instance in which participants interacted with their phones in the subfilms and discussed reasons and motivations for the specific interaction, as well as smartphone use in general.

The interview recordings have been transcribed literally and prepared for analysis using *directed Qualitative Content Analysis (QCA)*. These transcripts make up a large corpus of complex, qualitative data, which needs to be structured and reduced to become manageable and comprehensible. QCA is perfectly suited to analyse such data, since it does not aim to fully describe the material. Rather, the goal of QCA is to carve out salient topics and unearth emerging ideas from the data corpus in a circular process, and to describe them in a coherent and systematic way [56, 57, 68], to generate valid and replicable results that are "divorceable from the authority of the researcher" [45:18]. The interviews from the initial phase of data collection (n=37) discussed smartphone use as it was naturally emerging from the Subfilm material and, thus, covered a broad range of topics around smartphone use reported in more detail elsewhere [39]. After having gained a general picture of empirical observations and participant interpretations of contextual smartphone use, we carried out a second round of Subcam data collection and Replay-interviews in November and December 2020 (n=4) to discuss moments in which it was unclear from the Subfilms why participants picked up the phone in more detail with them (proactive use; see below). Overall, the data corpus comprises over 200 hours of video material.

5 GENERAL QUALITATIVE ANALYSIS

We first present our qualitative findings based on the Replay-interviews where participants commented on their actions, intentions, and emotions as they review their own recordings. This phase informed the systematic quantitative coding of locked smartphone use in the Subfilm material, which is presented in section 6. The

[1] UK (12), Italy (5), Germany (5), France (3), India (3), Latvia (3), America (2), Russia (2), Colombia (1), Czech Republic (1), Iran (1), Netherlands (1), Singapore (1), Spain (1), Sweden (1).

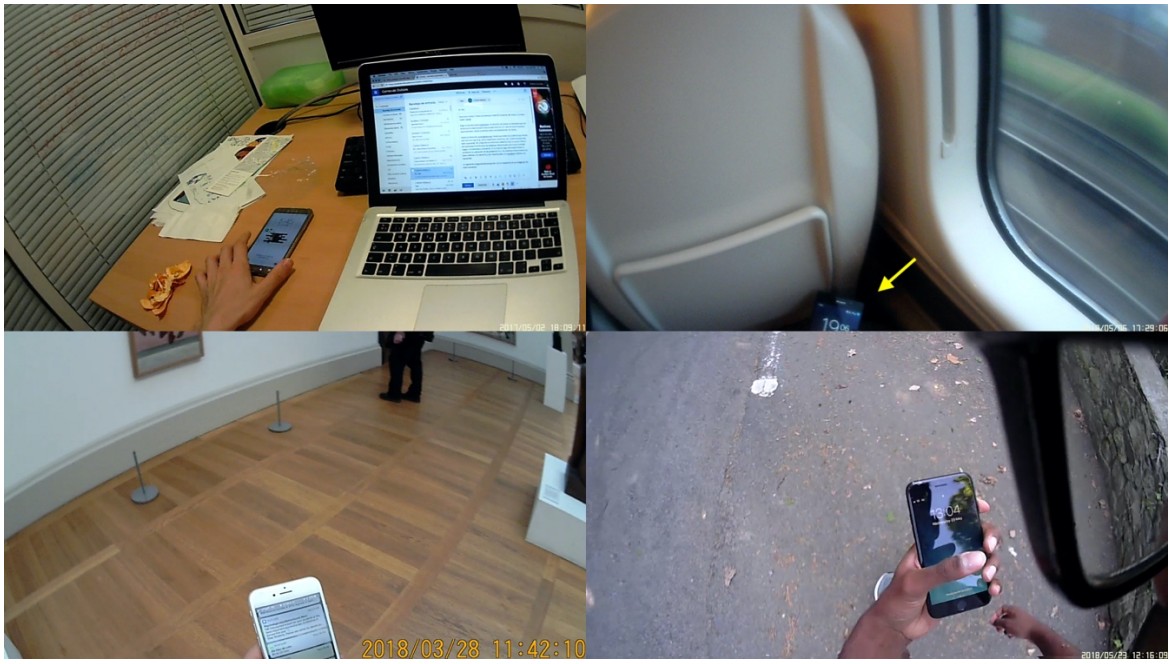

Figure 2: Various contexts of locked use (clockwise: At work, on a train, while walking outside, at a museum).

qualitative content analysis of this rich material yielded four major themes around locked smartphone use that our participants talked about: *Managing awareness*, *Displacement Activities*, *External Causes for Locked Use*, and *Automatic & Unconscious Engagement*. The detailed coding frame is provided in Appendix A1.

5.1 Managing Awareness

The first and most frequently discussed explanation for locked smartphone use participants gave was that it provides awareness of relevant information at the discretion of the user. This mainly refers to the ability to 'stay on top of incoming notifications', but also included other widgets commonly included on the lock screen, like time, weather, or calendar and traffic alerts.

Participants use lock screen checks to monitor their phones when they are waiting for a specific notification such as a reply to a message or a delivery confirmation for a parcel without having to go through the process of unlocking and fully engaging with the device. In addition, locked use also is a means to check for messages that are not explicitly expected. In this way, participants make sure that they stay informed and do not experience *fomo*, the fear of missing out on interesting or urgent information their phone provides them with [29]. One participant, thus, poignantly mentioned:

> "I think we're constantly conscious that someone might have sent a message." (P29)

Participants also used the lock screen to manage how they access their phone and what type of information they receive, and to avoid the phone intruding on their other activities. Many of our participants selectively tailored which apps or even which specific chats would be displayed as notifications on their lock screen, to make locked use even more efficient for their purpose. We generally observed two strategies: Some participants "pre-programmed what's important" (P19), minimising the overall amount of notifications that show up on the lock screen and making sure that those that do are important. Others also included notifications with information that they did not regard as urgent or important, but which they felt they would otherwise not get ("football news for example, which I would completely miss out on otherwise."; P5). In both cases, reading the information on the lock screen often provided sufficient awareness for participants to not take immediate action. Some participants also selectively deleted notifications from the lock screen either because the information was not needed, because reading it on the lock screen fulfilled its purpose (e.g. traffic alerts, short news headlines), because the information was not regarded as 'urgent' or 'priority' and returning to it at a later point in time was sufficient, and also to intentionally keep those notifications that remain on the lock screen as a reminder.

Regardless of the specific strategy, the lock screen provides our participants with *awareness of* information directed towards them, allowing them to deal with it more flexibly and to reduce potential disruptions to their other activities by the device. On a side note, turning off lock screen notifications for certain apps also sometimes meant that users had to unlock their phones and actively open specific apps to check for new notifications, which is more costly in terms of time.

Lastly, on a more abstract level, participants also reported using lock screen checks for impression management. On one hand, participants discussed the tension between wanting to not be interrupted by notifications and wanting to reply to important messages quickly to appear as hard-working and "on top of work" (P10) to clients, managers, and colleagues. On the other hand, participants

also sometimes only read notifications on the lock screen because the other party would not receive read receipts, and they reported that they decidedly do not respond to a notification at times for example to appear busy, to wait for other people to comment first in a group conversation, or to 'make the interlocutor wait', usually with partners or on dating apps.

5.2 Displacement Activities

Another theme emerging from the discussions with our participants was the use of lock screen checks as a displacement activity (see [6] for an overview). Most participants reported that they would check their phones more towards the end of their workdays when they were getting tired, and when they were getting bored with a specific activity:

> "I'm trying to concentrate on the statistics, but every 5 minutes I'm looking at what is happening on the phone - 'Can someone take me out of my misery...'" (P18)

These checks offer a quick and easy way for participants to find an excuse to take a break from working. The phone also seems to be the object that participants direct their attention to when they are having difficulties to focus. Note that in these cases, participants are not merely looking to find a reason for an unlocked interaction and lock screen checks only represent a failed attempt at displacement. Participants also re-read existing notifications, manage the information on the lock screen and play with the phone's screen (see section 5.4) rather than unlocking the device precisely because they know they need to continue with their other activities. Fully unlocking the device appears to be perceived as more intense escapism by participants than 'only' engaging with the lock screen for a moment.

Some participants, moreover, also reported briefly checking their devices in moments they felt anxious or uncomfortable. This applied to social settings when participants did not feel included in the group or did not know how to contribute to the conversation, and especially in work or university meetings when they felt scrutinized or unable to answer questions. The phone was, thus, characterized as a pacifier, and lock screen checks were described as a way of "being gone for a second" (P16).

5.3 External Causes for Locked Use

Several participants also hinted at situational and environmental cues that lead them to briefly check their devices. When participants took breaks from an ongoing task to stand up, stretch, open a window, etc., they often briefly checked their phones. Moreover, one participant also commented that a brief interruption to scratch herself, and the resulting process of moving her body and arm led her to perform a lock screen check on the phone that was lying next to the laptop she was working on.

Similarly, environmental disruptions that divert the attention of participants from their main task for a moment, such as a noisy washing machine, colleagues having a conversation, or a change to the lighting situation in the room (e.g. caused by motion sensors or clouds passing in front of the sun), often resulted in participants briefly checking the phone before returning to their previous activity ("Too much chit-chat around me, so I quickly check my messages. Nothing there. Back to work."; P4). Brief interruptions to the flow of the ongoing main activity, either arising from the natural progression from one activity to another, or from external factors, thus appear to be moments where participants briefly check their smartphones because they are not clearly focusing on a specific task or have already lost focus of their previous activity due to external reasons.

5.4 Automatic & Unconscious Engagement

Fourth and finally, however, participants were unable in many instances in the Replay-interviews to give a clear explanation for why they interacted with their phone in a specific moment and reported that checking the phone often happens unconsciously. Lock screen checks were thus described as an automatic behaviour without a clear goal or reason, and something that "just feels normal" (P27), and the phone was even described as being "like a part of me" (P24).

One participant also interestingly mentioned that playing with the widgets and the unlocking pattern on his phone (Android pattern unlock) was calming and "almost therapeutic" (P3). It thus appeared that participants were usually able to remember what they did with their devices and why, but in several cases they did not know why the picked up the device in the first place. We therefore carried out another round of data collection aiming to gain some more insights on these unclear moments.

Focusing specifically on unclear moments ('proactive glances'; see section 7.1 below) captured in the Subfilm in our second round of data collection, participants were able to provide clarifications in some instances in the interviews, typically for moments where they had either spontaneously remembered that they had something to do with the phone (e.g. reply to a message, look something up), or where they were not actually focusing on the activity they appeared to be engaged in the Subfilm and were already thinking about the phone (e.g. while watching TV). However, even during this focused investigation we were unable to reconstruct the reasons for many instances of locked phone use, and our participants indicated that they did not know why they interact with their devices in these moments:

> "And sometimes I would l just check the phone as an automatic gesture. Because I realize it's not like other times here, not like a conscious thing. 'Oh, I want to check this notification or I just want to go to Instagram or whatever'. I don't know, it is just like a passive thing that I do." (P39)

Overall, this suggests that briefly checking the lock screen of the phone has become habitual and is not a conscious decision at times, as indicated by participants, and locked use seems also to be a way in which participants check the phone during breaks between activities.

6 GENERAL QUANTITATIVE ANALYSIS

Following the qualitative analysis, we followed an ethological approach for the quantitative analysis of the Subfilm data, first of all to show trends, patterns and differences in smartphone use among participants. For every instance during which participants used their smartphones on tape, we recorded duration, time elapsed

since last phone interaction, location, type of interaction, where the phone was in the physical space, the context they were in (e.g. working at the office, commuting), whether there was a notification (and if so, what type), and the nature of the activity. Overall, this resulted in a dataset of n=894 unique smartphone use sessions, of which 221 (24.7%) constituted locked phone use.[2]

All participants engaged in locked smartphone use and we observed between 2 and 17 lock screen checks per user with an average of 6.5 lock screen checks (standard deviation 4.5) and roughly five hours of Subfilm material per person. Lock screen checks ranged between 1s and 22s and lasted 4.2s on average (median 3s, standard deviation 4.1s). Given the nature of our data and our sample size, we investigated the relationships between the key variables around smartphone use we observed using non-parametric tests (Fisher's exact test and the Kruskal-Wallis H-test where appropriate). We have, however, not applied a Bonferroni correction of p-values, as we do not believe the number of tests performed in a paper influences the ability to make inferences from individual tests (see [63] for a detailed discussion). We have thus relied on a value of $p < 0.05$ to determine the statistical significance of our findings in the following.

First, we tested for a relationship between the time since users had last interacted with their phones and locked use. The results are highly significant, with the mean time since the last interaction with the phone being longer before lock screen checks (180s vs 163s, $H(1) = 4.277$, $p = .039$). Second, we find a significant interaction between notifications and lock screen checks in our sample. While 23% (181/789) of interactions are lock screen checks when the interaction was initiated by users, 31.9% (40/105) of interactions are lock screen checks when a notification led to the interaction ($p = .001$). Third, looking at the potential influences of time of day, we did not observe significant differences in frequency of locked use throughout the day in our sample (06:00-12:00, 12:00-18:00, 18:00-24:00; $H(2) = 2.850$, $p = .241$), ruling out direct effects of fatigue or daily cycles of participants on lock screen checks. Fourth, on the other hand, we do find an influence of work on locked phone use. When participants were working, slightly more smartphone interactions were lock screen checks compared to when they were not working (28.1% (110/392) vs. 22.1% (111/502), p = .025). Fifth, we also looked at the differences in locked and unlocked use for different locations participants were in. We observed significantly less locked use when participants were in public transport (5.9% (2/34) vs. 25.4% (219/860), $p = .004$), and significantly more locked use when they were outside (35.5% (22/62) vs. 23.9% (199/832), $p = .033$), but no differences when they were at home (23.5% (113/480) vs. 26.1% (108/414), $p = .211$), or at work (27.3% (58/213) vs. 23.9% (163/681), $p = .188$). Finally, in contrast to previous studies, we did not find a significant effect of participants being alone or in company on locked phone use (24.4% (104/426) vs. 25% (117/468), $p = .450$).

[2]Unfortunately, the Subfilms for three participants were corrupted in the transfer process after the interview, leaving us with data from 38 participants only for the quantitative analyses.

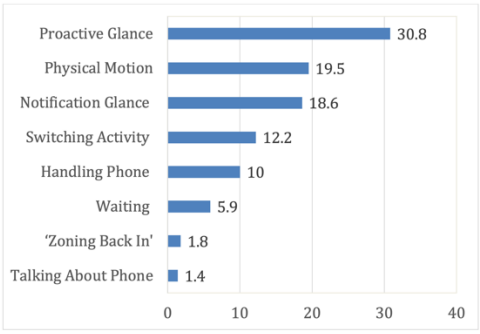

Figure 3: Eight categories of different contextual antecedents to lock screen checks in the sample in percent (n=221).

7 MIXED-METHODS ANALYSIS OF CAUSES & ANTECEDENTS OF LOCKED USE

After analysing the Replay-interviews and coding the general descriptive variables of locked smartphone use in our Subfilm sample, we took a closer look at the moments immediately prior to the instances of locked use our participants recorded in the Subfilm. Based on participant comments in the Replay-interviews, our qualitative analysis, and the contextual factors captured in the Subfilms, we classified the individual instances of locked use in our sample into 8 different categories of 'contextual antecedents' (see Figure 3). These categories reflect how different instances of locked smartphone use arise from the flow of activity of participants. After an initial round of coding the videos, a framework of coding instructions was produced (see Appendix A2), and the videos were double-coded independently two more times by two researchers. In the first round of double-coding, we found an inter-coder reliability of 81% (Krippendorff's $\alpha = 0.74$) [46]. We then updated the coding instructions and merged two categories because of overlap, which resulted in a 94% agreement for the second round of coding (Krippendorff's $\alpha = 0.91$). The remaining mismatches were reviewed jointly by coders and resolved. The following sections focus on the different contextual antecedents of locked smartphone use and provide an in-depth description of what actually happens when participants briefly check their phones in situated contexts.

7.1 Proactive Glance

The most common type of locked screen use in our sample is the 'emblematic' notion of the lock screen check, where participants proactively interrupt the flow of their current activity to check their phones. These checks are not, by and large, performed as a response to an external prompt, or following from a prior 'build-up phase'. However, we did observe that major changes in location while participants were on the move led several participants to perform proactive lock screen checks, most notably getting off public transport or entering the workplace. In the Replay-interviews, participants were usually not able to explain why they checked their phones in moments categorised as proactive glances, and sometimes exhibited surprise, but usually referred to the activity having become automatic and unconscious:

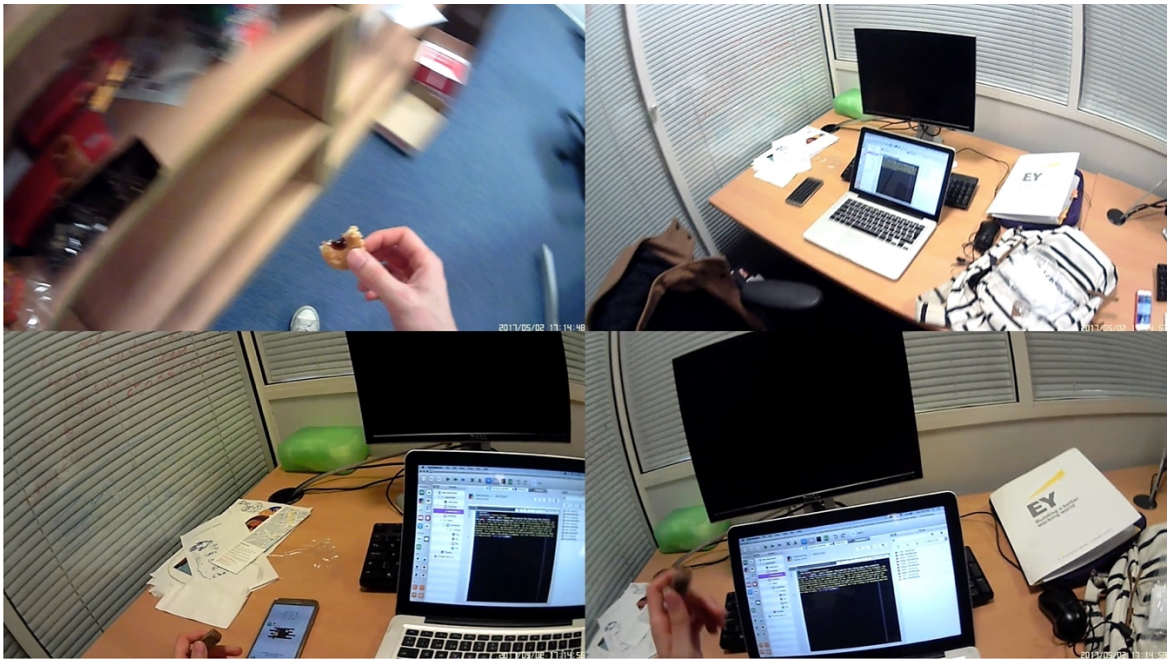

Figure 4: A participant fetching a biscuit and checking their phone after sitting back down (top left to bottom right).

> "I think it's one of the times that I kind of mindlessly, not exactly mindlessly, but I don't know. I have this automatic thing that I check my phone every once in a while. I think it's because, yeah, I'm supposed to be working and I want to make sure that I got no notifications." (P37)

> "So I looked at my phone and didn't do anything. I have no idea what I did. I just went and had a look." (P14)

And while we did not find a significant difference in the likelihood of proactive glances being followed by locked or unlocked use (24% (68/283) vs. 25% (153/611), $p = .406$), the overall prevalence of proactive lock screen checks (7.6% of all smartphone interactions in our sample) reflects participant sentiments around unconscious and automatic use.

7.2 Physical Motion

Another common trigger of locked screen use was when participants had interrupted themselves and were already moving in close proximity to the phone, especially when they were moving their hands, or when their physical motion caused the phone to enter their field of vision. Illustrative examples were picking up or putting down objects like a mug or a tv remote in close physical proximity to the phone, or sitting down with the phone within arm's reach (see Figure 4). In cases where participants checked their phones after being in motion already, they usually did not have an immediate main task they were pursuing, or have taken the decision to take a short break already, which allows the phone to intrude into the flow of activity:

> "I go on it just out of boredom. I'm not even looking at the screen properly, it's just out of nothing better to do." (P21)

> "I was sort of scratching myself and then just picked the thing up." (P39)

Lock screen checks following physical motion again support the automatic character of regular brief checks of the phone our participants talked about in the interviews. They further sit well with participant comments on external interruptions; and it appears that the phone intrudes into the activities of users, but also that they become aware of the device and the opportunity to briefly check their phones once they have already interrupted what they were doing. Further inquiry as to whether this leads them to check their phones briefly only, or whether they engage with their devices fully is necessary, however, as the statistical difference is close to, but not fully significant (30.5% (43/141) vs. 23.6% (178/753), $p = .054$).

7.3 Notification Glance

The third most common type of locked phone use, glances in response to audio-visual cues sent by the phone, are the only type we observed that is not initiated by the user. In our sample, receiving a notification immediately led participants to interrupt their current activities, with the mean time between arrival of notifications in the Subfilms and participants picking up their devices being 2.1s (standard deviation 2s).

> "I try and put it a bit away but obviously if a message pops up then I want to answer right away. Not that I always do but I want to." (P26)

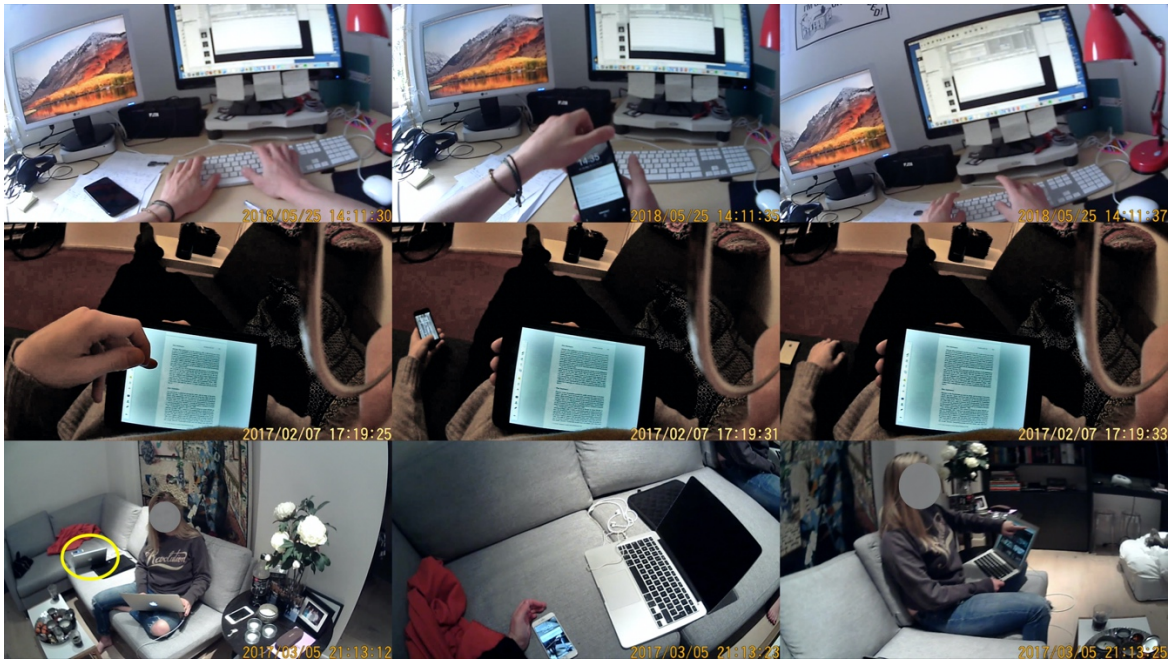

Figure 5: Three instances of lock screen checks (top to bottom): Notification glance followed by deleting unwanted notifications from lock screen, Physical motion check after moving hand to turn page while reading, phone moving into the visual field of the participant (yellow circle) while talking to a friend followed by sitting down. Note the time stamps as well.

> "I checked it again here, for the same stupid reason. Because a notification could be anything. Could be WhatsApp, Telegram, Facebook..." (P28)

We also observed that participants visibly jolted their heads to move the device into their visual field as soon as a notification arrived. However, in roughly 40% of interactions that followed a notification, participants just read the notifications, swiped the lock screen up or down, or removed the notification from the lock screen without engaging with the prompt in more detail (see Figure 5, top row). This replicates previous findings on notifications and locked use [5], and reflects participant sentiments that most notifications do not require an immediate response. Notification glances also support the notion that locked use is a means for users to balance the capacity to be alerted to new information with the option to not fully engage with it in the exact moment. The finding that locked use follows almost twice as much as unlocked use when the interaction is triggered by a notification, compared to when participants interacted with their phones for other reasons further underlines this (39% (41/105) vs. 22.9% (180/789), $p < .001$). We also find that notification glances are more likely to occur while participants were working, compared to when they were not (30% (33/110) vs. 8.1% (9/111), $p < .000$), which is in line with participant sentiments around using the smartphone as a displacement activity during work. Notifications that arrived while participants were working were, however, perceived as "embarrassing" and "annoying to colleagues", and we accordingly find that participants were more likely to set notification delivery to visual only compared to sound, vibration, or a combination of the three in these moments (85.7% (54/63) vs. 68.6% (338/493), $p < .000$).

7.4 Switching Activity

Participants also performed lock screen checks when switching between different activities. In 'digital contexts', brief locked screen use followed events such as sending out an Email, or switching to a different software:

> "It's just a moment where I don't think. But it's also curiosity, what are my friends doing? But not even that... Yeah it is almost automatic: 'Ok. Break, drink, [pretends to pick up phone]. Nothing interesting happening, [pretends to put phone back down], focus."' (P17)

We also observed locked use after a wide range of switches in real world activities such as cooking, tidying up, or looking at paintings in a gallery. Turning the page while reading stands out as an exemplary case of a short break within an activity that routinely leads users to engage with their phones. Similarly to when participants were moving already, brief lock screen checks in between activities often appeared habitual and automatic, and enabled users to make sure with a quick glance that they are not missing out on important information:

> "I just collect the notifications on the [lock] screen, and I can select myself when I see them and when not, so to speak. I collect them and then I delete those I don't want to see anymore." (P5)

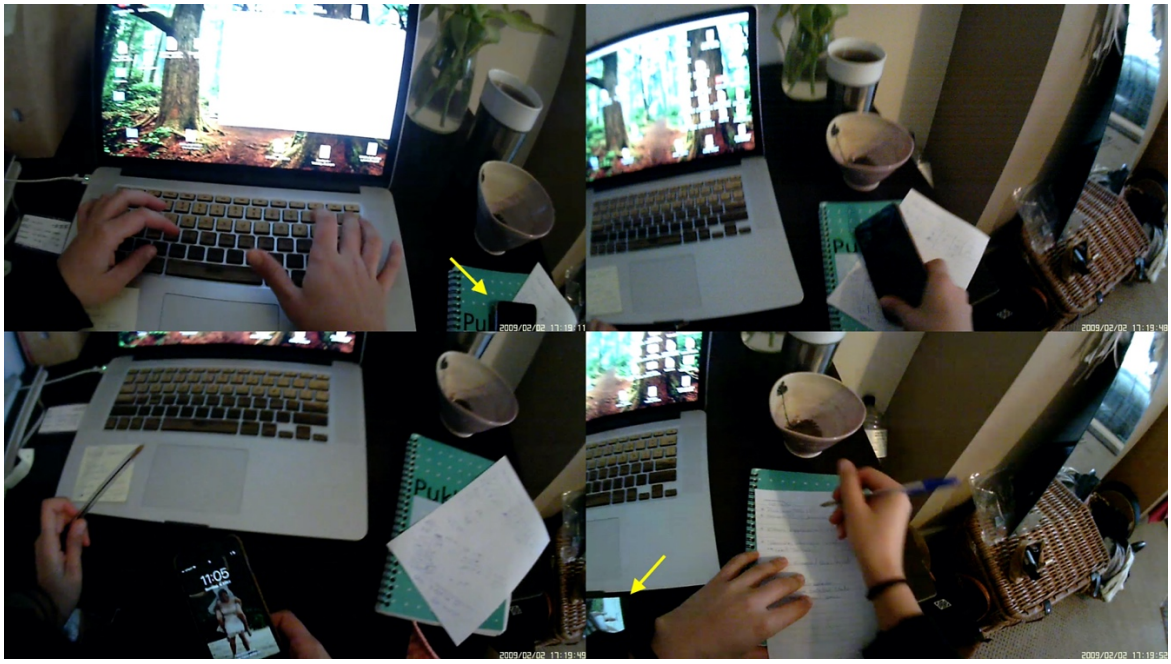

Figure 6: Lock screen check after moving the phone out of the way to access writing pad.

However, switching activities significantly more often led to fully-fledged, unlocked interactions in our sample (26.8% (194/723) vs. 15.6% (27/171), $p = .001$), which confirms participant comments around using the opportunity to fully engage with their phones when there is a break or another opportune moment:

> "Sometimes it's like: 'Oh, I've gotten this thing done. Now I can take a small break. Oh, I'll look at my phone as a sort of small break!' And then I'll maybe check WhatsApp cuz I have a few groups and my boyfriend texts me of course." (P17)

This is also supported by the finding that duration of smartphone use is significantly longer for interactions that occurred when users were switching activities (38.4 vs. 32.1s; $H(1) = 7.394$, $p = .007$).

7.5 Handling Phone

Another situational trigger of locked phone use was when participants were handling their phones as physical objects without the intention to use its affordances. Typical cases comprise rearranging objects on the desk and, thus, moving the phone, picking up the phone to place it in a bag or pocket, or connecting the phone to a charging device (see Figure 6). Naturally, locked use followed proportionally more often after participants were handling the phone than unlocked use compared to other lock screen checks (51.2% (22/43) vs. 23.4% (199/851), $p < .001$). We also observed that lock screen checks following handling the phone often occurred even though participants had used the device only moments before, when they could have a reasonable degree of certainty that no new information would be present. This, again, supports the narrative of automatic and habitual engagement with the phone:

> "Well, I guess I had it in my hand already, so I peeked and then put it out of the way." (P33)

7.6 Waiting

The sixth type of locked screen use we observed followed brief periods of idleness, typically while participants were waiting for their computers to download or launch something, but also in everyday activities such queueing for a coffee. This reflects the sentiment expressed by participants that they want to optimize the use of their time in situations where they have nothing else to do:

> "No, I don't think there was a vibration. I'm just swiping away some notifications so I don't see them anymore. I think I'm just waiting for the computer." (P6)

Moreover, one participant poignantly described that they checked their phone because they did not want to *look like* they have nothing else to do: "I'm just going on it because I'm awkwardly standing in line", (P27). Smartphone use while participants were waiting therefore also supports the notion of lock screen checks as a displacement activity. And while the slightly higher proportion of locked use compared to unlocked use in situations of waiting we observed suggests that users often did not find anything to do with their phones, the difference was not statistically significant (34.2% (13/38) vs. 24.3% (208/856), $p = .118$).

7.7 'Zoning back in' and Talking About Phone

The last two types of locked phone use only make up a small percentage of our sample, partly also because they are difficult to observe. Nevertheless, we found it important to report on these as well. On a few occasions, participants had 'zoned out' for a moment, e.g. staring onto a wall or out of a window being completely idle,

or fully falling asleep (which we have only been able to capture on tape once). Once they returned from that idleness, usually marked by shaking their head and heavy breathing, participants immediately checked their phones, both as a clock but also to see whether messages had arrived. Yet, in none of these cases, even where notifications had arrived, did they unlock their phones immediately. Instead, they took a moment to fully get back to their senses before interacting with their phones in an unlocked state. These findings resonate with participant comments on the intimate relationship with the phone and sleep: For example, it was mentioned that "the phone is the first thing I check after I wake up" (P18) and "the light of the phone helps waking up the eyes" (P10). Again, these findings also hint at the compulsive nature of the *fomo* that leads participants to interact with their devices. Lastly, when phones or apps were mentioned in a conversation by participants or interlocutors, both as a general topic ("Have you heard that the WhatsApp servers were down all over Europe for 30 minutes yesterday?") or targeting the user's device in specific ("Should I send them a text and ask if they want to grab a drink tonight?"), participants tended to perform a lock screen check.

8 DISCUSSION

8.1 General Discussion

Our analysis revealed that lock screen checks are much more than just a quick glance for users. We find that about a quarter of smartphone interactions represent using the phone for a very brief amount of time (3-4s on average) in a locked state. With a range between 2 and 17 lock screen checks per user and an average of 1.6 instances of locked use per hour, our results reproduce earlier findings, albeit at the lower end of the spectrum [37, 40, 75]. From the perspective of the participants, lock screen checks enabled them to time-efficiently manage their awareness of new information that arrives on their phone, helping them to cope with the demands of their daily lives but also to effectively deal with *fomo*. These sentiments are in line with our quantitative findings, showing that intervals between smartphone interactions were longer before locked use, and that locked use was more likely to occur when participants were working. Thus, especially when participants were engaged in longer periods of focused activity, they utilise lock screen checks to balance the desire to be focused with the worry of missing important information.

This is also reflected in the finding that lock screen checks were more likely to occur when users themselves initiate the interaction with the device compared to notifications. The majority of participants reported that they would silence their phone in one way or another when they had to be particularly focused, to not get distracted by it. While muting the device enables participants to reduce the amount of times they are being interrupted by their phones, this also creates the need to proactively check the device to stay aware of incoming notifications, for which the lock screen check seems to be the most convenient [see 29,30].

Interestingly though, we observed that locked use following a notification was twice as likely to occur when participants were working in our sample, reproducing earlier findings [5]. This suggests that they are willing to make a trade-off and allow short interruptions to their work activities to occur in exchange for being alerted to new information promptly and being able to choose whether to engage with it or not. It is important also that working usually entailed sitting at a desk for most of our participants, with the phone positioned in their peripheral vision, notifying participants of new notifications not through sounds or vibrations, but only by activating the screen. Thus, when participants were working, the phone clearly served as a glanceable display, which has important implications for design (see section 8.3).

The location participants are in also influenced locked use in our sample. While we did not observe a significant influence of participants being at home or at work on locked use, participants engaged in locked use significantly more often when they were outside, and significantly less often when they were on public transport. As commuting often leads to longer periods of idleness, participants either fully engaged with their phones or spent their time doing other activities (e.g. reading, listening to music) in our sample. This reproduces earlier findings on short bursts of smartphone use while being 'on the go', and longer interactions while being stationary [27, 49], but adds an important nuance for public transport, as commuting can be seen as a part of being on the go but appears to constitute idleness for users.

We further observed that our participants often used their phones during natural breakpoints in the flow of their activity, when they were switching from one task to another. In these instances, we found that participants significantly more often engaged with their devices in a full, unlocked way. This suggests that these moments provide an opportune moment to fully engage with the information that has arrived since their last unlocked interaction with the device, but has not required and immediate response or interaction. And it is exactly this information which participants had, in turn, ascertained and managed with lock screen checks previously. Again, the ability to use the lock screen as a glanceable display to come to quick decisions whether immediate action in response to a specific piece of information that has recently arrived on the smartphone seems to be one of the core functionalities of how participants in our sample engage with their devices. Locked smartphone use, thus, allows participants to alternate between full unlocked interactions that require more focused attention and are more time-consuming overall, and brief glances that allow them to return to their other activities quickly and to increase the duration of the intervals between instances in which they have to direct their full attention to the device.

On the other hand, we also observed that brief smartphone interactions sometimes are not so clearly purposeful or focused on efficiency. Participants described regular checks as automatic and unconscious, while holding, touching, and swiping on the device's screen were characterised as natural and therapeutic. Here, the categories of locked use we identified tell an illustrative story of the phone as a *habit forming* device [61]. Roughly half of all lock screen checks in our sample (51%), apart from notification glances, which are a response to the device's functions, and proactive glances, occur as a response to contexts or environmental cues which participants have consciously and unconsciously earmarked for themselves as moments in which they can engage with the device. Locked use after setting down a glass or switching between work tasks on a computer are illustrative examples of this. Importantly, we find

strong evidence that these habits are not merely, and perhaps not even mainly, driven by and rooted within the framework of the software of the device (e.g. swiping down to refresh the Email inbox), but in the hardware and the surrounding context in which users and devices are embedded. Given that the contextual cues associated with the different antecedents of locked use we have identified are ubiquitous in the daily lives of participants, it is not surprising that the majority of participants do not perceive what exactly causes the urge or 'brings to mind' the thought to pick up the phone. This is the reason why smartphone use is experienced as natural, automatic and almost unconscious by participants. However, with almost a third of the lock screen checks in our sample being proactive glances, and participants usually unable to give a concrete reason why they interacted with the device in these instances, it will be crucial to examine these moments in more detail, together with users, to develop a way towards how these interactions, and what causes them, can be studied.

An interesting starting point for further inquiry emerging from our data seems to be the salience of the device for participants. Whenever they had lost focus of their main activity, or their main activity ended, it appeared to be the phone that immediately attracted their attention in our sample. Moreover, a phone being talked about was sufficient in many cases for participants to engage with their devices, if only briefly.

Another potential explanatory factor can be found in our participants' descriptions of using the phone as a displacement activity. Following from the ethological observation of the behaviour of animals who, caught between two competing urges, find relief in a third, unrelated activity [70, 71], locked smartphone interactions in our sample that occurred when participants were idle or waiting for something out of their immediate control seems to reproduce these patterns. Also, proactive lock screen checks could arise from a tension between conflicting desires, and some participants provided indications that they check the phone as a means to escape an uncomfortable situation, for example when they were unable to answer question but felt that they should be, or when they wanted to get a specific task done but disliked or struggled with the work required to do so. However, in our second round of data collection focusing specifically on proactive smartphone use, participants did not usually report that they interacted with their smartphones as a form of displacement in these moments. Hence, further investigation as to whether this is indeed the case or not, whether participants struggle with remembering or even consciously taking note of moments of cognitive tension that drive them towards displacement, and how the difficulty with recording this could be remedied will be required.

8.2 Classifying Smartphone Interactions

Overall, we also found ample evidence for the usefulness of classifying smartphone interactions into different types such as *glance*, *review*, and *engage*, based on their nature and 'intensity' as suggested in [5]. However, in our study, locked use (=glance sessions) made up only a quarter of all interactions rather than half. More importantly, however, based on the fine-grained differences in locked use we observed, our data suggests that both a lot of 'reviewing' as well as 'engagement' actually takes place during glance sessions,

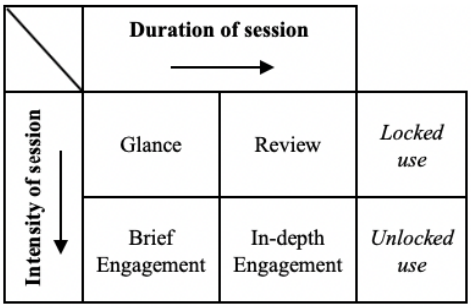

Figure 7: Classification of types of smartphone interactions.

that is, locked use, which renders the naming of the categories counterintuitive. We suggest the label *glance* session should only apply to the shortest of instances of locked use in which users look for notifications or the time, do not interact with the touch screen, and move on with their activities immediately after the phone screen lights up. *Review* sessions would then apply to locked usage during which users spend more time on their phone, actually read notifications, or manage the information on the lock screen. Unlocked use should differentiate between brief interactions (the original *review* session category) and more in-depth interactions (the original *engagement* session category). The label 'engagement' could then be supplemented with qualifiers such as 'brief' and 'in-depth', or replaced by a label focusing on the number of apps used or different activities performed, as we observed 'engagement' and proactive use in other categories as well. Overall, this classification would yield a typology of two types of locked use during which users manage awareness (*glance* and *review* sessions), and two types of unlocked use during which users engage with information (*brief unlock* and *in-depth use* sessions), differentiated in their respective duration and intensity of interaction, which would, based on our data, more adequately represent the rough categories of smartphone interactions (see Figure 7). In a next step, when discussing habits around smartphone use more broadly, it will be highly informative to look at the antecedents of unlocked use as well and draw a more detailed comparison between locked and unlocked usage habits and cues (e.g. for switching between activities, which seems to trigger unlocked use, or proactive glances, for which the evidence is less clear). It will then, furthermore, be possible to look at the different types of smartphone use and see whether certain types of antecedents are more or less likely to lead to certain types of interactions.

8.3 Implications for Design and Interventions

Based on this analysis, we will now point to several pathways for design and interventions. Our data shows that being sedentary or spending longer periods of time at one place when users are not working is much more likely to lead to unlocked phone use when the device is picked up; when users are moving around or working, more brief instances of locked use follow, which also makes sense intuitively. From a design standpoint, ESM or Slide to X applications could tap into device data on whether people are moving or sedentary (which could also be supplemented with

GPS patterns, but not everyone works in the same office every day). If repeated locked use occurs, users are probably working and want as little distraction as possible. When they are moving, they might be looking for specific information, but there is a chance that they would be willing to briefly interact with the phones when they are just walking around. Here, again, using data from the phone's sensors and position data to present information based on location, preferences, and predicted state the user is in may increase willingness to engage and overall take up, and reduce perceived disruptiveness.

Locked use also appears to be more likely to follow after the arrival of a notification. In line with participant interpretations, many notifications only require a quick glance rather than a full, unlocked interaction, and they use notification glances to manage their awareness of incoming information. However, although this allows participants to not miss out on and respond timely to important information, putting the phone into a setting that allows notifications to be delivered noticeably also causes more instances of external disruption where the information provided is not relevant, either situationally or generally. This is problematic because studies on interruptions show that users only return to their original activity after an interruption in 40% of cases [59], that they take more time and make more errors completing it after being interrupted [10], and that they are more likely to self-interrupt after having been interrupted externally [18]. Moreover, external interruptions have been shown to increase feelings of stress, time pressure and frustration, as well as perceived effort and workload [53].

Based on our observations, locked smartphone use following notifications shows a clear direction for notification design to revise the affordances of the device to reduce negative user experiences. And while ways to reduce the amount of interruptions by the device have of course been explored already to reduce interruptions (e.g. [19]), it is important to bear in mind that the phone not delivering messages will increase fomo and lead to subsequent self-interruptions. Therefore, systems that enable users to distinguish between different types of notification delivery for different applications and to easily prioritise them over each other in specific moments appear especially promising and could leverage findings on decreasing the overall disruptiveness of notifications, for example around batching [29, 54], predicting appropriate breakpoints [25, 60, 62, 76], and offering different and new types of notification delivery [42, 44, 50, 66]. Users could, thus, distinguish between information that they want 'forced' upon them, be gently alerted to, and information that only needs to be included in the 'digest' the next time they check their lock screen to manage their notifications.

Moreover, more complex ways to interact with notifications on the lock screen check have already been shown to make device interactions more efficient [5, 55], and while responding directly from the lock screen, for example, has been incorporated into most systems, features that allow for more complex sorting, clustering, or setting delayed reminders, for example, could be a fruitful way to incorporate the desire of participants to use the lock screen to manage their awareness of incoming information into software design. It is important to note, however, that a study has found that users may not actually make use of these more fine-grained settings when they are being given the opportunity [77], which means more effort than simply providing these features may be required.

For *switching* or interrupting activities such as intellectual work tasks, but also everyday activities such as cooking, however, we observed a significantly higher chance for unlocked use to follow. It seems that users take the time to reset and relax their brains in between tasks and take short breaks. In these moments, participants engage with the information that the notifications they have often been managing on their lock screen prior to this full interaction represent, and the more complex sorting and response options described before can unfold their full effect for an efficient and enjoyable users experience. At the same time, they also describe being conscious that these breaks can spiral out of control and take much longer than planned. It appears that when users take their phones and are willing to unlock and properly engage with them, they are also in a receptive state of mind. This presents an excellent design lever for ESM and Slide to X approaches. Application designs could thus seek to harness participant desires for these breaks and try to provide tasks or content that combine the purpose of the application with the user's willingness to take a break, functioning as little 'brain teasers', while also highlighting that the type of break they are offering is more likely to be rewarding than uncertain scrolling through information on social media. More importantly, such approaches could emphasize the temporally limited nature of these breaks to not cause negative consequences for users by getting them 'caught in the loop' and causing cyberslacking [38]. A straightforward application of this could be an unlocking choice that allows users to swipe to choose a time for when they receive a reminder that their 'break time' is over (e.g. 1, 3, or 5 minutes), or to choose between different HITs (reading an article, filling in a survey, etc.) or different components of the ESM instrument (quick multiple choice or in depth-diary) to complete during the break depending on their length.

On the other hand, the automatic and unconscious instances of locked phone use, following after *handling the phone*, *physical motion*, and *proactive glances* are key examples for the automatic behaviours that are perceived as disruptive by participants and often do not generate informational gain or any other added value for users. From a design point of view, suppressing questionnaires or HITs on the lock screen when the phone is being connected to headphones or a charger, for example, could be used to try and increase acceptance and lower perceived disruptiveness for participants.

However, given that about half of the brief smartphone use we observed occurs automatically, triggered by habits or contextual factors, and keeping in mind issues around *fomo*, it is clear that changing the design of the device can only partly address these problems, which is why the user should be moved into the centre of the stage for interventions that aim to reduce problematic smartphone use and the perceived disruptiveness of devices. From an intervention point of view, these are the interactions that lead to negative feelings towards the phone for having it in one's hand constantly without knowing the reason why. They should, thus, be tackled to improve participant representations of the phone, and healthy device use overall. A starting point could be the previously tested *glanceable display* approach, e.g. changing the background of the lock screen to include a reminder to use the phone less or

regularly display metrics based on usage statistics (see for example "Screen Time" on iOS).

The numbers of instances of *waiting* we observed in our data were relatively low, so we can only make some tentative suggestions. Studies on interruption management have shown that users perceive notifications from the phone when they are idle or waiting as the least disruptive, and actually welcome them as a distraction [20, 24]. Our observations are in line with this 'common sense' interpretation, but it also appeared that participants often do not find what they are looking for when the perform a lock screen check in these instances. This may be because there was no relevant information available to be displayed to them, or because the options displayed were inappropriate for the situation they are in (watching a video with sound may not be desirable when queuing at the supermarket checkout, replying to an Email may take too long). If existing approaches like [51] can be further developed to efficiently predict that users are waiting for something external when unlocking the phone, these would be excellent instances to apply brief ESM or Slide to X treatments, not only increasing acceptance because they would not constitute disruptions in these cases, but also by leveraging the user's desire to reduce the time spent 'idling' and putting it to efficient use instead.

9 LIMITATIONS

We have employed a mixed-methods approach to triangulate our findings, but this study is ultimately based on data from 41 participants. Our sample only includes young adults, and two thirds of participants in the sample are university students. This study therefore presents a relatively narrow snapshot of the smartphone use of a group of users who to tend to be tech-savvier on average compared to older generations, but also distinctly differ in their usage patterns from younger users. It is therefore unclear how well the findings in this paper apply to different age cohorts, especially to the generally under-researched older parts of population compared to millennials and members of gen Z when it comes to smartphone use. Another issue is that the SEBE technique is heavy and labour-intensive for participants. Particularly the Replay-interviews require a lot of time and focus from participants, and it was sometimes not possible to fully explore everything that was recorded in the Subfilms, which is for example why we had to do a second round of data collection.

Another limitation of the technique is that the cameras are not always recording data, like logging applications would. We specifically noticed that smartphone use immediately prior to going to sleep and after waking up was talked about by our participants in the interviews, but they did not record these moments in the Subfilms, which is, although not surprising given the nature of the technique, problematic since smartphone use habits seem to be intimately interwoven with sleep (e.g. [9, 34]). A detailed investigation of in situ smartphone use connected to sleep, although difficult, would provide a tremendous contribution to our understanding of smartphone use.

While quantitative approaches using device and application logs would not have been able to obtain some of the findings of our study, they produce more reliable data on the prevalence of usage patterns in society, which is needed to consolidate the evidence we have found. This, in combination with the mixture of conforming and contrasting results from previous studies substantiates the case for replication of smartphone use studies that has been argued in the mobile HCI community in recent years [4, 14, 78]. We therefore believe that the use of in situ techniques should always be the first step in a line of research that attempts to understand situated user and device interactions and deeper underlying motivations in detail, and quantitative approaches should be used to triangulate these findings. It is also important to bear in mind that, while the differences in results may be due to the different study populations, there also might be a gradual shift in usage that may occur over the years, which is then reflected in differences between the 'snapshots' that individual studies take.

10 CONCLUSION

In this paper, we have investigated locked smartphone use with a situated first-person video ethnography technique (SEBE). We have observed eight different categories of contextual antecedents to lock screen checks which depend on the device, the user, and the situation they are in. From the qualitative analysis of the interviews with our participants, locked smartphone use has emerged as the 'middle ground' between not being distracted by the device too much and being alerted to relevant information, as well as not experiencing *fomo*. It was also used as a means to manage the way participants engaged with their devices and sometimes served as a displacement activity in moments where participants experienced discomfort. A large share of locked use, however, also appeared to be driven by automatic habits following from situational cues rather than by conscious choices participants made.

Our quantitative analysis confirmed these interpretations and revealed that lock screen checks are especially useful for managing the way participants engaged with information on their phones while they were working, but also that locked use is highly habitualised and automatic, which relates back to over-use and perceived disruptiveness of the smartphone. Importantly, because locked smartphone interactions were often triggered by environmental cues which mostly go unnoticed by users, they contributed to the perceived disruptiveness of the device and are the reason why smartphone interactions were described as unconscious and automatic in our conversations with participants.

Based on this analysis grounded in naturally occurring behaviour, we suggested that notification systems could be tailored more specifically to the different ways in which users interact with the lock screen to reduce the disruptiveness of the device and increase their efficiency at managing awareness of information that hey afford users. Specifically Slide to X and glanceable display approaches appeared appropriate to leverage differences in antecedents and purpose of locked screen use to improve user experience.

The next steps in this line of research will be to put the recommendations arising from our analysis to an empirical test, and to extend our findings on locked smartphone use to full, unlocked use and compare the two in more detail. Particularly a further development of the typology of smartphone interactions (see Figure 7), based on an in-depth characterisation of unlocked use, as well as a systematic investigation of the relationship between these different types of smartphone interactions and the different types of

contextual antecedents to smartphone interactions will be informative. Lastly, our observations underline the importance of moving towards understanding habitualised behaviours and shaping embodied competences when it comes to smartphone use.

ACKNOWLEDGMENTS

I would like to thank the anonymous reviewers for their thoughtful comments that have helped significantly improve this paper. I would also like to thank Saadi Lahlou for his helpful feedback and advice, and Atrina Oraee for her help with coding the data.

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APPENDICES

A.1 CODING FRAME FOR QUALITATIVE ANALYSIS

QCA Lock Screen Checks			
Category	**Subcategory**	**Description**	**Example**
Managing Awareness	Staying up to date	Participants describe how they use the lock screen checks to stay aware of incoming notifications	Yeah, phone, checking that nobody wrote me and nothing interesting happened and back to work (P17) Here I check the phone to see the time. And I wanted to see if I had any messages from my supervisor telling me that I was late. Because I was late. (P28)
	Managing access/avoiding intrusion	Participants describe how they manage their use to the phone, and the notifications settings they choose	I just collect the notifications on the [lock] screen, and I can select myself when I see them and when not, so to speak. I collect them and then I delete those I don't want to see anymore. (P5) I try and put it a bit away on the desk but obviously if a message pops up then I want to answer right away. Not that I always do, but I want to. (P26)
	Impression management	Participants describe how the use lock screen checks to be seen in a specific way by others	You know, so it doesn't come up as read? Because sometimes it's something quite important. And I actually want to think about a response. And if it's important and I read it and ignored it then they're gonna be like: "Oy, reply, what's wrong?" (P37)
Displacement Activities	Boredom/ Need a break	Participants describe how they use lock screen checks when they are bored with or tired of an activity	I probably need a break. Yes. So usually when I do that, it's like I'm bored or tired or something like that. And checking the screen is a quick, easy thing that I can do, uhm, and get engaged for like a few seconds (P40)
	Escape from uncomfortable situation	Participants describe how lockscreen checks enable them to briefly avoid uncomfortable moments	If I'm in a situation where I feel a bit observed or scrutinise, or like at work, we're having a meeting about something and I'm not really sure what to answer to some questions, I might just like. My eyes might dart down, and I might look at my phone because it is a bit of a pacifier. (P41)
External Causes for Locked Use	Situational cues	Participants describe specific moments that lead them to check the lockscreen of their phone	I was sort of scratching myself and then just picked the thing up. (P39) Yeah I just took a break and since I'm standing there already I'll just check my phone. (P7)
	Environmental cues	Participants describe specific external cues that lead them to check the lockscreen of their phone	I think I was also getting really distracted by the washing machine. I was, you hear it right? It's spinning and it's very loud, and maybe it's like, again, sort of a reaction to check the phone. (P39)
Automatic & Unconscious engagement	"No clue"	Participants state that they do not know why they engaged with the device and sometimes provide possible explanations	So, I looked at my phone and didn't do anything. I have no idea what I did. I just went had a look I guess. (P14)
	Normal/Calming	Participants describe how interacting with the device feels normal and calming	I really don't realise it. It just feels normal. (P27) Yeah, it's like nice how it moves [picks up phone during interview and shows how he plays with the unlock pattern]. There, as you can see, I'm not doing anything. I'm just moving around the things. (P3)

A.2 CODING INSTRUCTIONS FOR CODING OF LOCK SCREEN CHECKS IN SUBFILMS

0. Proactive Glance

The participant checks their phone abruptly, "without warning", and without a clear, identifiable, external or contextual prompt.

1. Notification Glance

The phone alerts the participant to a notification that has just arrived (audible, vibration, visual) and they check their phone in response to that.

2. Physical motion

The participant is already in motion and checks their phone while they are performing their activity, or after finishing it. Typical cases include moments when participants are moving their heads and the phone enters their field of vision, stretching or scratching while working at a desk, interacting with an object in close physical proximity to the phone, or sitting down within reaching distance of the device.

3. Handling Phone

The participant is handling the phone as a physical object without the intention to use its affordances. Typical cases include moments when participants are rearranging objects on the desk, picking up the phone to place it in a bag or pocket, or connecting the phone to a charging device.

4. Switching Activity

The participant is switching from one activity to another and checks their phone before the next activity begins, or there is a natural break point within an activity. Typical cases include moments when participants have finished writing an Email and send it off, turning the page of a book, when a meeting they attended or a film they were watching ends, and finishing a meal.

5. Waiting

The participant is waiting for something to happen that is out of their immediate control and checks their phone. while they are idle. Typical cases include moments when participants are waiting for the bus, queueing at a café, or a software loading on their computer.

6. Talking about the phone

The participant talks about the phone or overhears talk about the phone and then checks their phone.

7. Zoning back in

The participant has fully fallen asleep, or is daydreaming, staring into one direction without doing anything noticeable for a longer period of time. They then 'zone back in', often accompanied by shaking their head, breathing heavily, yawning, and or stretching, before checking the phone.