Exploring Current Practices for Battery Use and Management of Smartwatches

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ABSTRACT

As an emerging wearable device, a number of commercial smartwatches have been released and widely used. While many people have concerns about the battery life of a smartwatch, there is no systematic study for the main usage of a smartwatch, its battery life, or battery discharging and recharging patterns of real smartwatch users. Accordingly, we know little about the current practices for battery use and management of smartwatches. To address this, we conduct an online survey to examine usage behaviors of 59 smartwatch users and an in-depth analysis on the battery usage data from 17 Android Wear smartwatch users. We investigate the unique characteristics of smartwatches' battery usage, users' satisfaction and concerns, and recharging patterns through an online survey and data analysis on battery usage.

Author Keywords

Smartwatch; wearable device; battery usage; recharging

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous

INTRODUCTION

Recently, a number of commercial smartwatches have been released as emerging wearable computing devices into the market, e.g., G Watch R, Moto 360, and Apple Watch. With processors, a screen, sensors, communication modules, and a battery well-integrated in small form factor, they provide new experiences as a smart device beyond a watch.

At the same time, there are many concerns about the smartwatch. One of the key concerns is its battery life; it has been a problem for more than a decade [8]. Limited battery size with small form factor can only ensure a few-day-long battery life. Accordingly, users are required to frequently recharge their smartwatch battery. This is a huge deviation from a traditional sense of a watch's year-long battery life. Many people conjecture that the limited battery life of a smartwatch would become a major hurdle for the success of the smartwatch in the market [3, 14, 16].

While there have been a number of works for human-battery interaction for smartphones [1, 5, 6], there is no systematic study for smartwatches, yet. Thus, we currently know little about whether users are satisfied with the battery life of the smartwatch, how they use and manage the smartwatch battery, and what makes it difficult to manage their smartwatch battery.

In this paper, we investigate the following questions: *What are 1) current main usages of a smartwatch, 2) unique characteristics of such usages, 3) key battery usage behaviors of users regarding discharging and recharging of a smartwatch battery?* To address these, we conduct two studies: one to examine usage behaviors of 59 smartwatch users via an online survey, and the other to analyze the battery usage data from 17 Android Wear smartwatch users.

Our contributions to ISWC community are as follows:

- To the best of our knowledge, our work is the first to explore current practices for battery use and management of smartwatches.
- Through an online survey and data analysis on battery usage, we present findings about unique characteristics of smartwatch's battery usage, users' satisfaction and concerns, and recharging patterns of smartwatch users.
- Our key findings reveal that 1) many users are satisfied with current battery life of their smartwatch or in a neutral position, 2) the drain rate of the smartwatch battery is relatively low compared to that of the smartphone even with very frequent interactions, and 3) users usually recharge their smartwatch once a day despite having sufficient battery remaining.

RELATED WORK

Smartwatch and its use

The smartwatch-related works have been actively conducted in a recent decade. Kamijoh et al. developed the IBM

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Age	10s (5), 20s (19), 30s (23), 40s (12)
Occupation	Student (16), Office worker (36), Salesman (2), Self-employed (4), Other (1)
Watch model	LG G-watch (8), LG G-watch R (24), Samsung Galaxy Gear (7), Samsung Gear 2 (4), Samsung Gear Neo (3), Samsung Gear Live (3), Sony Smartwatch MN2 (1), Sony Smartwatch 2 (2), Motorola Moto 360 (7),
Period of use	Less than 1 month (9), 1-3 months (17), 3-6 months (21), more than 6 months (12)

Table 1. Participant demographics of the online survey; *the parenthesized numbers represent the number of the participants*

wristwatch computer, an early prototype of a smartwatch and presented its energy-related challenges and tradeoffs based on the power measurement in a lab setting [8]. There have been considerable efforts to provide users with new experiences using smartwatches, e.g., interface [2, 15] and context recognition [13, 17]. However, since smartwatches have been commercialized recently, there has been a lack of efforts to study how users use smartwatches in their daily lives. To the best of our knowledge, our work is the first to systematically address how smartwatches are currently used, especially in terms of the battery.

Study on Smartphones' Battery Use

There has been a rich body of literature for understanding how people use and manage their smartphone battery. Ferreira et al. investigated the recharging habits of Android device users and discussed design opportunities for battery management [5]. Falaki et al. conducted a comprehensive study of smartphone usages and showed that there is a large diversity in smartphone usage depending on the individual [4]. Banerjee et al. examined users' battery-recharging behaviors and proposed context-aware battery management [1]. Several works studied abnormal battery drain of smartphones such as energy bugs [11, 12]. They systematically detect its causes and provide a guide for battery life improvement. Different from such works, we focus on studying the battery usage of the smartwatch. While smartwatches share several features of smartphones, we found that users' use patterns of smartwatches are much different from those of smartphones.

ONLINE SURVEY

We conduct an online survey with 59 participants (including 2 females) in order to understand the following three aspects of the smartwatch: 1) its main usage, 2) concerns about its battery life, and 3) recharging patterns of its battery. To examine unique characteristics of smartwatch battery usage, we compare the responses with those of smartphone battery usage. We recruited the participants from the online community sites for Korean smartwatch users. Table 1 shows their basic demographics. We did not include the users of fitness bands such as Fitbit and Jawbone UP. Each participant compensated a gift card equivalent to USD 2.

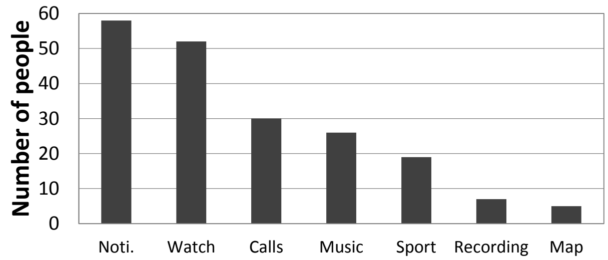


Figure 1. Major usage of smartwatch; *Noti.: text message, email / Watch: time, stop watch* ***(****Direction****:*** *Please select smartwatch features that you often use. You may choose more than one****)***

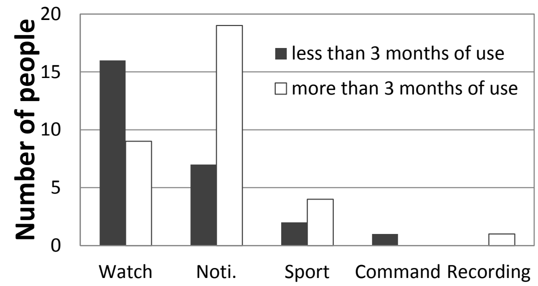


Figure 2. Most wanted features *(Question: If a power saving mode allows usage of only one feature and restrict the rest, which feature would you prefer to use?)*

Smartwatch Usage

Regarding a question about the main usage of smartwatch, "checking smartphone notifications" was selected by almost all of the participants (58 users, 98%) (see Figure 1). The next was "using watch functionality," e.g., checking time, and using stop watch and alarm, (51 users, 86%). "Activity tracking (sport)", e.g., step count and movement distance, was selected by 34% of the participants. Main features used by many users were 1) smartphone-dependent ones, e.g., checking messages, making phone calls, controlling music player apps, and 2) the traditional watch functionality. We consider that killer apps or special use cases for the smartwatch were not offered yet.

We further examined which smartwatch feature is regarded as most important by current smartwatch users. To study this, we asked the participants about their most wanted feature while assuming that only one could be activated in a power saving mode. Interestingly, their needs were different depending on the period they had been using their smartwatch. We classified the participants into two groups: one with less than 3 months of use (26 participants,) and the other with more than 3 months of use, (33 participants.) The former represents the group with members who were new to their smartwatch, undergoing its learning curve and the latter doing so for those who had used their smartwatch long enough to be familiar with its features. As shown in Figure 2, among the former 26 users, more than half of them chose the watch feature (16, 62%) as the most wanted one. The ratios of notification and activity tracking were relatively small, (7, 27%) and (2, 8%), respectively. On the other hand, among the participants who used more than 3 months, more than half of them selected a notification feature (19, 58%).

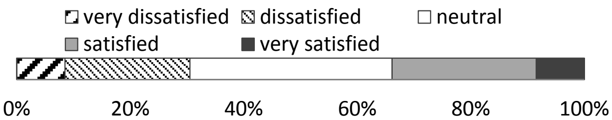


Figure 3. Satisfaction of smartwatch battery life *(Question: Are you satisfied with the battery life on your current smartwatch?)*

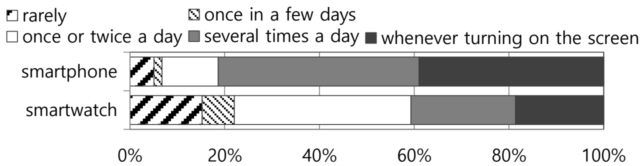


Figure 4. Frequency of checking remaining battery level *(Question: How often do you check the remaining battery level on your smartphone/watch?)*

The ratios of watch and activity tracking were 24% and 12%, respectively. We conjecture that the longer they use their smartwatch, the more accustomed to checking smartphone notifications via the smartwatch they are. We believe it would be interesting to examine the changes in long-term behaviors of the smartphone usage.

Diversity in Levels of Battery Life Satisfaction

Regarding the level of satisfaction with the battery life of the smartwatch, the participants' responses were widespread. Overall, 35% of the participants were satisfied (very satisfied: 5, satisfied: 15) and 36% of them were neutral. 31% of them were dissatisfied (very dissatisfied: 5, dissatisfied: 13). The number of the participants dissatisfied with the battery life was smaller than we expected (see Figure 3). We investigated why the participants showed different levels of satisfaction. To this end, we asked "*How often do you experience situations where you need to, but cannot recharge your smartwatch?*" Members of the dissatisfied group more frequently experienced that they could not recharge their smartwatch quickly when it ran out of battery. 53% of them responded that they had such an experience more than once a week. On the other hand, 85% of the satisfied group experienced that they could not recharge their smartwatch quickly only once or twice a month.

We also asked "*Do you keep wearing your smartwatch when it could not operate due to running out of battery?*" Intriguingly, these two groups also exhibited different patterns in their responses. 15 among 20 satisfied users responded that they kept wearing their smartwatch (75%). On the other hand, only 8 among 18 dissatisfied users did so (44%); the remaining took off their smartwatch when it ran out of battery. Those who kept their smartwatch on even after it turned off attributed their behavior to the absence of having the smartwatch on their wrist, being concerned about losing it if they took it off, or simply wearing it as an accessory (40%, 40%, and 20%, respectively). 8 participants who took it off mostly answered that this was because the drained device offered no functionality if it was not turned on.

Different Degrees of Concerns about Battery Life

In response to the command, "*Describe your level of discomfort if your smart device were to be turned off for the whole day,*" the majority of the participants felt discomfort in not being able to use their smartphone, but not so inconvenienced by their smartwatch. 46% of the participants responded with "very uncomfortable" for smartphones, while 33% of them answered with "neutral" for smartwatches. As mentioned above, the main usage of the smartwatch was the secondary device of the smartphone; there is little use of the smartwatch as a stand-alone device. On the other hand, the smartphone is a key device for online connectivity and communication with other people, which is critical to most of the users. Accordingly, we conjecture that they felt more uncomfortable when they could not use their smartphone than when they could not use their smartwatch.

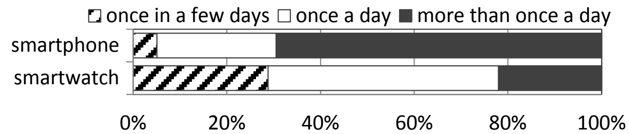


Figure 5. Recharging frequency *(Question: How often do you recharge your smartphone/watch?)*

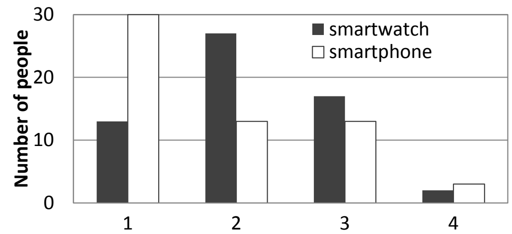


Figure 6. Recharging time of smartphone and smartwatch
(Question: When do you recharge your smartphone/watch?)
1: When there is an available recharger
2: At a specific time of day
3: When they think remaining level is low
4: When a low battery level warning is given

To examine the sensitivity to the remaining battery, we asked about the frequency of checking the battery level. As shown in Figure 4, 59% of the participants answered that they checked the battery level of their smartwatch less than twice a day (rarely: 15%, once in a few days: 7%, and once or twice a day: 37%). However, 81% of the participants checked the battery level of their smartphone more than two times a day (several times a day: 42% and whenever turning on the screen: 39%).

From these results, we could see that users' concerns about the current battery life of the smartwatch are relatively lower than those for the smartphone. This would be mainly because the main usage of the smartwatch so far is smartphone-dependent, i.e., an auxiliary device of the smartphone, as mentioned above. If smartwatches have special features used as a stand-alone device, however, the discomfort regarding the smartwatch battery would increase.

Recharging Frequency, Inconvenience, and Opportunity

About half of the participants responded that they recharged their smartwatch once a day. 13 (22%) and 17 (29%) participants recharged their smartwatch more than and less than once a day, respectively. However, the participants

Figure 7. LG G-Watch (back) and its recharging cradle

usually recharged their smartphone more frequently. While only 15 (25%) participants recharged their phone once a day, 41 (70%) participants did so more than once (see Figure 5).

Also, timing of recharging smartphones and smartwatches was different as shown in Figure 6. A half of the participants responded that they recharged their smartphone whenever possible. However, only 22% of the participants responded that they recharged their smartwatch when its recharging was possible. About half of them responded that they recharged their smartwatch at a specific time of day.

We believe that the participants wanted to recharge their smartphone frequently whenever available because they were more concerned about its battery life than that of the smartwatch. On the other hand, since smartwatches exhibit relatively longer battery life and steady drain rate, less frequent recharging at a specific time of day could meet the needs of users (see the following section for the related analysis).

We told the participants, "*Please select inconveniences experienced when recharging smartwatches (you may choose more than one).*" The most dominant inconvenience, selected by 77% of the participants, was that the smartwatch can only be recharged by its dedicated recharging cradle. Also, 16% of them felt inconvenient since they had to put a rather conscious effort into positioning their smartwatch on the cradle properly. Currently, off-the-shelf smartwatches require a specially designed cradle for recharging as shown in Figure 7. Thus, their recharging opportunity has to be limited compared to that of smartphones.

We asked the participants about how many rechargers they possessed and where they mainly recharged their smart devices. Overall, 90% of the participants responded that they possessed more than 2 smartphone rechargers and ensured the opportunity of recharging their smartphone at multiple places, e.g., at home, in the office, and in the car. On the other hand, 86% of the participants had only one smartwatch recharger and they usually recharged their smartwatch at home.

DATA ANALYSIS ON BATTERY USAGE

We conducted an in-depth analysis of actual battery usage of smartwatch users. To this end, we recruited 17 Android Wear smartwatch users (see Table 2); they also participated in the online survey. They have been using their current smartwatch for an average period of 3.4 months.

For data analysis, we collected battery usage data from the participants over a period of 3 weeks in Feb. 2015. We targeted Android Wear devices since they are widely used and programmable for the data collection while they support many smartwatch models. After the data collection, we further performed one-hour semi-structured interviews by phone to collect the participants' detailed experiences. Each participant was compensated with a gift card, equivalent to USD 45. With the collected data and the interview, we performed an in-depth analysis on how they use and manage their smartwatch battery.

ID	Age	Occupation	Watch model	Phone model	Period of use (month)	Ambient mode[1]	Satisfaction[2]	# of cradle
P1	25	Stu.	GW	S3	1	On	3	1
P2	32	Stu.	GW	GN	1	On	3	1
P3	36	O.W	GW	N5	1	On	2	1
P4	21	Stu.	GWR	N5	3	On	4	1
P5	26	O.W	GW	N5	3	On	3	1
P6	17	Stu.	M360	NT4	1	Off	5	1
P7	39	O.W	GWR	GP	3	On	5	1
P8	27	O.W	M360	XZ	5	Off	2	1
P9	37	O.W	GWR	S3	2	Off	1	1
P10	35	O.W	GL	S5	5	Off	1	1
P11	24	O.W	GWR	A5	4	On	4	1
P12	34	O.W	GWR	G3	6	Off	4	2
P13	21	Stu.	M360	NT4	12	Off	5	2
P14	21	O.W	GWR	NT4	2	Off	3	1
P15	26	O.W	GWR	XZ	3	On	3	1
P16	31	Stu.	GWR	S3	4	On	4	1
P17	35	O.W	GWR	NT4	1	Off	3	1

Table 2. Participant demographic of in-depth analysis

*(**Stu**: student, **O.W**: office worker, **GW**: G-Watch(400), **GWR**: G-Watch R(410), **M360**: Moto 360(320), **GL**: Gear Live(300), **S3**: Galaxy S3(2100), **GN**: Galaxy Nexus(1750), **N5**: Nexus 5(2300), **GP**: G Pro(3140), **XZ**: Xperia Z(2330), **S5**: Galaxy S5(2800), **A5**: Galaxy A5(2300), **G3**: LG G3(3000), **NT4**: Galaxy Note 4(3220); parenthesized numbers are battery capacities (mAh)))*

[1]Ambient mode: watch screen kept on (dim) even without user interaction.

[2]Battery life satisfaction: (1: very dissatisfied, 5: very satisfied)

For data collection, we developed an Android application that logs various events and uploads the collected data to a server via Wi-Fi automatically. Table 3 shows the event types, the values, and the intents that we used. For the comparative study, we also collected the smartphone data. The logger application is implemented as an Android service that runs autonomously in the background without user interaction. The application running on the smartwatch transmits the collected data to the smartphone on a daily basis via Bluetooth. On the smartphone, it transmits the data to the server only when the phone is recharging and connected to Wi-Fi. While the data collection was set to 24 hours per day, the actual collection time varied due to logging app updates, battery depletions, and the participants' own reboot of either their smartphone or smartwatch. Finally,

Event type	Values	Related Android Intents used
Battery	battery level, plugged/unplugged, temperature, voltage	ACTION_BATTERY_CHANGED
Screen	turned on/turned off	ACTION_SCREEN_ON, ACTION_SCREEN_OFF

Table 3. Data collection details

6,929 and 7,453 hour-long data were used in total for the smartwatch and smartphone, respectively[1].

How Do the Users Use Their Smartwatch Battery?

Interaction with smartwatch and smartphone

We examine how long and often the participants interacted with their smart devices. The interaction session is defined as the duration while the screen is being turned on as in [4]. For each participant, we calculated the daily average duration and count of interaction sessions. As shown in Figure 8, overall, the participants interact with their smartwatch for a short time, but frequently. On average, the interaction duration and count were 20.6 minutes and 95.6 per day, respectively. This implies that an interaction session of the smartwatch lasts 13.0 seconds on average. Unlike the smartwatch, the participants interact with their smartphone in a different manner, for a long time (232.3 minutes per day) and frequently (104.9 times per day) as well. Interestingly, while the interaction duration of the smartphone over the participants shows a large variation (stdev: 125.2 minutes), that of the smartwatch shows a small variation (stdev: 12.7 minutes).

Figure 9 depicts the cumulative distribution of the session durations. It shows that the participants mainly interact with their smartwatch in short bursts, 99% of sessions last less than one minute; and 38% and 80% of sessions last within 5 and 10 seconds, respectively. Similar to the smartwatch, the majority of the smartphone sessions are also short, but some are very long. 20% of interaction sessions last more than 1.4 minutes. Also, a part of sessions, 4.8%, are more than 10 minutes. We believe that such instant use of the smartwatch makes the variation of the interaction duration among the participants small, although the interaction count largely varies depending on the participant.

We further investigate the correlation of the interaction patterns between the smartwatch and smartphone. As shown in Figure 10, the interaction count shows a strong relationship (*corr*=0.59). This implies that the participants who frequently interact with their smartwatch also do so with their smartphone. However, the interaction duration shows a weak relationship between both (*corr*=–0.17). That is, longer interaction on the smartwatch does not guarantee longer interaction on the smartphone.

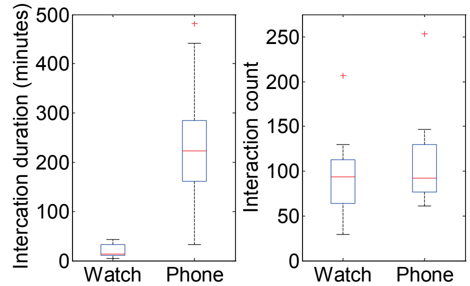
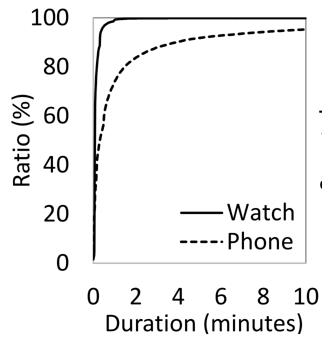


Figure 8. Interaction duration (left) and count per day (right)



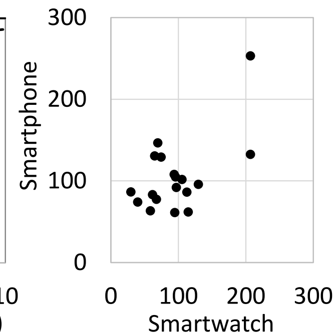


Figure 9. Cumulative distribution of interaction duration (left)
Figure 10. Relationship of interaction counts (right)

Battery usage

We analyze the energy consumption of the smartwatch and smartphone. As an energy use metric, we adopt the battery drain rate (%/h), an average decrease in battery levels for an hour. We compute it by using the consecutive samples of <*timestamp*, *battery level*> obtained while the device was discharging, as used in [6, 12]. Figure 11 shows the box plot of daily average drain rates of the participants. Over all the participants, the average rate of the smartwatch is 2.3 %/h, which implies that the fully charged smartwatch can last about 42.8 hours without recharging. Contrarily, the smartphone battery usage shows a relatively high drain rate, 7.0 %/h on average. We expect that a smartphone battery, even when fully charged, would last about 14.3 hours only.

As expected from the fact that the total interaction duration of the smartwatch is similar among the participants, the drain rates of the smartwatch do not vary much as well. This is remarkable since they use different smartwatch models and applications. On the other hand, the battery usage of the smartphone largely varies across the participants (stdev: 4.3 %/h). The highest drain rate of the smartphone was P7's 19.1 %/h, whereas the lowest one was P1's 2.6 %/h.

Available battery capacity

We study the available battery capacity of the smart devices in the participants' daily lives. As a metric for the available capacity, we use the remaining battery level (%) in a discharging period, i.e., the percentage of battery life remaining while the devices are not recharging. Figure 12(a) shows the cumulative distribution of remaining battery levels.

[1] The data is available at http://nclab.kaist.ac.kr/smartwatch

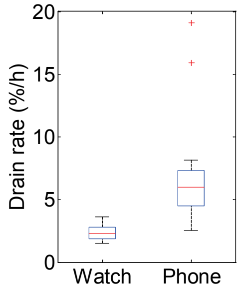


Figure 11. Battery drain rate

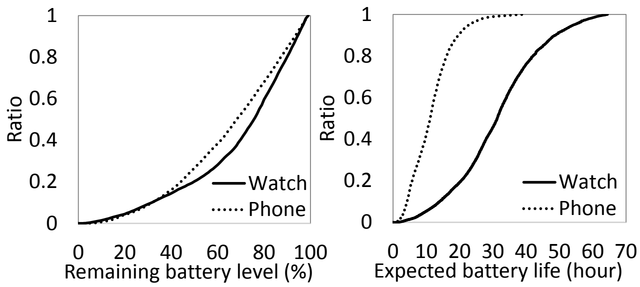


Figure 12. CDF of (a) remaining battery levels (left) and (b) expected battery life (right) in a discharging period

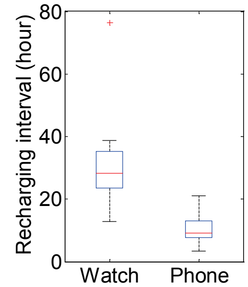


Figure 13. Recharging interval

Interestingly, although the Android devices notify the battery warning at 15%, for the smartwatch, the time period below 15% only occupies 2.9% of the total discharging time. For more than 80.0% of the discharging period, the smartwatch battery level remains over 50%.

While the cumulative lines of the smartwatch and smartphone show the similar trend, it does not mean that both devices have a similar pattern of available battery capacity. To investigate this, we compute the expected battery life by dividing the remaining battery level by the drain rate of each participant. As shown in Figure 12(b), the expected battery life of the smartphone is mainly less than 14 hours. This means that the smartphone battery can be depleted even in the daytime unless users pay close attention and thus users should check constantly on its status. Contrarily, the smartwatch has more than 20 hours of battery life on average over 81% of the discharging period. This shows that it has sufficient available battery capacity most of the time.

How Do the Users Recharge Their Smart Devices?

Frequency of Recharging

We investigate how often the participants recharged the battery of their smartwatch and smartphone. Figure 13 shows the average time interval between consecutive recharging events. We count the recharging event based on the battery replacement or the *plugged* event, i.e., the start of recharging; we exclude short recharging events that contribute to less than 5% increase in battery levels. Overall, the participants recharged their smartwatch at the interval of 31.2 hours on average, but the interval ranged from 12.9 to 76.5 hours. Interestingly, the average recharging interval of the smartwatch (31.2 hours) is much less than the expected full battery life (42.8 hours). This means that the participants recharged their smartwatch much earlier than the battery was depleted. Unlike the smartwatch, they recharged their smartphone much more frequently, at the interval of 10.7 hours on average ranging from 3.4 to 21.0 hours. The interval is a little less than the average battery life of the fully charged smartphone, 14.3 hours. We look into the detailed recharging patterns in the following subsections.

We investigate the relationship between the drain rate and the recharging interval. Figure 14 shows its scatter plot for the participants. As expected, they tend to recharge their device at shorter intervals as its drain rate is higher. The

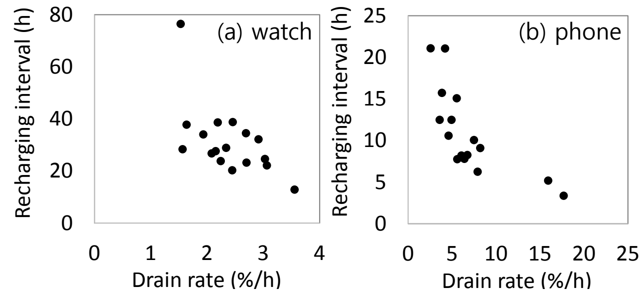


Figure 14. Relationship of drain rate and recharging interval

correlation values of the smartwatch and smartphone are –0.54 and –0.70, respectively.

We demonstrate a few interesting cases. P16 recharged his smartwatch two times per day on average, most frequently among the participants. As expected, his drain rate is also the highest, 3.6 %/h. In the interview, he mentioned that he installed 17 smartwatch applications and actively used them. Contrarily, P1's interval is the longest, 76.5 hours. He is the only participant whose recharging interval is longer than the average full battery life of his smartwatch, 64.5 hours. He stated that he mostly used his smartwatch only for watching time. Even when he realized that his smartwatch battery was depleted, he used his smartphone to watch time, rather than trying to recharge the smartwatch.

Recharging Patterns

Time of day: We examine when the participants mainly recharge their devices. For each participant, we compute the ratio of recharging counts depending on the time of day to the total count. Figure 15 shows the average ratios over the participants. They mainly recharged their smartwatch at night. 47.7% of recharging events occurred from 8 p.m. to 2 a.m. the next day. Unlike the smartwatch, the participants recharged their smartphone relatively evenly spread across the day.

Remaining battery level: We investigate the recharging patterns based on the remaining battery level upon recharging (see Figure 16). The participants often recharged their smartwatch even though its available battery capacity was sufficient. 59.2% of smartwatch recharging events occurred while the battery level was higher than 50%. They recharged their smartwatch although it could last more than one day without recharging. However, the participants

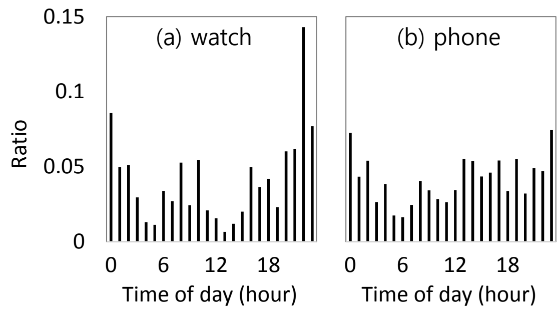


Figure 15. Recharging ratios depending on time of day

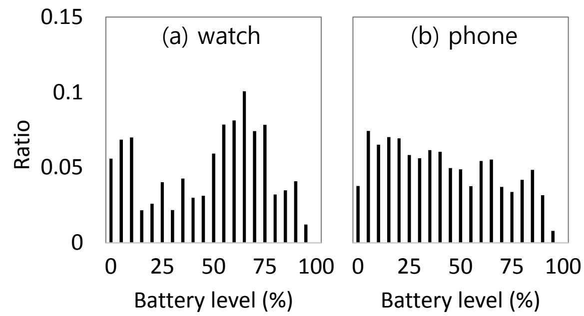


Figure 16. Recharging ratios depending on battery level

recharged their smartphone regardless of the battery level. The recharging events were mostly evenly spread across battery levels from 0% to 80%.

Why different recharging patterns? We study the reason why the participants show different recharging patterns for the smartwatch and smartphone. In the post-interview, we asked about when they usually recharge their smart devices. 12 of the participants often recharged their smartwatch at fixed hours regardless of the battery level. They stated that they recharge it habitually either when they go to bed or return home. This is interesting considering that the average battery life of their fully charged smartwatch, 42.8 hours is longer than a single day. We conjecture that this is mainly because the participants are already habitualized to recharge their smart devices on a daily basis. Note that we do not generalize this finding to all smart devices. Some of them, e.g., Pebble watch and smart bands, provide longer battery lives from several to tens of days and the recharging habit could be different. However, when the devices' battery life is around a couple of days like Android smartwatches, people may tend to recharge the device habitually.

Unlike the smartwatch, the participants tend to recharge their smartphone whenever recharging is possible. This is mainly due to high drain rates of the smartphone. Currently, with the usual app usage, it lasts less than half a day even fully charged. Interestingly, while the participants feel bothered from such frequent recharging, they try to keep their phone alive to maintain the connection with others.

DISCUSSION

Limitations

Target smartwatches: For data analysis, we target the Android Wear smartwatches due to their relatively wide deployment and easy programmability for data collection. Thus, the findings might not be generalized to other types of smartwatches with longer battery life. For example, Pebble watches are known to provide seven days of battery life and users' battery usage of such devices may be different. For future work, we will study the battery usage and recharging patterns for diverse types of smartwatches.

Target participants: The majority of our study participants were male users in their 20s and 30s whose period of smart watch usage was within six months. This is natural because the smartwatches are widely used by such group of people[2] and it has only been about a year since the Android Wear smartwatches have been released. Nonetheless, other groups are also starting to use the smartwatches more and they might have different battery usage. We plan to extend our study to encompass more diverse demographic groups.

Implications

Needs for new studies for wearable devices: We found that the battery usage of smartwatches differs significantly from that of smartphones. Our findings strongly motivate the need for new research focusing on human-battery interaction and management regarding wearable devices, especially smartwatches. In recent years, there have been many relevant studies targeting smartphones. Considering different usage patterns of the smartwatch, we can easily expect that the findings from such previous studies are not applicable to the smartwatch. New studies will be necessary for a number of issues, e.g., deeper understanding of human interaction with smartwatch battery, the design of effective battery interfaces, and battery-recharging strategies for wearable devices. For example, it would be interesting to study the effect of an active recharging alert considering the limited recharging opportunity of smartwatches. Another example is to manage battery use of mobile apps cooperatively between the smartwatch and smartphone [10].

Potential for using more energy for enriched services: Due to small form factor, the smartwatch inherently has limited battery capacity, especially compared to other mobile devices [8]. While state-of-the-art smartphones employ a battery with more than 3000 mAh, smartwatches' batteries still remain around 400 mAh. Thus, much effort has been made to overcome such a limitation. For example, LG employs 700 mAh battery for its recent smartwatch model[3]. However, as observed from our studies, many smartwatch users are not significantly dissatisfied with the limited battery power. This is because 1) the fully recharged smartwatch lasts a couple of days and 2) users already made a habit of recharging their devices daily, and 3) the drain rate of the smartwatch battery is relatively low, 2.3 %/h on average, even though a number of smartwatch applications have been released and used. Based on these, we observe

[2] The Demographic Divide: https://goo.gl/15Hazq

[3] LG Watch Urbane LTE. http://www.gsmarena.com/lg_watch_urbane_lte-7070.php

potential for using more energy to provide more enriched services without increased battery capacity or energy optimization. The drain rate up to 4-5%, i.e., 20-25 hours of battery life, would be acceptable since it might not interfere with current recharging patterns. One example of such enriched services is conversation monitoring applications [7, 9]. Smartwatches may be better suited than smartphones to record and analysis daily conversations among users. While smartphones can be positioned in a pocket, bag, or away from the user, smartwatches are worn on the wrist for most of time and thus can record the speech from the user better.

Implication for recharging of other wearable devices: A variety of wearable devices also have been proposed, e.g., bracelet, glass, and shoe. Undoubtedly, it would be preferred if the larger battery capacity is provided as long as it does not degrade the user experience. In terms of battery life, users will be likely to use wearable devices if they provide several days of battery life, since many users are already accustomed to recharging their smart devices on a daily basis. Thus, it might be more important to help users easily recharge the devices. For example, applying wireless recharging might be one of the important solutions.

CONCLUSION

We explored current practices for the battery use and management of smartwatches. For the study, we conducted an online survey with 59 participants and analyzed the results in three aspects, 1) the main smartwatch usage, 2) satisfaction with and concerns about smartwatch battery life, and 3) the recharging patterns of the smartwatch. For a deeper understanding, we further collected the real usage data from 17 Android Wear smartwatch users and characterized how they use and recharge their smartwatch battery. From the study, we show that the battery usage of the smartwatch significantly differs from that of the smartphone and discuss the potential for using more energy and the implication for recharging other wearable devices.

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