Battery Information Display in Mobile Devices
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Abstract
In this exploration of the human battery interface, the way in which battery information and notifications affect interaction are analyzed through two small scale studies and a design proposal which is then user tested. With the first study, an attempt is made to gauge user’s feelings toward the current battery information display on their smartphones through a brief online questionnaire. Participants who were selected for further study installed battery monitoring software on their devices and shared the resulting data. This data was then analyzed and some usage patterns were extrapolated. After surveying current market solutions and research in the field, design opportunities were explored and a final design proposal was created and tested with possibilities for further applications being discussed.

Background
Batteries are everywhere. Since their introduction in the 1800’s, they’ve changed the way we live, allowing for the development and pervasiveness of mobile electronic devices. As they are often concealed deep within our devices, it’s easy to forget they are even there at all. Until they need to be charged.

Human-battery Interaction, a term coined by Rahmati, Qian, and Zhong in their 2007 paper on the subject is an often overlooked topic. This paper will explore the display of battery information and notifications, particularly on smartphones, propose a novel form of information display and discuss feedback on that design received from users in field testing.

Motivation
My personal interest in batteries stems from when as an industrial design student, in Shenzhen, China, I witnessed the assembly of rechargeable lithium ion battery packs destined for use in power tools, this sparked the realization that nearly everything uses the same basic battery technology. From a $5 MP3 player to a $100,000 luxury electric vehicle, lithium ion batteries power the mobile world we live in. Most people carry at least one around with them on a daily basis, but how do we interact with batteries? What do we do when they die, and what if our batteries were better able to convey their needs?

Research Question
How does the way that we are notified of battery levels affect our interaction with mobile devices?
Definitions

Mobile device
An untethered electronic apparatus. In this paper, the term mobile device covers anything which is portable and uses electricity to function. Examples include smartphones, electric vehicles and power tools.

Charging routine
The rituals surrounding the charge and discharge of batteries in mobile devices.

Range anxiety
Ordinarily discussed in the context of electric vehicles, range anxiety occurs when a user is fearful that the finite energy resources of their mobile device will be depleted before an end goal is reached. Rather than becoming stranded on the side of the road in an inoperable electric vehicle, mobile phone users may find themselves disconnected, in a communications desert until they are able to charge their devices.

Notification overload
An over-abundance of information potentially distracting users from completing important tasks.
Part II: A Broad Overview of Batteries
(batteries are well packaged explosions)
What is a battery?
According to Merriam-Webster’s Dictionary, a battery is defined as “a device that is placed inside a machine (such as a clock, toy, or car) to supply it with electricity.” (Merriam-Webster, 2015) This is a very broad definition, but it helps to highlight the fact that once you get past the chemical makeup, batteries are just a way of storing energy.

With their roots in the early modern experiments with electricity, the battery as we now know it has a long, interesting history (Buchmann, 2011). Today’s batteries are not far off of the lead acid batteries which began the rechargeable revolution, but we use them in ways unimaginable to the early scientists and inventors who pioneered their use.

In short, a battery is a means of storing energy for later use in the form of an electrical charge. Currently, the most common type of rechargeable battery in portable devices are the lithium ion variety (Brookhaven National Laboratory, July, 2014). As a single product line is set to double the number of lithium ion batteries produced in the world by 2020, the number of rechargeable batteries in use appears to be on the rise with no signs of slowing (P. E., 2014).

What is a battery level?
As a battery is a place for storing electricity, a way to measure the level of energy left in storage is needed. Historically, energy levels in batteries have been measured in a variety of ways. To the right is an illustration displaying a method of finding the charge level in a lead acid battery by manually measuring the specific gravity of the sulfuric acid within (Buchmann, 2011; Foresman, n.d.).

The way this state of charge, as it is called is measured and displayed has varied based on the chemistry of the battery, how the battery is interacted with, and the many physical characteristics which impact how charge is stored (Buchmann, 2011).

Battery management systems govern and monitor the charge and discharge of modern rechargeable battery packs. These systems prevent damage and allow for the optimal use of power (Bergveld et al., 2002). This provides a level of abstraction to design on top of, removing the need to take things like battery health into close consideration when looking at the battery information systems in today’s mobile devices.

Measurement of fuel storage levels is often a difficult task, and although some batteries have had easily tangible characteristics which show their remaining charge level, such as being able to lick the contacts of a 9 volt battery to test charge level, their information display is generally screen based these days.

Designing for energy awareness
With the important issue of Human-induced climate change in the public eye, recently there has been much research into displaying energy information in a way which aids efficient use. Household energy savings especially have been thoroughly studied over the past decades (Abrahamse et al., 2005). Providing individually tailored information and feedback has been found to help in this arena (Abrahamse et al., 2007). At the product level also, providing
additional energy use information has been found to increase efficiency (McCalley & Midden, 2002). In one study, when provided with a minimalistic display of real-time household energy use, study participants were able to identify and reduce their participation in individual high-power activities (Yun, 2009). DiSalvo, Sengers, and Brynjarsdóttir provide an interesting look into the emerging area of sustainability through Human Computer Interaction in their 2010 paper on the topic (DiSalvo et al., 2010).

Primary concerns for this paper included allowing people to see their usage levels in a manner that gives them the opportunity to change habits (Jensen, 2003), potentially reducing range anxiety and avoiding the over-display of information, especially in a way that distracts them from a primary task; notification overload (van Dantzich et al., 2002).

Standout examples in battery informatics

Smoke detectors
Although decidedly non-mobile, modern smoke detectors are an excellent example of a product where battery level is a crucial, even lifesaving piece of information. Because of this, the display of information must be unmistakable and also use very little power itself. The ear-piercing piezo buzz of a low battery warning from a smoke detector is designed to be un-ignoreable. Although the information communicated is minimal with no visible indicators of power level, the impossible to ignore shrill combined with limited options forces the user to investigate.

An early patent for the Battery operated fire detection unit filed in 1975 tells of a low voltage indicator which sounds “once each 30 seconds to provide the low voltage indication and need for battery replacement” and goes on to describe the specialized circuitry involved in this process (Webb, 1977).

Flashlights
As one of the first mobile electronic devices created, the common flashlight deserves mention as a prototypical device lacking an additional battery indicator. The only way that battery level is indicated is through the primary function of the device. As the battery’s power level diminishes, the beam of light produced weakens accordingly. In many applications this is an acceptable way of gauging battery power. Another example of this behavior can be seen in cordless power tools, where most have no external battery level indication but the user is able to roughly estimate battery life based on the mechanical performance of the device.

Apple iBook charge indicator
A feature of some Apple computers, dating back to the iBook g3 snow released in 2001 was a simple battery indicator button located on the battery itself. A small round button accompanied by 4 small colored LEDs and no labels of any kind, this simple power indicator was an interesting feature in that it allowed for a user to check the power level of their computer without booting up (Apple, 2012a). The main indication of this button and LED arrangement’s function was its physical placement on the laptop’s battery. It drew on user familiarity with the bar graph style battery indicator. (Illustration based on a photo by Yong, 2006)
Apple Macintosh Portable
Launched in 1989, the Macintosh portable was one of the first portable computers with a fully-fledged graphical user interface (Apple, 2012b). It made use of lead-acid batteries which are commonly used today as starter batteries in automobiles. Its battery state of charge was accessible through the main system drop down menu; presented to the user graphically as seen to the right. (graphic created from video by Jason, 2014)

Nokia 2110
The Nokia 2110, released in 1994 was one of the first phones to use the battery icon as we now know it (Mansfield, 2014). Other notable user interface enhancements that created a lasting impression were the now famous Nokia tune (Luke, 2014), and softkeys which debuted on this device. Its predecessor, the Nokia 1011 used the letter B in place of the battery symbol. (graphic created from image by Mustaraamattu, 2014)

State of the battery
Today’s smartphones are an excellent agent for the study of battery information. They are used on a daily basis, constantly communicate with users and have highly variable power needs (Falaki et al., 2010). On top of all of this, smartphone users are often dissatisfied with the performance of their devices (Power & Associates, 2012).
Part III: Exploratory Design Research
(a foray into the field of battery information)
Research Methods
At the onset of this project, two exploratory ventures were made into the subject of smartphone battery information display as a way of discerning pain points and places where user experience could be improved. The first was an exploratory survey and the second was through the collection of actual battery data from smartphone users.

Exploratory Survey
An online survey was conducted to gauge user attitudes toward mobile battery life and assess their charging patterns. A total of 30 people were surveyed and of them, 5 were selected for follow up information. Survey participants were between the ages of 17 and 57 with a relatively even gender split. The questions used in the survey can be found as an appendix at the end of this paper. 48% of respondents used each iOS and Android with the remaining 4% using Windows phone. The average length of time participants had been using a smartphone was 3 years.

Operating system appeared to have little effect on charging patterns and perception of battery information. All but two of those surveyed stated that their phone warned them of its charge level at some point. Beeps, buzzes and visual feedback were the reported forms of notification, and these events happened most commonly between ten and twenty percent of battery life remaining. The majority reported never having used a third party battery application such as Battery HD, the program used in the latter half of the exploratory research.

More than one respondent indicated that they would like to be able see a percentage of battery life more easily, but overall, most of those who took the survey were happy with how power levels were displayed on their devices.

Some of the most interesting feedback from respondents was information that they shared about their charging habits and routines. Of the 30, only two stated that they waited more than one day between charges and even then, the longest reported time between charges was two days. Some indicated charging their devices two or even three times per day. The most popular time for charging was at night while sleeping, when the device was not in use as was reported by 18 of the 30 participants.

Similar to what was reported by Rhamati, Qian, and Zhong in their paper *Understanding Human-Battery Interaction on Mobile Phones*, people appeared to fit into one of two categories when it comes to charge patterns (Rahmati et al., 2007). The regular chargers who follow a routine and charge their phone regardless of remaining battery level and then the more spontaneous who rely more heavily on battery level indicators and notifications and charge only when necessary. A humorous aspect of this seen in the collected data is that due to today’s limited smartphone battery lives, the charging routines of the two groups ends up being very similar in practice.
Collected data
After the initial survey, five users volunteered to install battery monitoring software on their devices to allow for further analysis of charging habits. Logs of readily available system data were stored on their phones and then collected after a period of time.

This included most importantly charging status, meaning whether the device was plugged in or unplugged and charge level in the form of a percentage. These values along with others, including the dates and times that the readings were taken were stored and later collected.

Altogether, the data collected comprised of almost 10,000 individual data points over a combined 52 days including 61 charge-discharge cycles. Coming from a variety of devices running the Android operating system, this sample is not representative of all devices in use, but rather a look into the usage habits of a few current generation smartphones and their users.

After collecting survey results through Google Forms, charge data was collected with the Battery HD app by smallte.ch and formatted in Microsoft Excel and Sublime Text 3. Graphs were rendered in a web browser with the help of the JavaScript libraries C3.js (Tanaka, 2014) and D3.js (Bostock, 2013).

8 Days of charging from 5 users compiled view
Charging cycles
In the following graphs, individual user’s charging cycles over an eight day period can be seen. A red horizontal rule has been placed at 15%, a common plug in point for many of the users. A more interactive view of these graphs can be seen on the author’s website at the following location: http://jess.pro/batterythesis

User 1

User 2

User 3
Discharge history
A view showing just the discharge phase of the charge cycle for each user can be seen on the following pages. The graphs are scaled to 1.6 days on the x-axis, the longest time from unplug to plug in of any participant in the study.

User 1

User 2

User 3
Patterns in device use
Looking at device data graphically, it’s easy to begin to grasp the variability experienced in daily use by individuals. Even from a full charge, in user 4’s case there was nearly a full 24 hours in usage difference between the shortest and longest times between charging.

Users 1 and 5 said they had more of a strict charging routine, reporting charging on a nightly basis compared to user 3 who wrote “I often forget to actually charge it. I do it whenever it comes to my mind.” They appear nearly identical in practice. Of these three, user 3 stated that they had no strong feelings towards the way that power information was displayed on their phone while user 5 said that they were happy and user 1 the opposite. Users 1 and 5 had both previously downloaded 3rd party battery applications.

As can be seen in the charging cycle graphs and mirroring the data collected in the initial survey, charging during the night seemed to be reasonably popular among all participants, with a major exception being user 4 who regularly charged from the early morning until afternoon.

Routines were often interrupted by periods of heavy power drain where an abnormally short period charging can be seen breaking up the more normal summits and valleys of regular use. These occurrences can be seen most visibly in the charge cycle graphs of users 2, 3 and 5.
Conclusions
As can clearly be seen in the responses and data collected in this and other studies, battery life depends highly on individual use, changing from user to user, day to day, and even from one minute to the next.

While quantifying the amount of energy use that is unintentional and possibly avoidable is difficult to pin down, assuming that most users would benefit from having to charge their devices less regularly is no large logical leap.

In some of the most in depth research on the topic to date, Falaki, Mahajan, Kandula, Lymberopoulos, Govindan & Estrin’s Diversity in Smartphone Usage discusses the wide range in typical smartphone use and proposes a personalized solution for estimating remaining battery life. They found that difficulty in blindly predicting future energy drain is due to high the variance, stating that in comparison to laptops “Energy drain prediction on smartphones is more challenging [...] Laptops provide a prediction of battery lifetime only for active use. Smartphone predictions on the other hand must cover multiple active, idle periods to be useful.”(Falaki et al., 2010) Their suggested solution is a personalized predictor which draws on patterns in user’s behaviors.

According to multiple market studies released in 2012,(Power & Associates, 2012; IDC, 2012) battery life is one of the areas where consumers are least satisfied with smartphones. In a release by marketing information services company J.D. Power and Associates titled Smartphone Battery Life has Become a Significant Drain on Customer Satisfaction and Loyalty, they found both “satisfaction with battery performance is by far the least satisfying aspect of smartphones, and satisfaction in this area is one of only a few attributes that have declined significantly”(Power & Associates, 2012). As internal technologies change, like in the addition of 4g communications mentioned by J.D. Power and Associates, usage patterns and factors leading to battery drain can increase on devices in ways unseen by the everyday user.

Responses in the exploratory survey as well as interviews by Ferreira et al. highlight the possibility that increased detail and clarity in the way battery information is relayed could greatly benefit a device’s user. In my brief questionnaire, multiple users mentioned wanting to see a percentage and questioned the accuracy of their current power level display while through interview Ferreira et al. conclude of users “they struggle to manage their devices’ battery life and that the standard battery life interface on their devices is still not helpful”(Ferreira et al., 2013)
Part IV: Battery information display in smartphones

(what is this🔋?)
Smartphone battery information

Today's smartphone market consists of three major operating systems, competitively grasping for dominance in a rapidly changing field.

Android

Currently the overall highest selling operating system worldwide, the Android operating system was the main reference point for this paper. Google, the owner of the open source platform announced in June 2014 that there are 1 billion active users (Warren, 2014). To put this into perspective, as of 2014, the estimated population of the earth is 7.2 billion (United Nations & Department of Economic and Social Affairs, 2014).

The operating system’s primary battery information display consists of a small icon in the upper right corner of the screen. This allows the information to be on screen at almost all times, but when shown without an additional percentage figure or estimated time remaining, gives a very limited view into the remaining battery life. The battery icon appears to be filled equal to the level of charge left in the unit when in fact it is not. In what seems like an attempt to make changes in battery level more visible, the icon changes at predefined levels. This in effect makes the icon into a seven segmented display while lacking visually distinguishable segments, making it falsely appear to be a smoothly draining fuel gauge style indicator.

[Battery icons to scale and above, the levels at which they are displayed on a reference device]

Devices in the Android ecosystem are spread across many build versions, each with slight variations in user interface. To illustrate this, the icons shown in the figure above are extracted from the system files of a device running Android 4.1.2, released October 2012 (Robertson, 2012), and below are those pulled from a device running Android 5.0.1 released in November 2014 (Motorola, 2014).

One of the highly touted features of Google’s latest Android release, 5.0, known as Lollipop is an efficiency gain brought about by an effort in the company known as Project Volta. Along with increased efficiency, a running battery percentage is now shown in a pull down notification drawer and a more detailed app level view of energy consumption and displays including a projected amount of battery life left can now be found (McGregor, 2014).

Other ways that battery information are displayed on Android phones commonly include pop-up style low and critical battery warnings, and the system battery display found through the system settings menu.
Part IV: Battery information display in smartphones

Currently the second most popular mobile operating system on the market (Mawston, 2014), iOS users are shown battery information in similar ways to those on Android and Windows phone (Ritchie, 2014; Verge Staff, 2013). As today’s third most popular mobile operating system, the Microsoft Windows Phone operating system is often overlooked (Microsoft, 2015).

3rd party battery applications

Clearly filling an unmet need, third party battery applications in mobile app stores have been installed on millions of devices. Some of the most popular applications claim to extend battery life by halting wasteful processes, but even more basic applications which simply display a more detailed level of battery information have tens of millions of downloads. Two examples are highlighted below.

Battery HD

A relatively basic battery application for Android. With more than 10 million reported installations, its main features are that it shows a battery percentage, gives estimated battery life times based on different activities and allows custom battery notifications (smallte.ch, 2015). This app was used in the data collection portion of this project because it allows users to easily export their battery data.

Normal

Spun off of a research project called Carat developed at UC Berkeley, in collaboration with the University of Helsinki, Normal is an iOS app that attempts to diagnose abnormal battery drain. By gathering data from a large pool of users, it attempts to find what is normal and give individualized suggestions to correct “energy bugs” (Oliner et al., 2013; Kuro Labs, 2014)
Overview of research on the subject

Much research has been done recently in the area of increased efficiency in smartphones. In attempts to achieve greater efficiency, most studies have been on attempts to inform users and save power on a per app basis (Metri et al., 2014; Zhang et al., 2012; Oliner et al., 2013; Ferreira et al., 2013), but little has been done to raise awareness of energy use at a system wide level.

For example, Ferreira, Ferreira, Goncalves, Kostakos, and Dey explored the display of battery information in their 2013 paper *Revisiting Human-Battery Interaction* with an Interactive Battery Interface. By studying usage and designing an interface which better displays the impact app use has on battery life, they were able to achieve gains of 27% battery life over the course of a day. In tying the battery interface to the applications which use the most battery, the researchers were able to raise user awareness of how they could ultimately save a large portion of the battery life (Ferreira et al., 2013).

Another interesting study is *Powerlet: an active battery interface for smartphones* by Jung, Chon, Kim, and Cha published in 2014. After gauging user attitudes and habits, they developed Powerlet, an interface which provides both application specific power use feedback and system-wide notifications after every 10% drop in battery level (Jung et al., 2014). This is a solid step towards providing real-time indications of system-wide energy use information, a strategy which has been shown to be an effective means of increasing efficient use in other fields.

Some choice quotes from research mentioned above:

“The growing complexity of mobile applications coupled with slow progress in the development of batteries has led to the requirement of energy-awareness in mobile devices” (Xiao et al., 2009)

“A more accurate indicator with better feedback may enable users to charge phones more conveniently” (Rahmati et al., 2007)

“This level of diversity [in smartphone usage] suggests that mechanisms to improve user experience or energy consumption will be more effective if they learn and adapt to user behavior.” (Falaki et al., 2010)
Part V: Design
(proposal and testing)
Methods
During the analysis of the early exploratory design research, and while researching information display in current smartphones, the generation of design concepts had already begun. The design opportunities and ideas that fell by the wayside are listed below followed by a design proposal which was elaborated upon and then tested.

Unselected ideas
Reserve fuel tank
Similar to the reserve level in the fuel tanks of some devices with combustion engines, smartphones could power down early with the intent of being purposefully re-started when needed. Phones already do this to some extent to allow for emergency calls and save things in volatile random access memory, but a larger reserve could be desirable.

BatCat: the battery that purrs
The haptic feedback mechanisms in a smartphone could be used to provide additional battery information. For example, a battery that uses the vibration function when a user wants to know their battery level.

Customizable notifications
Inflexible notification schemes, are often a complaint of users, this could be explored by allowing for more customizable battery communications.

Empathetic batteries
Rather than screaming that they are in danger of dying with low battery alerts, phones could take a more emotional path, creating a stronger bond between battery and user. Making human interaction with batteries more pleasant with friendlier notifications and warnings could possibly improve the way that we regularly interact with our devices.

Location aware batteries
By giving battery information systems the ability to leverage more of a phone’s features like location services, its utility could be greatly improved. An example being a phone alerting a user when it is near a pre-determined charging point and is not currently in use.

Learning charging ecosystems
There is a lot to be improved upon by building more intelligent battery systems. In one scenario patented by Apple in 2012, by learning a smartphone user’s routine, a phone is able to implement battery saving methods like lowering processor power draw and alerting users when it feels they should charge based on past scenarios (Ingrassia & Lee, 2014).
Design Proposal
After surveying possible design opportunities, a re-designed battery icon which actively displays rate of battery drain was selected for further exploration.

[Images of battery icon in different states]

Normal use  Elevated drain  Rapid drain

As was mentioned in the segment on designing for energy awareness, providing real-time feedback on activity can allow people the opportunity to take proactive steps towards reducing un-necessary use.

Shifting Slope
In the redesigned icon, the shifting slope of the leading edge gives three points of present and recent past reference. Similar to the way that earlier screen based battery level displays used the bar graph as a metaphor in their design (Ijntema et al., 1988), this proposal invokes the time series line chart.

Adding the dimension of time to the icon is meant to give the user a visual point of reference to objectively judge how the activities they are partaking in effect the rate of discharge on their device. Similarly to the way that Falaki et al. discuss using recent past to generate system predictions of remaining battery life, but recommend systems which learn user behavior, visualizing rate of drain allows users to take into account previous activity while adding the element of actual future plans, a feature currently unmatchable by artificial intelligence.

Color thresholds
In addition to providing an active look into use history, abnormal levels of power consumption can be highlighted. As was found in the studies on carat (Oliner et al., 2013; Athukorala et al., 2014), this can help users to curb abnormal energy usage. For increased visibility, the proposed icon has three color states indicating different levels of battery drain.

The re-design is meant to give more context to the rate of change in an easily visible way, allowing the user a way to meter battery usage that wasn’t previously available. Showing the user how quickly the battery is depleting, in theory removes some of the guesswork involved in estimating how quickly a device’s battery life is being used, and provides recent energy usage information at a glance.
Prototyping

Beginning with a series of sketches on the back of a boarding pass, this design made it through a series of minor alterations before taking the form that it was user tested with. The re-designed icon draws upon the current android battery icon and other compact forms of data display like the sparkline (Tufte, 2001), as its main inspiration. The following graphic is from a handout used to discuss the proposed benefits with users during testing.

**What does it mean?**

**Normal Battery Use**
This is how things normally look, your recent use is shown in the slope of the icon

**Elevated Drain**
When you’re doing something that drains the battery like watching an HD video or playing a 3D game, the battery lets you know

**Rapid Drain**
The battery’s running out quickly, maybe you should close some background tasks or turn down the screen brightness?

**What does it do?**
The new icon shows the change in battery level so that you can easily see how fast your battery power is running out

The digital mockups seen on the next page were created from a phone screen capture to better visualize the proposed design in-situ. These graphics were used mainly for informally discussing the concepts involved with friends, relatives and fellow designers. This process shaped the version that was tested with outside users and gave early insight into some of the problems that would arise during testing.
Video Prototype

Short of actually implementing the new icon at the operating system level, a video prototype was decided upon as the best way to nearly seamlessly integrate the proposed design into a phone for testing.

The video prototypes were 40 seconds long and consisted of a simulated notification bar overlaid on top of stock B-Roll video footage from the United States National Parks Service (National Park Service, 2011).

Two videos were used in user testing. One video (Video B) was created as a baseline, featuring a simulated phone interface running stock android version 4.1.2, and the second video (Video A) used the same interface, but with the battery icon in the top navigation bar being swapped out for the re-designed icon. The videos were created to be played back full screen on a Motorola DROID RAZR MAXX. The videos used can be seen online here Video A (vimeo.com/118336367) and Video B (vimeo.com/118336368). For the test, the proposed icon was scaled to fit the size of other notification icons, and measured in at 30 pixels across by 17 high compared to the vertical 24 pixels by 16 across of the stock icon. On the physical device this translated to the redesigned icon having a width of 3 millimeters.

For the purpose of the video testing, a direct equivalent of the stock icons was generated. As in the reference device the battery icon steps from 60% (displayed as 57%) to 49% (displayed as 43%), an equal jump was made in the filled in volume of the re-designed icon. This is not representative of an ideal change for the redesigned icon. Only updating a user once during an 11% change in state of charge with a 3 pixel difference in fill height is pretty minimal. The re-designed icon shifts in slope, fill volume and color to note this amount of activity.

Video A

[Image of video A]

Video B

[Image of video B]
[A to scale comparison of the icons used in video testing]

[From left to right: The reference screen capture used in creating the video prototype, a frame of the overlay used in Video A, and on the far right, a frame of the overlay used in Video B]

Testing setup

[Images of the testing station]
The video prototypes were tested in the main atrium of the Orkanen building at Malmö University. Being the largest university building at a school which enrolls around 25,000 students, a veritable torrent of welcoming testers were expected (Portland, 2009).

An empty desk in the building lobby was selected as a testing station. The testing station consisted of an outward facing sign to attract interest to the prototype, the phone used for testing, and assorted official looking documents. The designer (and author of this paper) sat at the helm of this testing station and attempted to entice strangers to come view the prototype.

Questions for testers were prepared beforehand and modified on the fly to fit a conversational style interview. In place of recording audio or video, a tricky proposal in public, on the street user testing, notes were taken by hand during and after discussion with participants.

During testing, eight people approached, or were summoned to the testing station seen in the photos on the previous page to participate. Each was first very generally briefed on the nature of the project and then shown one of the two video prototypes. After the video, questions related to the interface were asked and if the participant wasn’t in a rush to leave, they were asked more general questions about their feelings on smartphone battery interfaces and shown a handout on the re-designed icon.

The test audience was a mix of students, university faculty and loitering members of the public. The first three participants were shown the re-designed video prototype first, the next three were shown the simulated stock prototype and for the final two, the re-design was again shown first.

**Summary of User Testing**

In this round of user testing, empirical differences between the stock android icon and the re-designed icon were inconclusive. Important feedback from users was collected which would greatly impact any further revisions made to the proposed design.

When asked about the re-designed icon after watching the video prototype, none of the participants were able to correctly assume the message that was supposed to be conveyed by the slope of the fill. After being shown the handout explaining the design, responses were generally positive. This reinforced the notion that the proposed icon is difficult to read on first glance, especially at the size which it was displayed at in testing. Further refinement and testing for use at small scale is needed.

Four participants made comments about the color change in the icon and were prompted to elaborate further. One who did not notice the re-designed battery icon change states said that he would prefer a higher contrast change than the blue to yellow shift shown in the video prototype, noting that his battery icon was green and that he thought it would be more noticeable if the icon shifted from green to yellow. Another participant, who did initially notice the re-designed icon thought the color shifted because of a drop in battery which he estimated at moving from 50%-30%.

Other interesting anecdotes about personal experiences with battery life and charging were shared through the user tests. The first user tested said that he was happy with the current level of battery information on his phone, noting that his main use of the battery icon was when the phone was running low, implying any extra information would not be useful to him.
Another tester, also stating that he was happy with his current setup, shared more detail about his battery conservation strategy which included using a third party application to halt background tasks and having the percentage displayed along-side the icon. He indicated that while he was happy with the battery life on his smartphone, as it lasted him three days on a full charge, the battery life on his tablet, which he used for important tasks was problematic. His use of the third party application on his phone seemed to be a point of pride, and a large part of why he was happy with the battery life on his phone but he also mentioned that he didn’t always know the implications of halting tasks, the example given was of stopping a messaging service and then no longer receiving wanted updates.

When prompted on why she liked having the percentage displayed alongside her current stock android battery icon, a later participant said that she liked the percentage because it allowed her quickly to look and see the status of her battery.

Some testers made critical statements about perceived flaws in the testing procedures. Three participants when asked if they noticed a change in the top notification bar made comments to the effect that they were not asked to watch the top notification bar but instead were watching the scenery displayed in the testing video. This is viewed as an indication of the success in re-creating a natural use scenario, as in daily use a user would not be asked by a bearded man standing beside them to watch the top notification bar of their phone.

Although user testing was short of being emphatically for the re-design of the icon, one major point of note was that of all four users who shared how battery information was displayed on their phones, each reported being ok with the way information was displayed and all had slight differences, indicating that there is a high possibility of at least minor change being well received.

Although the clarity of information in the current proposed design is suspect and further revision is suggested, further re-designs of the icon would seek to simplify the means of communicating elevated battery drain. Including more detailed feedback in tandem with a glanceable display like the proposed design is also recommended. A percent charge or estimated time remaining can provide a set point to scale expected use to.

As with every design change, there are some perceivable drawbacks to this solution. One of the biggest outstanding questions is where to set thresholds, in the proposed design there are many that would need to be resolved for a pleasant user experience. The three color states used to differentiate between high, medium and normal battery drain would likely have to be set on a per device basis, or as recommended by Falaki et al., would have to learn and adapt to each device’s properties over time. The visibility of changes in the icon in motion will also need to be further refined.
Part VI: Conclusion
Conclusions
As can be seen through the exploratory research, design, and testing of the prototype, today’s smartphones could benefit from a more dynamic system level energy display. Through further refinement of the proposed design, a solution which harnesses the information already provided by battery management systems can be achieved. Helping users become more aware of their energy use habits allowing them to make more well-informed battery life decisions, and worry less about unintended battery drain.

Refinement

After taking into consideration the results of user testing and further scrutinizing research, a series of additional refinements have been made to the proposed design.

As more than one user tester expressed their expectation that color change meant something critical was taking place, use of color during the elevated drain state was dialed back. Instead of changing the entire icon’s fill color, a past reading of battery state of charge is highlighted and the most current reading overlaid on top of it. By highlighting the recent change in this way, through the leading edge of the icon, more emphasis is placed on ongoing change in battery status rather than solely relaying current status. This more subdued use of color also reflects design trends in the Android operating system.

After receiving multiple comments from users who liked having a percentage displayed, confirming earlier thoughts about higher amounts of battery information being desirable, the current battery percentage is displayed alongside the icon. The icon was also flipped for greater left to right readability, but this especially would benefit from further user testing.

Closing thoughts
For an area which handles an aspect so vital to consumers, the battery information display in mobile devices has changed surprisingly little in the past two decades, especially when considering the different activities undertaken by today’s user.

In all, until the need to recharge is removed from mobile devices, a battery display that provides more immediately visible feedback on battery drain is a possibility for alleviating user frustration with poor battery performance. Giving consumers more information about their battery usage habits has the potential to greatly impact mobile device manufacturers as well. According Buchmann in *Batteries in a Portable World,* “Cell phone manufacturers say that 90 percent of batteries returned under warranty have no problem, and tests conducted in the Cadex laboratories confirm this finding.” (Buchmann, 2011) Taking this into account along with general consumer dissatisfaction with battery life, distrust in batteries is an issue that clearly needs to be worked on and increasing the clarity and quality of battery information to the consumer is the obvious next step.
Directions for further inquiry

**History of battery information display**
A prominent part of so many of the screens we use, the evolution of battery information display is deserving of a more in depth look.

**Visualization of energy flow**
As energy systems are made increasingly intelligent, visualizing the journey of energy is a task which could impact all levels of energy use from the individual product to household and community scales. Visualizing rate of change in anything is a complicated task, especially in a commodity as intangible as electricity.

**Animation in system icons**
The ability to flawlessly animate objects in motion on today’s smart devices offers interesting possibilities in the notification of users. With this comes a great possibility of unnecessary visual clutter.

**Active versus intrusive notification of system information**
Displaying ever changing information without overwhelming is a difficult challenge, but as most research into sharing system information with users takes the form of intrusive alerts, more study of the effectiveness of minimally intrusive information displays must be done.
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Part VII: References and appendix
References


Appendix

Exploratory survey questions

Age

Gender

Do you use a smartphone?

What kind of phone do you use?

How long have you been using a smartphone?

How often do you charge your device?

Do you have a charging routine?

Does your phone ever warn you of its charge level?

When, or how often does it warn you?

How does it warn you?

Are you happy with the way that the power level is displayed on your phone?

Have you ever used a third party battery app?

Email Address