Mobile Information Visualization Design of the *Adkintun Mobile* App

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Abstract
Mobile devices are becoming increasingly more powerful, offering new possibilities to collect, process, show, and interact with information visualization data directly on them. Despite the appearance of a plethora of mobile apps with clever InfoVis designs, particularly in the area of personal visualization (e.g., fitness, energy), surprisingly little research has been conducted on information visualization on mobile devices. In this paper, we explore information visualization on mobile devices by presenting a first design iteration and an initial evaluation of the *Adkintun Mobile* app, which measures the quality of service (QoS) of mobile Internet connections. Based on our findings, strategies to both assist people in making sense of data and designers in creating effective visualizations for mobiles are discussed.

Author Keywords
Mobile InfoVis; mobile devices; user studies.

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

Introduction
Information visualization [13] has made its way into the media (e.g., TV, websites, newspapers), helping us

make sense of data by presenting it at an appropriate abstraction level and in an aesthetically pleasing manner [11]. Although initially meant for presentation and consumption on large print and display surfaces, information visualization data can now realistically be collected, processed, shown, and interacted with directly on our mobile devices. However, desktop visualizations do not scale well to mobile [3].

We present a first design iteration and an initial evaluation of the *Adkintun*[1] *Mobile* app, which measures the quality of service (QoS) of mobile Internet connections. Originally conceived as a website where people could review their mobile Internet usage from a tablet, a desktop, or a laptop screen, a first iteration of the mobile app was designed using established guidelines for (mobile) user interface design [6,9,10] in an attempt to help people visualize QoS information directly on their mobiles and while on the go. In a user evaluation of the app, participants understood the information presented by the different parts of the app (i.e., connection time, type, and signal quality) thanks to the use of familiar metaphors (i.e., traffic light, natural light), but not all were familiar with specific services (i.e., GPRS, Edge, H, and H++).

Related Work

Over the last 30 years, the field of HCI has been studying information visualization (or InfoVis) [4]. Its main goal is to generate interactive, visual representations of information spaces to amplify users' cognition [2]. InfoVis research has traditionally found a home in Computer Science communities. However, when a human perspective is taken, InfoVis is an activity that is carried out by a human being when forming a mental model of something, which can be enhanced through computational support by representing, presenting and interacting with information [8,13].

Despite the appearance of a plethora of mobile apps with clever InfoVis designs, particularly in the area of personal visualization (e.g., fitness, energy), surprisingly little research has been conducted on information visualization on mobile devices [3]. Pattath et al. [11] used PDAs to visualize network information during (American) football games. By monitoring people's association/dissociation from wireless access points, their system allows detecting crowd movement and event activity inside a stadium. MobiVis [12] is a visual analytics tool to explore and make sense of social-spatial-temporal data captured by mobile devices. Social and spatial information is presented as a heterogeneous network in a 2D graph visualization.

Adkintun Mobile

Since 2012, the *Adkintun Mobile* project has been measuring the quality of service of mobile Internet connections in Chile [1]. The service gathers 46 million data tuples every three months by means of a crowdsourcing infrastructure. Based on the metrics of antenna coverage and Internet connectivity, the app passively monitors and measures QoS directly from people's Android devices without generating network traffic. Its first version included a website where people could review their mobile Internet usage. The visualization consisted of vertical lines representing connection time on a horizontal timeline, which formed

[1] Adkintun means observer in Mapudungun, the language spoken by the indigenous inhabitants of south-central Chile, the Mapuche people.

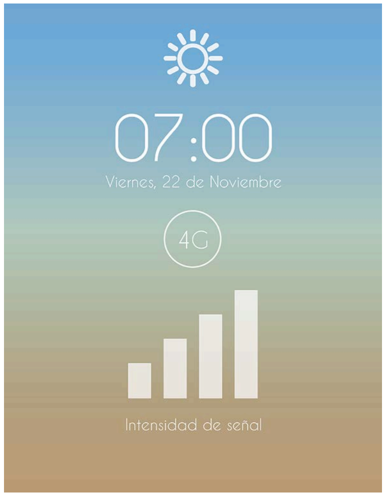

Figure 1: Adkintun Mobile signal quality (4G) in the morning (7:00).

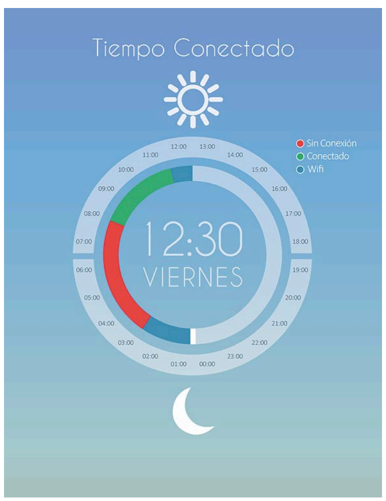

Figure 2: Connection time (offline/ online/Wi-Fi) in the afternoon (12:30).

visual blocks whenever there was a concentration of lines, and thus was better suited for display on a large tablet, a desktop computer, or a laptop screen.

Based on the existing literature and established guidelines for (mobile) interface design (i.e., *affordance, efficiency, consistency, simplicity,* and *metaphors* [6,9,10]), we designed a first iteration of the app to help people visualize QoS information directly on their mobiles and while on the go. The main questions that users can explore in the data regarding their mobile Internet connectivity are: *the time of the day when it has been active, the type of connection used,* and *the signal strength available at any given time*. To serve those questions, the interface uses a 24-hour clock dial and doughnut chart, traffic light and natural light metaphors, and simple iconography, all combined to provide information on connection time, connection type, and signal quality.

Connection Time

The app monitors mobile Internet connectivity for 24-hours, each day. A phone is considered to be offline even though the device appears to be connected, as calculated by comparing the connectivity among devices of the same Internet service provider (ISP). To provide a familiar representation of time, we used the 12-hour clock dial. However, as the app monitors activity over an entire day, we decided to use a 24-hour clock dial instead (Figure 2). The dial is split horizontally in two halves, one for each 12-hour cycle. The top half covers the time between 6:00 in the morning and 18:00 in the afternoon, while the bottom half corresponds to the time associated with the evening and night between 18:00 and 06:00. In addition, we introduce simple iconography representing the sun and the moon to further assist people in recognizing the time of day when the data is presented. By looking at the 24-hour dial, people can at a glance figure out, for example, if they are looking at day (closer to the top of the dial) or night readings (near the bottom of the dial). This is particularly useful to help people know that when they look at "11:00", it corresponds to 11:00 am instead of 11:00 pm. Such a dial allows people to get a quick overview for the whole day, while at the same time avoiding other alternatives such as using a double 12-hour dial or overlaying one dial over the other and playing with opacity levels. The 24-hour dial was further complemented with characteristics of a digital watch (i.e., time and day). SpiraClock [5] provides an alternative way to represent time on computers by combining an analog clock with a white spiral inside that represents the near future, on which nearby events are depicted as colored sectors.

Using a traffic light metaphor, different colors were used to show on a doughnut chart whenever the Internet connection was online (i.e., green) or offline (i.e., red). In addition, the color blue was used to indicate the use of Wi-Fi. Connection readings start at midnight, which is shown as a white bar.

Connection Type

The app also shows the connection type during a day (Figure 3). Similarly as for connection time, the same 24-hour clock dial is used, but this time six types of connections (i.e., GPRS, Edge, 3G, H, H++, and 4G) are displayed on the doughnut chart using different color hues than the ones previously applied for connection time. In this way, all variables (i.e., for connection time and connection type) are coded using a different color each. A legend showing the different

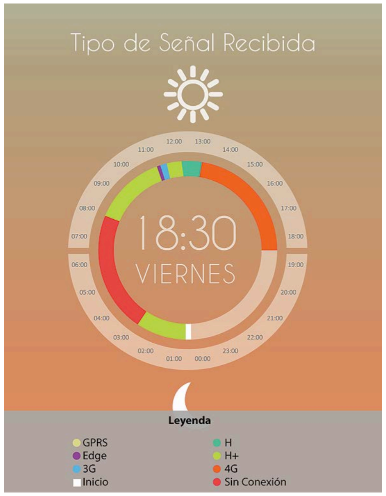

Figure 3: Connection type (GPRS, Edge, 3G, etc.) in the evening (18:30).

Figure 4: Signal quality (3.5G) at night (22:30).

connection types is presented at the bottom of the screen. Finally, and for sakes of consistency, the start of the connection type readings is shown as a white bar, while an offline connection is displayed in red.

Signal Quality

We provide ways for people to check the signal strength at any given moment (Figures 1 and 4). Signal quality is calculated by comparing the signal strength of several devices at the same time and area (e.g., antenna, neighbor). Using the metaphor of natural light [7] at different times of the day, we present people with different background gradients depicting morning (Figure 1), afternoon (Figure 2), evening (Figure 3) and night (Figure 4) times. We then overlay connection type and signal strength information on top of the respective gradients, together with the aforementioned icons for the day (i.e., sun) and night (i.e., moon). The natural light metaphor is also used in the background when presenting connection time and type (Figures 2 and 3).

Initial Evaluation

In order to assess the ease of use of the *Adkintun Mobile* UI and how people perceive different aspects of the proposed information visualization, we conducted an initial user evaluation. We collected quantitative and qualitative data by means of a questionnaire and during semi-structured interviews.

Participants, Procedure and Analysis

The evaluation was conducted with 10 participants from the Santiago metropolitan area who varied in gender (5 female, 5 male), age (between 20 and 35), and education (5 professionals, 5 students). All participants owned a mobile phone (i.e., smartphone) and were familiar with other touch devices (e.g., iPad).

Each 30-minute session consisted of three parts: introduction, task, and semi-structured interview. First, the experimenter greeted the participant, collected background information from them, and provided a description of the study (10 min). Next, participants were asked to complete a series of tasks on the *Adkintun Mobile* app (10 min). Participants rated interface aspects on a 5-point Likert scale (where 1 is strongly disagree, 5 is strongly agree, and 3 is neutral). Finally, semi-structured interviews were conducted where a consistent number of open-ended and multiple-choice questions were asked (10 min). All sessions were conducted in a meeting room. Participants sat at a table and a Samsung Galaxy S Mini running the *Adkintun Mobile* app was placed in front of them. No compensation was given to the participants.

All sessions including the semi-structured interviews were recorded on video, transcribed, and translated from Spanish by the second author. Two researchers independently coded the transcripts.

Findings

Connection Time

Regarding connection time (Figure 2), almost all participants (9/10) found it fairly easy to identify and make a relation between the hours of the day and the type of connection they had in a certain time period. According to these users, the visualizations and the colors used were easy to understand: *"(It shows) connection time, the type of connection or the lack of it, (and) the start of the day is (also) indicated."* [P5] In the questionnaire (Figure 5), the high ratings and low standard deviation for the 24-hour clock dial and doughnut chart (M=4.7; SD=0.48) seem to confirm this. One participant had some trouble with the 24-hour dial and doughnut chart and was therefore unable to clearly identify specific time ranges. When asked in the questionnaire (Figure 5) whether they felt additional information could be presented on such a visualization (Q2), participants seemed to be less positive and show more disagreement (M=4.0; SD=0.81).

Connection Type

Regarding connection type (Figure 3), although all participants but one (9/10) were able to quickly recognize connection types according to time using the legend, half of them (5/10) were unfamiliar with the specific services (i.e., GPRS, Edge, H, and H++): *"I understand the (visualization), but I'm not familiar with the different types of data."* [P1] *"Perhaps there should be something that explains what H and H++ are."* [P2] One participant thought the visualization showed most convenient (i.e., price) service types at a given time.

Signal Quality

Participants quickly identified signal strength (Figures 1 and 4). Regarding the use of the natural light metaphor, the use of gradients and color transitions allowed almost all of them (9/10) to easily identify the passing of the hours during the day, which Q3 of the questionnaire (Figure 5) confirms (M=4.5; SD=0.7). In one task, we presented the four backgrounds shown on Figures 1-4 but without any other UI elements overlaid on top of them, and asked them to assign them to one of four time ranges (i.e., morning: 6:00-12:00; afternoon: 12:00-18:00; evening: 18:00-21:00; and night: 21:00-6:00). All participants (10/10) agreed on the evening (Figure 3) and night (Figure 4) backgrounds, but seemed to disagree on the morning (6/10 picked Figure 1) and afternoon (6/10 picked Figure 2) color gradients. However, when we specifically asked them about the icons representing the sun and the moon, almost all (9/10) recognized them as indicators for night and day. The high ratings for Q4 of the questionnaire (Figure 5) seem to confirm this (M=4.8; SD=0.42).

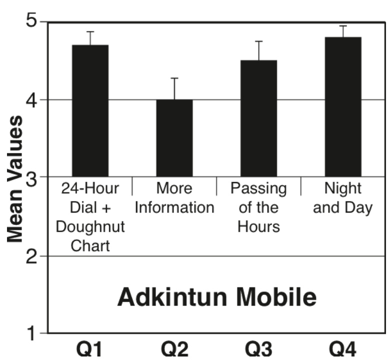

Figure 5: Mean values and standard error for the four questionnaire items.

Discussion

Use Context

The original goal of the first design iteration for the *Adkintun Mobile* app was to allow people to visualize mobile Internet connectivity QoS information directly on their mobile devices. The app does indeed allow collecting and displaying such information on mobile devices and people were able to successfully make sense of the data. However, we also wanted them to obtain this information while they are on the go. In this respect, our initial lab evaluation does not take people's potential use context into account. We would like to study how context might affect people's interaction with the app or the visualizations' required level of detail.

Increasing Visual Complexity

An important challenge when designing information visualizations on mobile devices is to avoid cluttering the limited screen space, while at the same time displaying all the essential information to make people's cognitive task easier [11]. From the questionnaire, participants seemed to agree with the idea of adding more information to the 24-hour dial and doughnut chart (Figure 2). However, we believe that the clean and minimalistic design, coupled with the use of white (or empty) space, plays an important role in helping people make sense of the data. Designers should carefully think about how to design effective visualizations for mobile devices before carelessly adding more visual complexity into their designs.

Conclusion

We have presented a first design iteration and an initial evaluation of the *Adkintun Mobile* app, which allows people to check their mobile Internet connectivity through information visualization shown directly on their mobile devices. In an initial evaluation of the app, participants were able to make sense of the visualizations presented by different parts of the app (i.e., connection time, type, and signal quality) thanks to the use of established interface design guidelines and familiar metaphors (i.e., traffic light, natural light). We also found that not all participants were familiar with specific mobile Internet services (i.e., GPRS, Edge, H, and H++). In future studies, we will study the use of the app in different parts of the city, and test different levels of visual complexity.

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