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Master 2 in Computer Science

Human-Computer Interaction Program

Design Considerations for Data Visualization on Smartwatch Faces

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Master Thesis

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Summary

This thesis presents my research on design considerations and user preferences for data visualization on smartwatch faces. Watch faces are the home screen of smartwatches that display a wide variety of data, including time information and other contextual information, such as weather information, fitness information, and device information [12]. Users can customize watch faces by syncing watch faces from watch face apps or websites, such as Facer [11]. Our goal was to understand the features of popular watch faces, the design characteristics of watch face visualizations, and users' preference for watch face visualization.

I started by the analyzing the characteristics of existing popular watch faces. From an exploratory analysis of Top100 premium watch faces on the Facer website [11], I derived a set of codes of types of features I found on the watch faces and corresponding visual characteristics that could modify these visual features. I analyzed the most common visual characteristics of popular watches including aspects of time display, the number of complications, data types, data correlations, graphical decoration types, hues, animations, and UI styles.

Based on my analysis of top watch faces, I summarized the characteristics that designers should consider when designing visualizations on watch faces. These design considerations consist of two levels: the whole watch face and individual complications. The whole watch face design considerations include smartwatch components (time display, number of complications, data type of complications, and graphical decoration) and visual features (use of color, animation, UI style watch face topic, and layout). The complication design considerations include data types on the smartwatch (absolute numeric, proportion, categorical, ordered, temporal and geospatial) and chart considerations (type, size, color, position, and theme).

After I derived watch face visualization design considerations, I wanted to understand users' preferences for different visualization design choices. So in the next step, I conducted a survey to measure aesthetic preference of five types of charts (bar chart, donut chart, gauge chart, discrete bar chart, and text) for visualizing proportion on watch faces. The aesthetic pleasure in design scale results shows that the donut chart was the most aesthetically pleasing compared with all other charts. I also included two items to measure the sophistication and comprehensibility of these five charts. The result shows that most participants chose "slightly agree" to the statement that the donut chart looked sophisticated, chose "neutral" for the statement that the discrete bar chart looked sophisticated, and chose "disagree" for the statement that bar, gauge, and text looked sophisticated. All five designs seemed comprehensible to people. From this, I concluded that among all five designs, the donut chart is most preferred by participants, and I recommend using a donut chart to visualize proportion data on watch faces.

Keywords

micro visualizations, smartwatches, visualization design, aesthetic pleasure measurement

CHAPTER 1

Introduction

Smartwatches that can track a wide variety of data are becoming increasingly popular. According to a recent research and markets survey, the global smartwatch market forecasts to grow at a Compound Annual Growth Rate (CAGR) of 17.1% from 2020 to 2027 [9]. However, the small size of smartwatch screens also creates unique challenges [4] that call for visualization research. In this thesis I contribute an understanding of the current space of smartwatch face designs, a design characteristic analysis, and a study on user preferences.

1.1 Motivation

Smartwatches can broadly be defined as a wearable computer in the form of a watch [28]. They can provide part of the functions of smartphones and computers, while also expressing the wearers' personality [15]. People mainly use smartwatches for tracking activities, checking notifications and keeping time [20]. Other specific usages of smartwatches include supporting students learning [8, 30], augmenting interactions in an office environment[3], monitoring diet [25, 27], etc.

Watch faces are the home screen of smartwatches, and watch wearers see it first when glancing or turning on their watches [12]. Since quick unprompted peeks are the most common way of using smartwatches [4], watch faces are the most frequently used screens of smartwatches. Watch faces often have two states: a dozing state and an awake state [17]. The dozing state is also called the always-on state, a simplified version of the watch face with low brightness. It displays basic time with ultra-low power consumption. The awake state shows the full watch face, which displays the time information as well as other contextual information, such as weather information, fitness information, and device information. Common shapes of current watch face are rectanglar (e.g., Apple Watch) or round (e.g., WearOS watch). Users can customize watch faces by installing watch faces on their watches.

People often want to see data beyond time and date on their watch faces. This data can be rich and benefit from dedicated visualization. On average, smartwatch wearers set their watches to display five different types of data in addition to time and date on their watch faces, which is a high amount given the size of a smartwatch screen [12]. The resolution of smartwatch displays is generally 128–480 pixels per side, with a viewing area of around 30–40 mm [4]. Therefore, data representation on these small displays is a visualization challenge.

Most prior research about smartwatch visualization focused more on the design exploration of certain specific data types (such as the number of step counts [10]), or the performance of certain specific charts (such as the bar chart, pie chart, or donut chart [4]). What is currently missing is an in-depth exploration of the design constraints and characteristics for smartwatch faces. Therefore, my work targets answering the following research questions:
Q1: What are the features of popular watch faces?
Q2: What are the design characteristics of watch face visualizations?
Q3: What are user preferences for watch face visualization?

1.2 Methodology

I started my exploration by collecting popular watch face data from Facer [11], a popular watch face distribution website, and qualitatively coded their designs. My findings from the inquiry summarized the features of popular watch faces and inspired me to develop a design considerations for visualization on watch faces. Based on the design considerations, I put forward five different watch face designs with one visualization of proportion-type data. I conducted a survey to measure the aesthetic preference of different visualization designs. The survey consisted of two main sections. The first was a 7-point Likert scale that asked participants to assess five visualizations on aesthetics, sophistication, and comprehensibility. Second, it asked participants to rank the five visualizations and explain why they chose the top design. By analyzing the survey results with both qualitative and quantitative methods, I concluded that the donut chart is the best choice for designers to visualize proportion data on watch faces.

1.3 Contributions

The key contributions of this work include: (1) An exploration of features of current popular watch faces designs, primarily focused on data representation (2) a set of design considerations for visualization on watch faces, (3) a survey about user preferences for how to visualize proportion-type data on watch faces.

1.4 Thesis Organization

This thesis is structured as follows:

Chapter 2 describes the related work on smartwatch visualization guidelines and design exploration. It covers research in smartwatch face design, smartwatch visualization, and aesthetic pleasure measurement.

Chapter 3 covers a systematic review of the top watch faces on the Facer website [11]. Here I coded 400 popular watch faces, and I analyzed the most common visual characteristics of popular watches from aspects of time display, the number of complications, data types, data correlations, graphical decoration types, hues, animations, and UI styles.

Chapter 4 describes design considerations for a whole watch face, including smartwatch components (time display, number of complications, datatype of complications, and graphical decoration) and visual features (use of color, animation, UI style watch face topic, and layout).

Chapter 5 describes design considerations for an individual complication, including data types on the smartwatch (absolute numeric, proportion, categorical, ordered, temporal and geospatial) and chart considerations (type, size, color, position, and theme).

Chapter 6 describes methods, analysis, and results of a survey of users' preference for different visualization designs on watch faces.

The last chapter summarizes the conclusions and suggests future work on this topic.

CHAPTER 2

Related Work

My work is closely related to watch face design, smartwatch visualization, and aesthetic pleasure measurement. In this chapter, I present research in these fields.

2.1 Smartwatch Face Design

As my thesis goal was to better understand the design of and how to design for smartwatches, I looked at related work on watch face design.

Both researchers and smartwatch companies have put forward guidelines for smartwatch design.

The main design guideline of Google Wear OS are "timely," " glanceable," " easy to tap" and "time-saving [24]." Apple provide a detailed document of human interface guidelines for Watch OS [2]. The design fundamentals of Watch OS are "target a single feature or task", "enable quick interactions" and "design and build for independence."

Other researchers also put forward some guidelines or design qualities for smartwatches, but they target different parts. In research, people have extracted guidelines when studying glanceable behavioral feedback, design mobile computing class, and explore usage of current digital watches.

Gouveia and colleagues took step count design as an example, explored the design space of glanceable behavioral feedback, and extracted 6 design qualities [10]:"1) Data abstraction; 2) Integrates with existing activities (e.g., Checking time); 3) Support Comparisons to Targets and Norms (e.g., Daily target or other people's achievement); 4) Actionable (e.g., Give suggestions); 5) Leads to checking habits; 6) Acts as a proxy to further engagement."

Esakia and colleagues used smartwatch design and development as a module of their mobile computing class. They documented the class process and proposed five design guidelines [7]" 1) Delegate prominent watch face space for typical (smart)watch functions (e.g., displaying time); 2) Provide frequently updated glanceable summaries; 3) Present users with information about quickly attainable goals; 4) Allow users to quickly obtain extra details of the summaries; 5) Delegate non-glanceable details onto the smartphone."

Lyons [18] explored how people use their current digital watches and transferred insights to smartwatch design. They found users preferred watch faces, which are "easy to read," "quick and glanceable," and "simple or non-cluttered." In terms of the aesthetics of watches, the typical positive concepts commented by participants were "sleek," "simple," and "not flashy," while negative concepts were "blocky," "bulky," and "clunky. "They also mentioned that the color of the watch was often indicated as a positive aspect. Some participants commented that the color of their watch was a differentiating factor. Participants also cared about how the watch looked on them. These reviews are for the aesthetic of the whole watch and can be referenced for the watch face design. Therefore, I took these guideline into account when I developed the design space in Chapter 4 and Chapter 5.

These three sets of design guidelines are important to several choices I made in the study of smartwatch aesthetics presented in Chapter 6. In particular, the importance placed on displaying time on the watch faces and showing data relative to identified goals.

2.2 Visualization on Smartwatches

Current research on smartwatch visualization is still limited. Most researchers focused on the performance of basic visual channels for smartwatch visualization or explored new visualization techniques for smartwatches.

Reviews of Visualizations on Smartwatches

Amini and colleagues [1] surveyed 39 health and fitness applications of smartwatches and they found the ways of data representation including text, donut chart, bar chart, pictograph or icon-based representation, and map. They also observed that these visualizations show summarized information rather than detailed information. My work also focuses on the ways of data representation on smartwatches. In my investigation of the design considerations of complication visualizations reported in Chapter 5 and in the design the survey in Chapter 6, I extracted types of charts as a visualization characteristic.

Islam and colleagues [12] surveyed 237 smartwatch wearers and asked about data representations on their watch faces. The authors found that health and fitness data was the most common data type on smartwatch faces, and icons accompanied by text were the most frequent representation types on smartwatch faces. This research is closely related to my work. In Chapter 3, I similarly investigated the most common data types on popular watch faces and compared my results with this survey.

Analysis of Visualization Encoding Techniques

There are different visualization characteristic on smartwatches that can impact users' reaction time.

Blascheck and colleagues [4] studied data comparison performance of different chart types on smartwatches. They investigated three chart types (bar chart, donut chart, radical bar chart) and three data sizes (7, 12, and 24). They conducted two perception studies to find a minimum time threshold participants would need to conduct a simple data comparison task. They found that bar and donut charts had similar performance, but radial bar charts have worse performance than the other two—the difference increases as the number of data values increases.

Lyons [19] studied visual parameters' impact on users' reaction times on smartwatches. They investigated the size of the visual notification (3 levels), the frequency of blinking (3 levels), and the color of the notification (12 levels). They found statistically significant differences for the impact of both size and frequency on reaction time, where bigger display size and quicker blinking frequency resulted in faster reaction times.

New Visualization Techniques

Prior research explored special visualization techniques for smartwatch-sized screens. For example, Chen [6] proposed a border visualization with a fisheye-based interaction technique exploring time-series data on smartwatch screens. Neshati and colleagues [23] proposed a glanceable representation of line graphs on smartwatches called G-Sparks, with a dense compression of line graphs along the x-axis. Klamka [14] and colleagues embedded display and touch technologies into smartwatch straps to extend the input and output capabilities of smartwatches.

2.3 Aesthetic Pleasure Measurement

In order to measure user preferences for different watch visualization designs, I explored research on aesthetic pleasure measurement.

Prior researchers developed several validated scales to measure the aesthetics of websites. Lavie and Tractinsky [16] identified that users' perceptions of aesthetics include two dimensions, which they termed "classical aesthetics" and "expressive aesthetics" in a series of four studies. They developed and validated a scale to measure the aesthetic of websites from these two aspects. The items they used for measuring classical aesthetics include "clean," "clear," "pleasant," "symmetrical," "aesthetic." The items they used for measuring expressive aesthetics include "original," "sophisticated," "fascinating," "creative," "uses special effects."

Moshagen and Thielsch [21] pointed out that Lavie's scale has the following problems: First, "uses special effects" and "symmetrical" are not necessarily aesthetic. Second, it is hard to explain why the item "aesthetic" only relates to the classic aesthetic dimension. Third, their items are too abstract to use for improving the design. Based on Lavie's scale, they identified four facets of visual aesthetics of websites and validated a scale to measure them. The items in the scales are such as "the layout appears well structured," "the design appears uninspired," "the color composition is attractive" and "the layout appears professionally designed."

Blijlevens and colleagues [5] pointed out that previous scales do not measure aesthetic pleasure separately from determinants of aesthetic pleasure. Therefore, Blijlevens and colleagues proposed the aesthetic pleasure in the design scale for measuring aesthetic pleasure for designed artifacts. In this scale, they distinguished between aesthetic pleasure and its determinants. Their scale includes five items, "beautiful," "attractive," "pleasing to see," "nice to see," and "like to look at," that together reliably measure aesthetic pleasure. In addition, they also pointed out some dimensions suitable for measuring prominent determinants of aesthetic pleasure, such as typicality, novelty, unity, and variety. In Chapter 6, I used this aesthetic pleasure in design scale to measure the aesthetic pleasure of different visualization designs on watch faces in my study.

CHAPTER 3

Existing Watch Faces Analysis

3.1 Motivation

In order to understand how current popular watch faces are designed, I wanted to analyze the characteristics of existing watch faces. Therefore, I did a systematic review of the top watch faces on the Facer website [11].

3.2 Methodology

Data Collection

Facer [11] is one of the most popular watch face distribution websites. There is a Top100 page on the Facer website, where we can choose to see the Top100 premium or free watch faces of the Apple Watch, WearOS watches, or Samsung watches. The list for WearOS and Samsung is the same, and the list for the Apple Watch is sometimes not complete. I learned through the Facer online community that the Top100 list is a real-time ranking based on sync count since last Sunday. It resets every Sunday at midnight. I considered the preferences of premium faces as most valuable because watch wears willingness to pay for watch faces shows they are deeply interested in watch faces. Therefore, I chose to analyze the WearOS premium Top100 watch faces. I collected the list every Sunday night for four weeks starting from March 14, 2021.

I recorded metadata of these 400 watch faces in a Google spreadsheet. The information includes: the timestamp of when I collected this watch face, its rank in the Top100 list, the watch face name, a watch face thumbnail, and a link.

Classification Scheme

I explored the top watch faces and derived a set of codes by first detailing the types of features found on the watch faces and then deriving visual characteristics that could modify these visual features. The final list of codes I used is listed in Table 3.1. The codes consist of two groups: components on smartwatch faces and visual features of smartwatch faces.

Based on a first exploratory analysis, I summarized components on smartwatch faces: data, graphical decoration, and functional buttons. Data on watch faces includes two parts, time-related data (e.g., time, date, day) and non-time data. Non-time data on watch face is also called complications [13]. For example, a watch battery level indicator is a complication. There can be multiple complications on the watch face, displaying different types of data. Graphic decoration refers to elements on smartwatch faces that are not related to data. Functional buttons are buttons that link to other functions of the watch, such as the Settings button. Among these components, data and graphical decoration are closely related to the visualization design on the watch. Therefore, I chose time display, number of complications, data types of complications as the three dimensions of the analysis of the top watch face.

	Dimension	Values
Smartwatch Components	Time Display	digital, analog, hybrid
	Number of Complications	0, 1, 2, ...
	Data types of Complications	watch battery, step counts, calories burned, ...
	Graphical Decoration	container, logo, background graphic, screen border, foreground graphic, divider
Visual Features	Number of Hues	0, 1, 2, ...
	Animation	animation for graphical decoration, data-related animation (heart rate, watch battery, weather ...)
	UI Style	skeuomorphism, semi-flat, flat

Table 3.1: Codes of visual features of top watch faces.

There are some visual features that affect the entire watch face design across components. Among these visual features, I identified some dimensions that are closely related to visualization on smartwatch faces, including color, animation, and UI style.

After I determined the codes, I analyzed the 100 top watch faces for 4 weeks and recorded the value of each dimension of each watch face into the Google spreadsheet.

3.3 Results

Among these 400 top watch faces, 201 were unique watch faces. By analyzing these 201 watch faces, I answered the following questions.

Q1: How is time displayed on watch faces?

Watch faces can be divided into digital watch faces, analog watch faces, and hybrid watch faces depending on how the time is displayed. Digital watch faces show time information as HH : MM : SS for hours, minutes, and seconds. Analog watch faces typically use the hour, minute, and second hands to indicate the time, which looks like conventional analog watches. Hybrid watch faces show both digital and analog time displays [13]. Figure 3.1 shows that majority of popular watch faces are digital watch faces (48.3%), followed by analog watch faces (29.4%) and hybrid watch faces (22.4%).

Q2: How many complications are there on the top watch faces?

I was first interested to see how many complications were shown on the watch faces. The median number of complications on a watch face is three. Figure 3.2 (a) shows that most watch faces have only one complication (19.4%). However, only 0.8% of watch faces have one complication in Islam et al.'s survey [12]. Watch faces with fewest complications had zero complications, see Figure 3.3 (a) as an example. The watch face with the most complications had 16 complications, as shown in Figure 3.3 (b). This max number is similar to the result of Islam et al.'s survey.

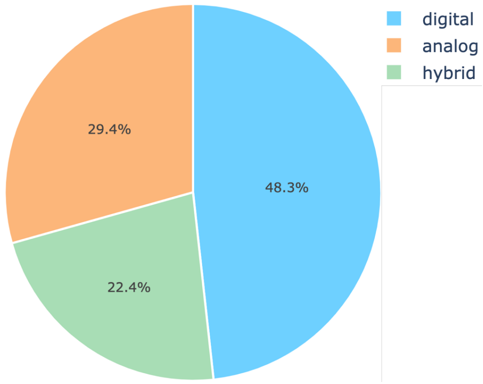

Figure 3.1: The most common ways to show time on the top watch faces.

Q3: What are the top ten most common types of data on the top watch faces? Next, I investigated the top 10 most common data types on the watch faces, as shown in Figure 3.2 (b). I followed Islam et al.'s survey [12] and divided the data into three categories: health-related data, weather-related data, and device-related data. As the result of Islam's survey, health-related data were most common, followed by weather-related data and device-related data.

I compared the top ten most common data types in my work with the top ten most common data types in Islam et al.'s survey, as shown in Figure 3.2 (C). Watch battery level, step count, heart rate, temperature, weather info, distance, calories, phone battery, sunset/sunrise time are the top ten in both studies. Especially watch battery level, ranked first in both studies. Moon phase was ranked 15th in Islam et al.'s survey but ranked 6th in my work. Bluetooth was ranked 7th in Islam et al.'s survey, but I did not see it on any top watch face. The main difference lies in the fact that Islam et al.'s survey studied watch faces that wearers saw on their watches, while my work focused on popular watch face designs to purchase. I speculate that there are three reasons why Bluetooth data is not displayed on the watch design images: 1) some smartwatches use WiFi instead of Bluetooth to connect to the phone, so it is not always necessary to show Bluetooth data on watch faces; 2) the Bluetooth icon is not on the watch face, but on other screens of the smartwatches, as shown in Figure 3.4 (a); 3) some smartwatches system will add a disconnected symbol to watch face when it is not connected to the smartphone, as shown in Figure 3.4 (b). The symbol disappears when the smartwatch is successfully connected, as shown in Figure 3.4 (c).

Q4: Which types of data are commonly shown together on the top watch faces? My supervisors and I performed a co-occurrence analysis of data types of the popular watch faces. Figure 3.5 shows pair-wise correlations between data types that were present on the unique top watch faces analyzed on the Facer application over a four-week period. The thicker the link, the stronger the correlation between the data types. Circle size corresponds to how often the data type was found on smartwatch faces. Circle color corresponds to cluster membership derived from a hierarchical clustering on the complete data type correlation matrix—only connections with correlations larger than 0.224 (the mean positive correlations) shown. We also generated a similarity matrix and a hierarchical clustering dendrogram of data types on watch faces, see Appendix A Figure 7.1

Q5: What are the most common graphical decoration types on the top watch faces?

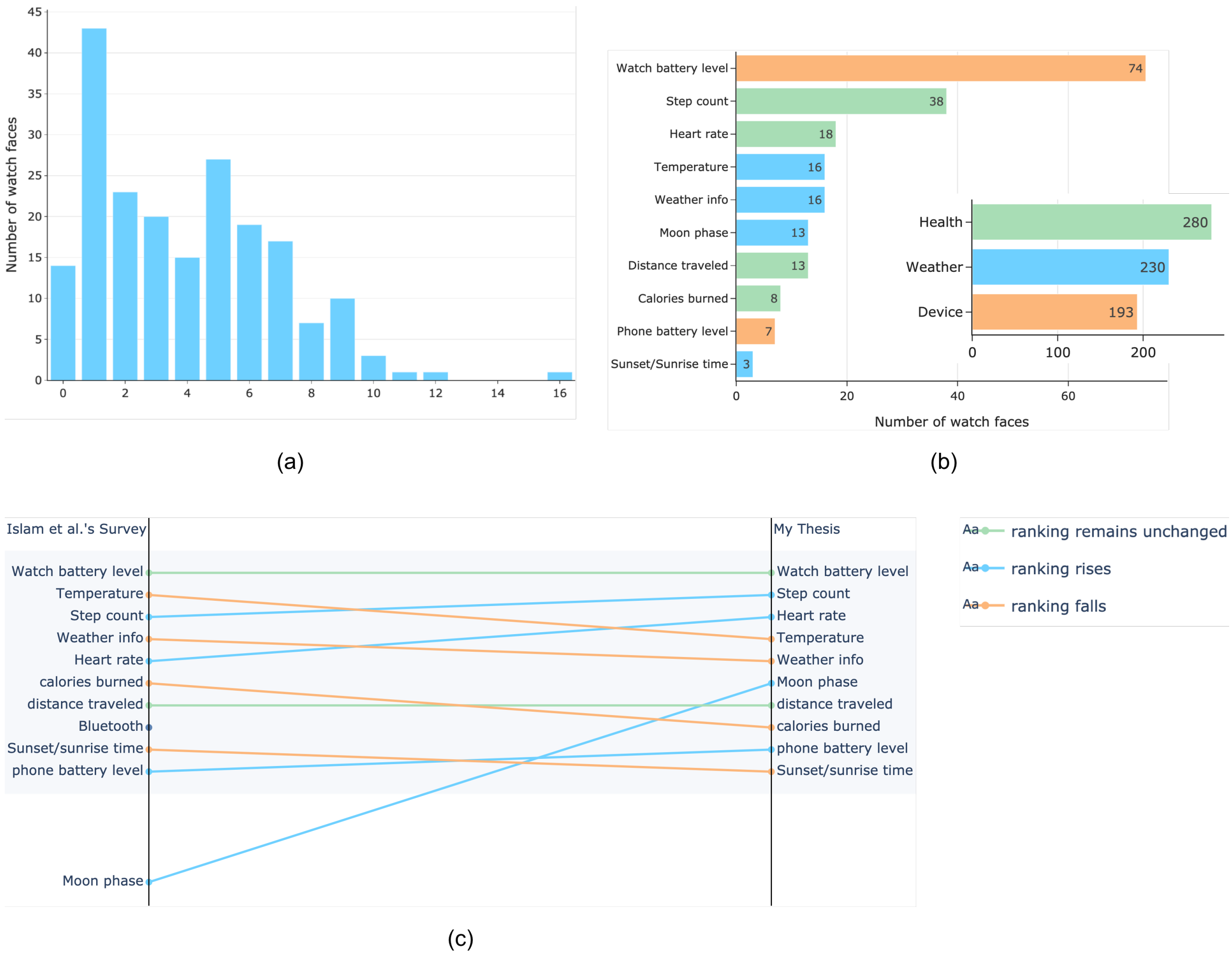

Figure 3.2: (a) Number of complications on watch faces; (b) top ten most common data types on the watch faces; (c) the top ten most common data types in my work were compared to the top ten most common data types in Islam et al's survey.

To study whether space is devoted to non-data carrying elements, I investigated the graphical decorations on the top watch faces. I divided the graphic decorations on watch faces into the following categories: container, logo, background graphic, screen border, foreground graphic, and divider. Container refers to the decoration surrounding data items, as shown in Figure 3.6 (a). Logo refers to the mark that is used to identify the brand or designer of the watch face, as shown in Figure 3.6 (b). Background graphic the decoration on the background of the watch face, as shown in Figure 3.6 (c). Screen border refers to decorations on the border of watch faces, as shown in Figure 3.6 (d). Foreground graphic refers to other decorations in the foreground, as shown in Figure 3.6 (e). Divider refers to the lines that split data groups, as shown in Figure 3.6 (f). Figure 3.9 shows that container is the most common graphical decoration on the top watch faces, followed by logo, background graphic, screen border, divider.

Q6: How many hues are there on the top watch faces?
To study how colorful popular watch faces are, I investigated the number of hues on the top watch faces. I did not count black, white and gray, as shown in Figure 3.7 (a). Figure 3.10 shows the number of hues that were present on the top watch faces. Nearly half of the top

Figure 3.3: (a) A watch face with 0 complications; (b) a watch face with 16 complications. Taken from Facer [11].

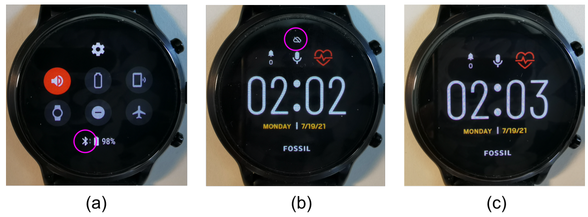

Figure 3.4: (a) A non-watch face page of a smartwatch, and the region highlighted in magenta color is the Bluetooth icon; (b) when the watch is not connected to the phone. The region highlighted in magenta color is the disconnected icon; (c) when the watch is connected to the phone, the disconnected icon disappears. Taken from Facer [11].

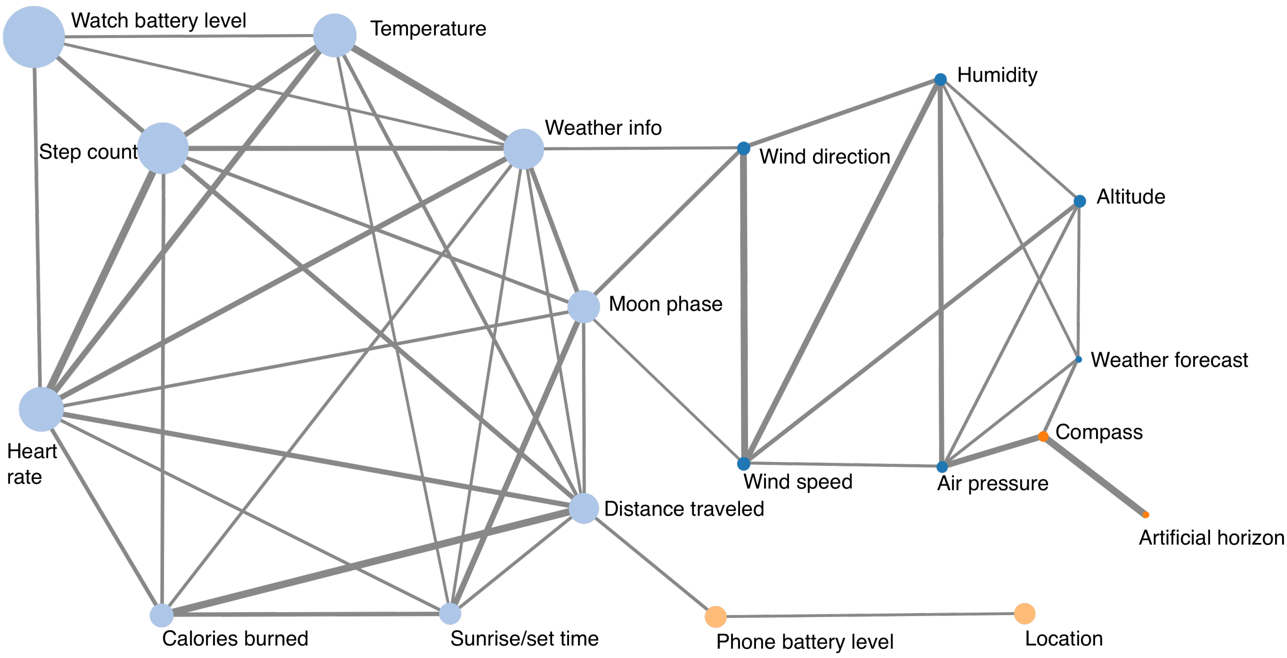

Figure 3.5: Pair-wise correlations between data types that were present together on the unique top watch faces.

watch faces (47.8%) have only one hue, as shown in Figure 3.7 (b). There were at most 7 hues on one watch, as shown in Figure 3.7 (c)

Q7: How is animation used on watch faces?
63.2% of the top watch faces had animations. None of the animations I found were based on data.

As shown in Figure 3.11, I found animations both on decorations and complications. The animations on complications were not encoding data, but meant to make complications look more vivid, such as a beating heart for a heart rate complication, or rain animation for a weather complication.

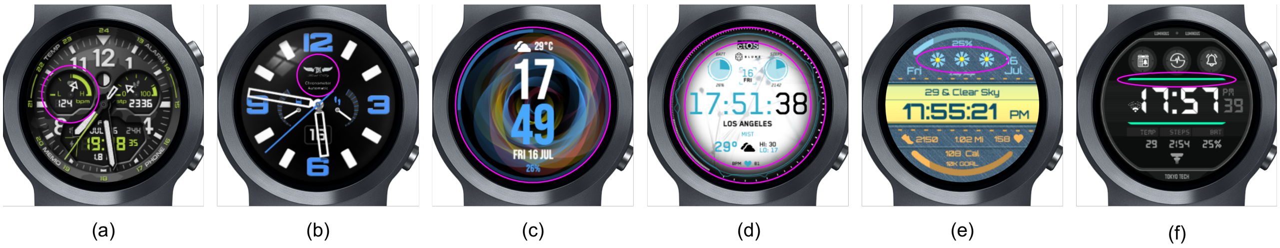

Figure 3.6: Graphical decorations on watch faces. The region highlighted in magenta color is:(a) a container;(b) a logo;(c) a background graphic;(d) a screen border;(e) a foreground graphic;(f) a divider. Taken from Facer [11].

Figure 3.7: (a) a watch face with zero hue; (b) a watch face with one hue; (c) a watch face with seven hues. Taken from Facer [11].

Figure 3.8: (a) Skeuomorphism; (b) Flat design; (c) Semi-flat design.Taken from Facer [11].

Q8: What are the most common UI styles of the top watch faces?

To study the popular style of design style of watch faces, I investigated the most common UI styles of the top watch faces. I divided the UI styles on watch faces into three categories: skeuomorphism, flat design and semi-flat design. Skeuomorphism and flat design are two main design trends that prevail in the field of user interface design. In UI design, skeuomorphism is a term used to describe a graphical user interface style in which elements mimic their real-world counterparts. Skeuomorphism deploys gradients, shadows, ornate details, as shown in Figure 3.8 (a). Flat design is a term used to describe a graphical user interface style in which elements do not have anything which would create the sense of depth on the interface, as shown in Figure 3.8 (b). This style highlights simplicity by concentrating on two-dimensional elements, clean lines, and bright colors [26]. Semi-flat design is in between flat design and skeuomorphism. It is a flat design with some realistic touches, such as shadows, as shown in Figure 3.8 (c). Although flat and semi-flat designs have been the more popular UI design styles recently, Figure 3.12 shows that skeuomorphism was the most popular style in the top watch faces.

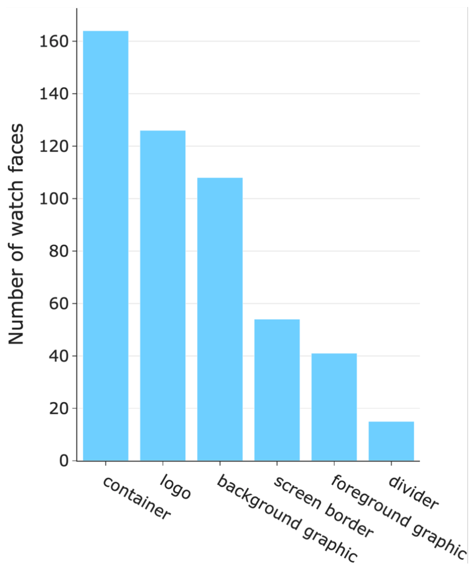

Figure 3.9: The most common graphical decoration on the top watch faces.

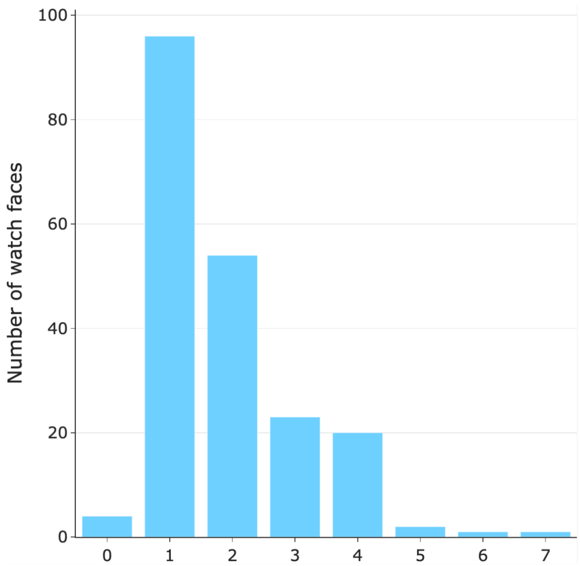

Figure 3.10: The number of hues on the top watch faces.

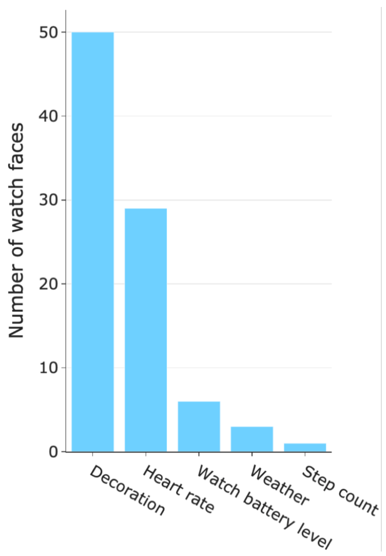

Figure 3.11: The most common types of components with animation on the top watch faces.

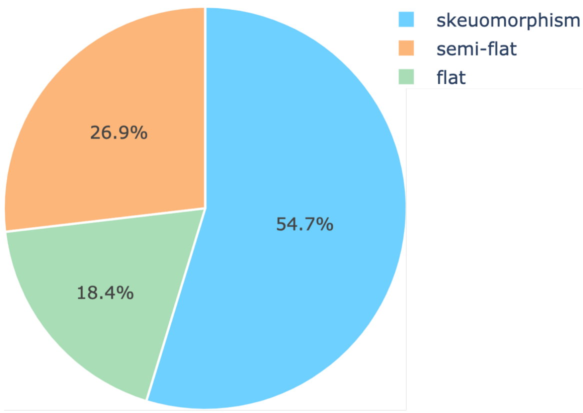

Figure 3.12: The most common UI styles on the top watch faces.

Chapter 4

Watch Face Design Considerations

When designing visualizations for smartwatch faces, designers need to consider design on two levels: the whole watch face and individual complications. In this chapter, I present design considerations for the whole watch face, and in the next chapter, I present design considerations for complications. These considerations allow to both study existing watch faces but can also guide designers in choices they have to make when deriving new watch faces.

Based on my analysis of top watch faces in the previous chapter, I summarize the following characteristics that need to be considered when designing visualizations on smartwatch faces. As I mentioned in Chapter 3, I divided these dimensions into two groups: smartwatch components and visual features. I added the layout dimension and watch face topic dimension to the visual features group.

4.1 Smartwatch Components

Time Display: This dimension describes how the time is displayed on a watch face. Its values include digital, analog, and hybrid. The main design choice for analog display is the style of clock hands, see differences in watch faces in Figure 4.1 (a) as an example. The main design choices for digital display include fonts, fonts sizes, and color; see differences in watch faces in Figure 4.1 (b) as an example. Main design choices for hybrid display include design choices of both analog display and digital display.

Number of Complications: This dimension describes how many complications are there on a watch face. Figure 3.3 (a) shows watch face with 0 complications and (b) shows a watch face with 16 complications. Designers can choose chart type, size, and position for each complication based on the number of complications on the watch face.

Data types of Complications: This dimension describes the data types of complications on a watch face. Designers can choose which data types to display based on the topic of the watch face, as shown in Figure 4.3.

Graphical Decoration: This dimension describes types of decorations on a watch face. Designers can use one kind or multiple kinds of decorations on the watch face, or don't use any decoration on the watch face.

Figure 4.1: (a) Different designs of analog time display; (b) different designs of digital time display. Taken from Facer [11].

Figure 4.2: (a) Color is used throughout the whole watch face; (b) color is only only in certain regions; (c) using colors to highlight some important content. Taken from Facer [11].

Figure 4.3: (a) a game-themed watch face; (b) a pilot-themed watch face; (c) a festival-themed watch face.Taken from Facer [11].

4.2 Visual Features

Use of Color This dimension describes how many hues are there on a watch face. Designers can use colors throughout the whole watch face (see Figure 4.2 (a)), or only use colors in certain regions (see Figure 4.2 (b)). Colors can also be used to highlight some important content (see Figure 4.2 (c)). The choice of color can be based on the theme, or just for aesthetics.

Animation: This dimension describes animations on a watch faces. Designers can use animation on decorations or use animation on complications.

UI Style: This dimension describes the UI style of a watch face. Its values include skeuomorphism, semi-flat design and flat design. The choice of UI style can be based on the theme, or be chosen just for aesthetics.

Watch Face Topic: This dimension describes the topic of a watch face. The topic of watch faces are diverse. Common topics include fitness, outdoor sports, games, festival, etc. There are also many watches that do not have a clear topic. The topic affects components and visual features on the watch face. For example, there may be game characters, game-related graphics, and game scores on a game-themed watch face (see Figure 4.3 (a)); air pressure, compass, altitude on a pilot-themed watch face (see Figure 4.3 (b)); festival related graphical decoration on a festival-themed watch face (see Figure 4.3 (c)).

Layout: This dimension describes the Layout of watch faces. The Layout can be impacted by for the form of traditional watches, follow some modern UI layout rules (e.g., grid system), or be more free.

4.3 Summary

On a higher level, designers have to make a large number of choices that are inter-related, because some of these considerations affects each other. For example, data types of complications and use of color and UI style are closely related to watch face topic, number of data types are closely related to layout.

CHAPTER 5

Complication Visualization Design Consideration

Complications are non-time data on watch faces [13]. To visualize a huge amount of complications on a small watch face is a unique challenge for smartwatch visualizations[12]. To tackle this challenge, I want to focus on understanding what needs to be considered when designing complications on watch faces. This chapter presents the design consideration of complication visualization and give an example of design considerations of proportion visualization. The complication visualization design consideration includes two dimensions, data types on the smartwatch and chart considerations.

5.1 Data Types on the Smartwatch

Most data shown on a smartwatch is a single data point encoding 

, while more complex encoding is also possible (e.g., multiple points over time or space).

The single data point encoding on smartwatch faces is commonly one number for one category because it is essential to have one dimension to specify the category of data (e.g., step counts) and another dimension to specify the value corresponding to that data category(e.g., 6700). In order to identify data categories, designers can place signs or rely on wearers to learn a mapping. The types of signs that can identify a data category includes

- text,
- icon (e.g., a foot icon for step counts),
- index (e.g., "km" for distance traveled, "cal" for calories burned).

A learned mapping does not require the depiction of the data category, because watch wearers can know what the data category is without a sign. For example, the "three rings" on the Apple Watch is an example of a mapping that requires learning . It uses three concentric donuts charts without a sign to represent the three data categories of movement, exercise, and standing.

As shown in Table 5.1, I divided the common data categories I saw in my study of the top 100 watch faces into six types based on the types of the value of the data: absolute numeric, proportion, categorical, ordered, temporal, and geospatial data. All five types of data can be visualized in text or graphs. The values in a data category can have many different data types through certain conversion operations. For example, a step count can be an absolute numeric (e.g. 6700), or it can be converted to a proportion (e.g. 67% of daily step goal). Next, I will introduce each data type in detail.

Absolute numeric

	Step count	Temperature	Heart rate	Calories burned	Distance travelled	Floors/Stairs climbed	Wind speed	Blood pressure
Single	2150	35°C	80bpm	725Cal	10km	11 floors	3mph	
Pair		Highest: 35°C Lowest: 30°C						120/81

Proportion

Real proportion	Humidity	Battery			
	42%	80% (of fully charged)			
Derived proportion	Step count	Calories burned	Sleep duration	Distance travelled	Floors/Stairs climbed
	80% (of 10k steps)	80% (of 3kCal)	80% (of 8h)	80% (of 10km)	80% (of 30 floors)

Categorical

Blueteeth	Weather	Moon phase	Wind direction
On	Rainy	Full moon	NW

Ordered

Derived ordered	Battery level	Wifi signal strength	Heart rate
	Low	Poor	Fast

Temporal

	Sunrise time	Sunset time	Sleep duration	Sleep phase
Single	7:14 am	6:34 pm	6h53min	
Multiple				1h13min:REM 4h11min:light 1h25min:deep

Geospatial

Location	Time Zone
Paris	GMT+1

Table 5.1: Common data types on the smartwatches.

Absolute numeric

The absolute numeric data on the smartwatch appears in the form of single number or a pair of numbers. For example, the temperature can be a single numeric data (35°C), or a pair of numeric data (Highest: 35°C ; Lowest: 30°C)

To study how we should dedicate display space to absolute numeric data, I discuss the following characteristics of absolute numeric data.

Absolute numeric data is infinite theoretically. Absolute numeric data can be theoretically visualized as text or charts. However, if we have no visual reference point established (either through convention or text or grid etc.), it is difficult to predict data mappings that will fit in the given display space and that can adjust to dynamic updates without confusing viewers. In micro-visualizations, such as visualizations on smartwatch faces, there is often not enough space for visual references. Therefore, it is rare to use charts to visualize absolute numeric data on smartwatch faces.

However, absolute numeric data often has a limitation in practice which can simplify data representation. For example, theoretically, step count can be unlimited. Nevertheless, in reality, considering the time limit (e.g., within a day) or the limitation of human physical ability, the value corresponding to the step count on the smartwatch face often has a potential limit. This is important due to its impact on the representation of absolute numeric data where a theoretical maximum can be assumed to reserve display space or calculate color scales.

Proportion

Proportion type data can be divided into real proportions and derived proportion. Real proportions mean that the value corresponding to this data category is originally captured or measured as a proportion, such as 42% humidity or 80% power (of fully charged). Derived proportions are proportions converted from absolute numeric data. On smartwatch faces, the proportion is often derived from a goal set by watch wearers, such as steps-67% (of 10k step), calories burned-67% (of 3kCal).

Categorical

Categorical data is a type of data that does not have an implicit ordering. Categories only distinguish whether two things are the same or different [22]. Categorical data is often represented by small graphical elements. We can use icons that stand for the categorical value (weather - rainy /sunny) or a sign with an indexical color (BLUETOOTH for on /off).

Ordered

As opposed to categorical data, ordered data does have an implicit ordering [22], for example, low-middle-high level of watch battery. Most ordered data on watch faces is essentially quantitative data. Ordered data is commonly represented either by icons or charts with added color scale encoding.

Temporal

Temporal data on smartwatch faces often includes sunrise time, sunset time, sleep time, etc. Some of these temporal data appear individually (e.g., sleep duration), and some appear in groups (e.g., sleep phases). Designers often visualize some temporal data in conjunction with the dial of the watch faces, such as sunrise and sunset times that are displayed as icons next to the hour numbers on an analog watchface.

Geospatial information

Geospatial data on the smartwatch faces includes location, time zone, etc. In addition to text and icons (e.g., landmarks), they can also be represented by maps.

Figure 5.1: (a) A donut chart that uses the circumference of the round watch face; (b)(c) the graph for moon phase and weather that fill the whole watch face. Taken from Facer [11] and Watchmaker [29].

5.2 Chart Considerations

Charts are a common way to visualize data on watch faces. To design a chart for a complication, designers need to consider chart type, chart size, chart color, chart position and chart theme.

Chart Type

The types of charts that are commonly used to represent data on smart watches include: bar chart, pie chart, donut chart, gauge chart, area chart, pictograph, sliding scale, etc. The data type may suggest the most effective chart types to use. The chart type directly affects its possible shape, size, and location. And because of the different shapes of different charts, it indirectly affects the use of colors and the expression of themes.

Chart Size

Chart size on smartwatch faces can be from the smallest size that a person can see to occupying the entire watch. Chart size is related to the shape of a chart. For bar graphs and sliding scales, size mainly refers to length and thickness. For pie charts, donut charts and gauge charts, the size mainly refers to the diameter. For the area chart and pictograph, the size mainly refers to the length and width. If a chart's shape matches a watch screen's shape, the chart can fill the watch face. For example, a donut chart can use the circumference of the round watch face (Figure 5.1 (a)), the graph for moon phase or weather can fill the whole watch face (Figure 5.1(b) and (c)).

Chart Color

Chart color describes how many hues are there on a complication. Its value is at least 0 hue. That is, black, white, and gray are used in the complication.

Embellishments (e.g., gradients) affect a charts' color. Gradients include gradients consisting of different saturation or brightness of the same hue or gradients consisting of different hues.

Chart Position

Chart position refers to the position of the chart on the watch face, and its value can be middle or periphery. The shape of the chart affects the possible position of the chart. For round

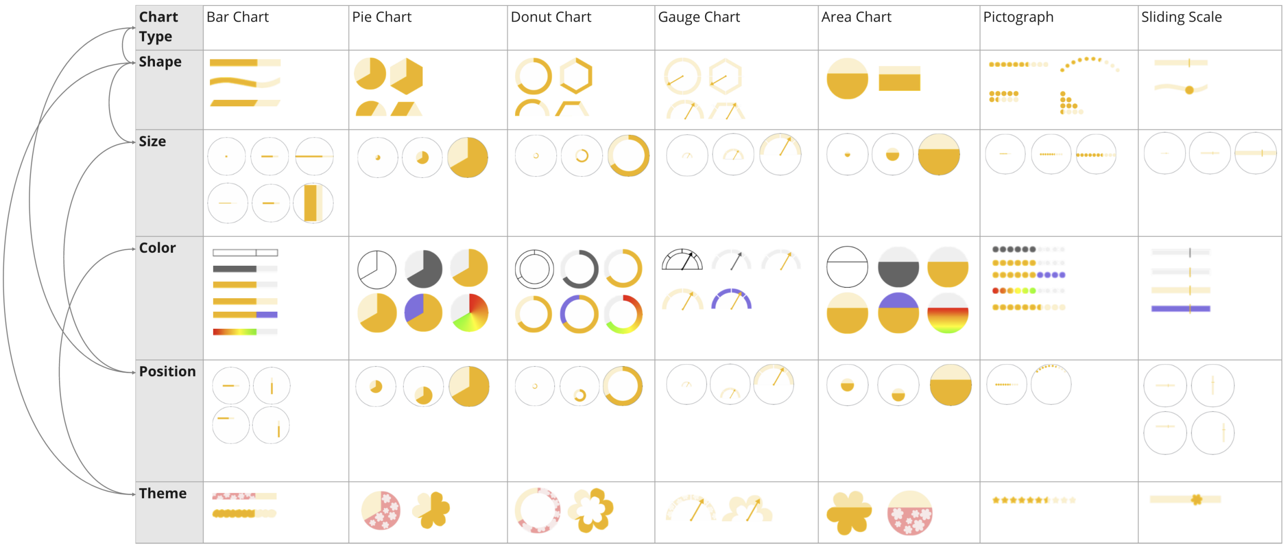

Figure 5.2: Design space for proportion-type data.

watches, ring-shaped or arc-shaped charts are most suitable for being located on the periphery of the watch face, and other shapes can only be located in the middle of the watch face.

Chart Theme

Theme refers to the theme of the complication, which often conforms to the overall topic of the watch face. Charts do not necessarily have a theme, but they can have topics. For example, in Figure 5.2, we use the topic of "flower" as an example to draw various types of charts. The theme can be represented by colors, shapes, etc. Texture filling can also be used to represent themes.

5.3 Design Considerations in the Example of a Proportion Visualization

As shown in Figure 5.2, dimensions of individual complication design space include chart type, shape, size, color, position and theme. These aspects influence each other. In Figure 5.2, I used links to connect the aspects that affect each other.

CHAPTER 6

Survey

6.1 Motivation

So far, I have derived a broad space of design considerations and provided many choices for designers. Previous studies have studied the effectiveness of different designs [4], however, user preferences for different design choices is still unclear.

In Table 5.1, we can see that that 8 types of data can be represented as a proportion, which is more than types of data that can be represented as categorical data, ordered data, temporal data or geospatial data. Therefore, I wanted to start by understanding user preferences for different chart types to visualize proportion type data on watch faces. I conducted a survey to measure the aesthetic preference of different visualization designs.

6.2 Method

We designed and conducted an anonymous online survey, for which we recruited participants who were at least 18 years old and spoke English.

Our survey consisted of two main sections. The first main section asked participants to rate the aesthetics, sophistication and comprehensibility of five visualizations and the second main asked participants to rank the five visualizations.

Survey design

I designed three versions of the survey with the same questions but different data items (calories burned, step count and watch battery level), as shown in Figure 6.1. For each version, I designed five charts (bar chart, donut chart, gauge chart, discrete bar chart and text), as shown in Figure 6.2. Participants saw one of the three versions randomly. The watch battery level version of the survey is shown in appendix A as an example.

In total, our survey consisted of five sections. The first was a consent form, the second was demographic questions. Then we asked questions about participants' background about using smartwatches. Next, participants saw five different watch face visualizations: a donut chart, gauge, bar, discrete bar chart, and text representation of a proportion. Participants evaluated

Figure 6.1: Three data items.

(a) bar chart (b) donut chart (c) gauge chart (d) discrete bar chart (c) text

Figure 6.2: Five chart designs.

the five designs based on a 7-point scale ranging from (1) “strongly disagree” to (7) “strongly agree”. The scale included the following five items from the aesthetic pleasure in design scale developed by Blijlevens and colleagues [5]: “This is a beautiful design,” “This is an attractive design” “This design is pleasing to see,” “This design is nice to see,” “I like to look at this.” We also added “This design is sophisticated,” and “This design is comprehensible”, because we deemed those two items important aspects of smartwatch visualization design. Two attention check items were also added in the scale for bar chart and donut chart to make sure that participants were focused when answering the survey. In the final section of the survey we asked participants to rank the five designs and provide a reason for how they chose the highest ranking one.

Participant recruitment

First, I recruited five researchers in our research group for a pilot and changed minor wording details. Then we distributed our survey on popular social media (Reddit, Twitter, Facebook, Slack, and Douban) and spread it to some researchers by email. The survey was available online for one month during June and July, 2021. A total of 300 people started the survey and 152 people completed it in full.

Data quality

From the 152 total participants of three versions of the survey, I excluded 1 participant who did not consent to participate in the survey and 14 participants who answered the attention questions incorrectly. We report results from the remaining 137 valid responses.

6.3 Analysis and Results

Background Information

Table 6.1 summarizes demographic information about the 137 valid responses.

Among the 137 valid responses, 80 participants regularly wore a smartwatch or a fitness tracker with a watch face. Among these 80 participants, 45 had used external apps or websites (e.g., Facer, WatchMaker) to change the watch face shown on their smartwatch. Among these 45 participants, 25 changed their watch face only once in the past, 9 have changed their watch face 2 - 5 times in the past, 9 changed their watch face 6 - 10 times, and 1 changed their watch face more than 10 times.

Gender		Age		Degree	
Female	39	18-24	31	Bachelor (or equivalent)	52
Male	89	25-34	53	Master (or equivalent)	38
Non-binary/Gender diverse	6	35-44	23	PhD (or equivalent)	30
Prefer not to answer	3	45-54	22	Other	17
		55-64	5		
		65 or older	1		
		Prefer not to answer	2		

Table 6.1: Details of valid participants of the survey.

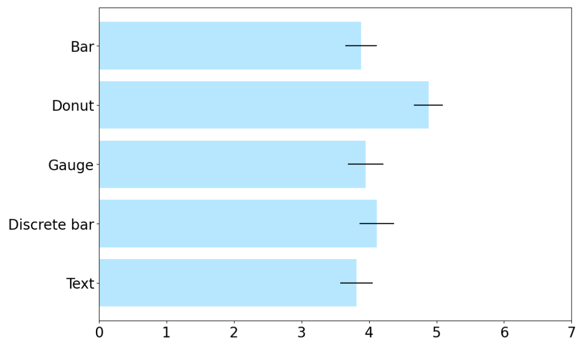

Figure 6.3: Average of average rating of 5 items in aesthetic pleasure in design scale.

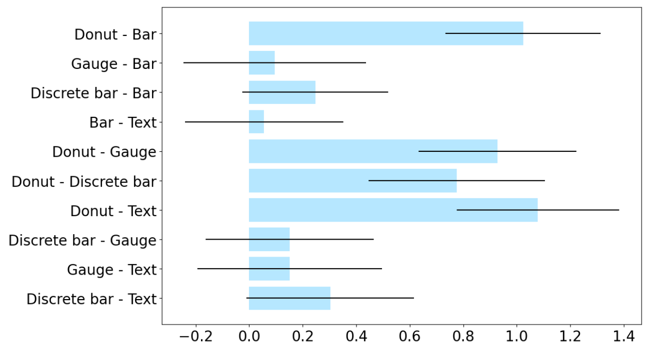

Figure 6.4: Differences of the average of average rating of 5 items in aesthetic pleasure in design scale of each pair of charts.

Aesthetic Pleasure

To analyze the aesthetic pleasure scales, we first averaged the five items per participant and per chart. Then, we analyzed this joined result across all participants.

Figure 6.3 shows the average of average rating of the aesthetic pleasure in design scale [5] with a 95% confidence interval. Figure 6.4 shows the differences between each pair of charts with a 95% confidence interval. From the results, we have evidence that the donut chart has the highest aesthetics score compared with all other charts. There is no good evidence of a difference between any pair of other charts.

Sophistication and Comprehensibility

For the other two items we chose, I calculated the median and mode independently across all participants' choices. The results are as follows:

Figure 6.5 shows that the median of the five designs are very similar, but modes reflect a clear preference. For the donut most participants chose "slightly agree" to the statement that donut looked sophisticated (mode = 5). For the gauge, bar and text, Most participants chose "disagree"for the statement that they looked sophisticated (mode = 2).

Figure 6.6 shows that all five designs seemed comprehensible to people, because the modes and medians of five design were all above "neutral".

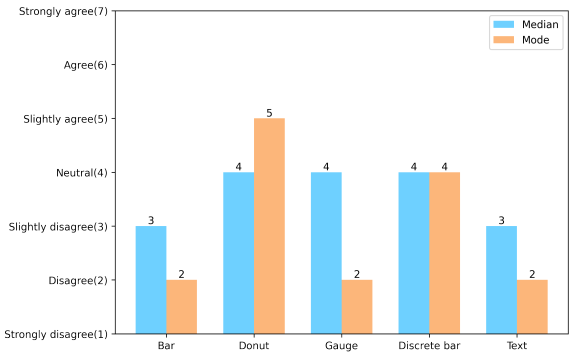

Figure 6.5: Median and mode of five designs for "It is a sophisticated design."

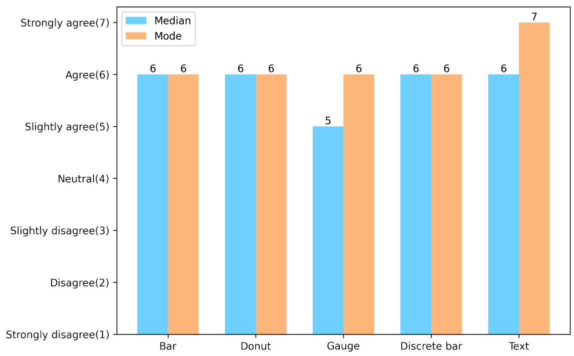

Figure 6.6: Median and mode of five designs for "It is a comprehensible design."

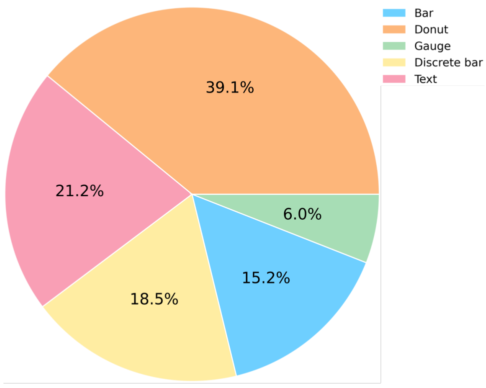

Figure 6.7: The chart ranked highest by participants.

Rank

I qualitatively coded the free-text answers about why or how people chose the highest ranking design. The final codes included: aesthetics, clear, clean, comprehensible, easy to customize, familiar, functional, glanceable, harmonious, intuitive, motivating, personal preference, precise, sophisticated, simplistic, space-saving.

Figure 6.7 shows that donut is most often ranked in the highest position by participants, followed by text, discrete bar, bar and gauge.

Figure 6.8 provides information on the number of times each code was mentioned when the five designs were ranked highest by the participants.

Glanceable and aesthetics are the two reasons that were most frequently mentioned by participants. In the 137 valid responses, glanceable was mentioned 44 times (32.1%), aesthetics was mentioned 39 times (28.5%). Among the five charts, donut is considered aesthetics and glanceable by the most users.

Donut was considered by the most users as aesthetics, clear, clean comprehensible, familiar, glanceable, harmonious, motivating, readable and simplistic. Especially glanceable and harmonious was mentioned for the donut by participants far more times than for other charts. However, most participants mentioned that donut was harmonious with the shape of the watch. Donut is round, and the watch we used in our survey is also round, which may affect this result.

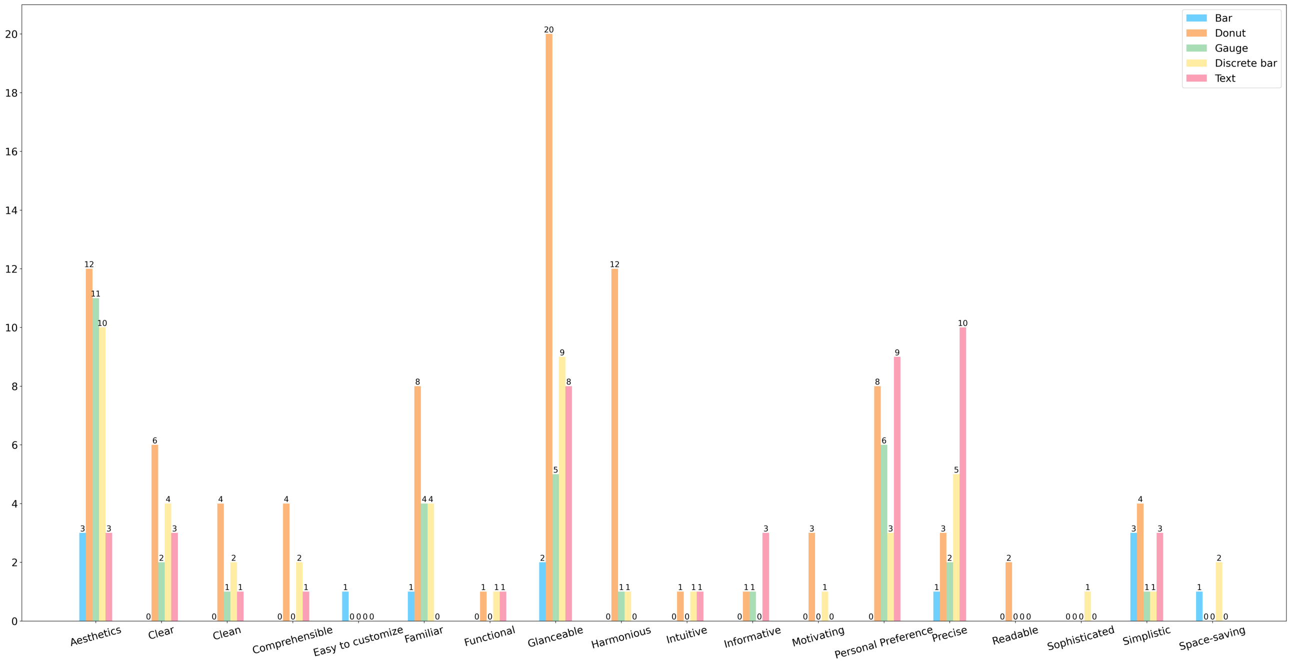

Figure 6.8: Number of times each codes were mentioned when the five designs were ranked highest by the participants

Text was considered precise and informative by most participants. Also, most participants chose the text for their watches out of personal preference. One of the main reasons they gave was that they personally liked to see numbers. In addition, some users who chose text mentioned that if there were more complications on the watch face, they might reconsider which design to choose.

Discrete bar ranked second in terms of aesthetics, clear, glanceable, precise, etc.

The fewest participants chose gauges for their watches, although we often see gauges appearing on popular watches. Some participants explained the reason of why they did not like gauge was that they associated the gauge with speed, which changes constantly.

6.4 Summary

Based on the analysis of the survey results, I recommend using donut on the watch to visualize the proportion data. The second choice is discrete bar. If there is only one complication on the watch face, designers can also consider using text.

CHAPTER 7

Conclusion and Perspectives

In this thesis, I present the findings on design considerations for data visualization on smartwatch faces. Through a literature review of current research related to watch face design, smartwatch visualization, I found most prior research about smartwatch visualization focused more on the design exploration of certain specific data types [10] and there was a research gap in the user preferences for visualization design on smartwatch faces. Because I wanted the study to be inspired by real-world popular watch face design, our first step was to explore the characteristics of popular watch faces.

In the next chapter, I presented the results of a systematic review on top watch faces on the Facer website [11]. I derived a set of codes and answered questions about visual characteristics of smartwatch faces, including time display, number of complications, data types, data correlations, graphical decoration types, hues, animations and UI styles. Based on my analysis of top watch faces, I summarized the characteristics that need to be considered when designing visualization on smartwatch faces from two levels, whole watch face and individual complications. The whole watch face design considerations include smartwatch components (time display, number of complications, data type of complications and graphical decoration) and visual features (use of color, animation, UI style watch face topic and layout). The complication design considerations include data types on the smartwatch (absolute numeric, proportion, categorical, ordered, temporal and geospatial) and chart considerations (type, size, color, position, and theme). I also gave a design considerations for proportion visualization. To understand users' preference of different design variations, I run a survey to measure aesthetic preference of five charts (bar chart, donut chart, gauge chart, discrete bar chart and text). Based on results of the survey, I recommend using donut on the watch to visualize proportion data on watch faces. The result of this work can be used as a reference for future watch designers to design visualization for watch faces.

In terms of limitations, our work only evaluated users' preference of how to visualize one proportion data item on a watch face, which is only a small part of the broad space of design considerations I derived. It opens up possibilities for future research to study other aspects of users' preference of smartwatch visualization. For example, it would be interesting to study users' preference of how to visualize multiple quantities on a single smartwatch face. The aspects that can be studied includes the number and types of data types, the size of complications, the position of complications, the use of colors, the use of animation, etc.

There is no validated scale to study aesthetics pleasure of visualizations. The scale I used to measure aesthetic pleasure is a scale for general design. Therefore, another interesting possibility would be to design a validated scale for evaluating aesthetic pleasure of visualization.

Appendix-A

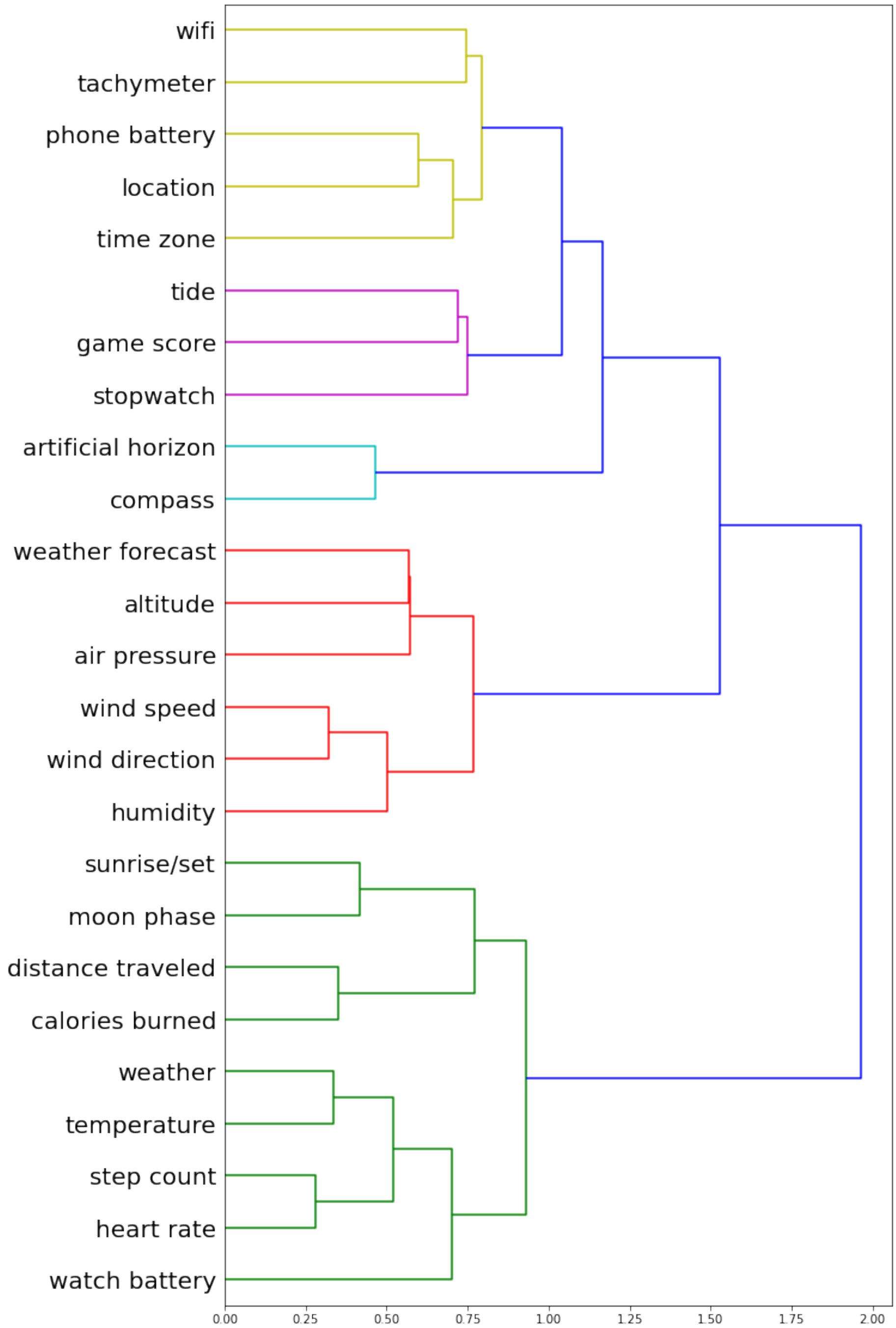

Figure 7.1: Hierarchical clustering dendrogram of data types on watch faces.

Appendix-B

Smartwatch Face Design Preferences.

You are invited to participate in a study titled "Data visualization on smartwatche faces". Watch faces are the home screen of smartwatches, and you see it at first when glancing or turning on your watch. The purpose of this research study is to understand users' preferences toward different types of visualization on smartwatche faces.

Watch Faces Examples

Please respond to this survey only if you:

- speak English,
- are at least 18 years old.

This study is conducted by

- Tingying He (Université Paris-Saclay, CNRS, LISN, Inria, France)
- Alaul Islam (Université Paris-Saclay, CNRS, LISN, Inria, France)
- Petra Isenberg (Université Paris-Saclay, CNRS, LISN, Inria, France)

Click "Next" if you are interested in further details about the study.

There are 33 questions in this survey.

Consent form

Introduction

You are invited to participate in a study titled "Data visualization on smartwatches". The purpose of this research study is to understand users' preference toward different types of visualization on smartwatches. This study is conducted by

- Tingying He (Université Paris-Saclay, CNRS, LISN, Inria, France)
- Alaul Islam (Université Paris-Saclay, CNRS, LISN, Inria, France)
- Petra Isenberg (Université Paris-Saclay, CNRS, LISN, Inria, France)

Who can participate

Anyone who (1) speaks English, and (2) is at least 18 years old can participate in this study.

What is involved in the study

Participants will answer close-ended and open-ended questions about the visualization for step count, calories, and watch battery on the smartwatch. Participation requires completing the survey that follows this consent form. Completing the survey takes approximately 5-10 minutes.

Voluntariness of participation

Participation is voluntary. Participants can stop filling out the questionnaire at any time without giving a reason and their data will not be included in our analyses. Withdrawal of participation in the research project will be without consequences of any kind.

Anonymity and Confidentiality

This survey is anonymous - we do not require participants to provide any information that could identify them in the consent form nor in the questionnaire. This means that we will not be able to withdraw data from the analyses as soon as participants have submitted their answers.

Risks/Discomforts

This study involves completing several questions as outlined above. We believe there are no known risks associated with this research study; however, as with any online related activity, the risk of a breach is always possible. We will minimize any risks by requiring no personally identifiable information such as names, addresses, phone numbers or email addresses and storing the raw data on password-protected computers.

Study results

This study will be published in an academic research paper. The anonymized answers to the questionnaire will be made publicly available on an open science platform.

Compensation

Participants will receive no compensation for their participation.

Contact details

Please feel free to contact Tingying He and Petra Isenberg if you wish to know more about the study, or if you have any queries.

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Please select your choice below. Clicking on the "Yes" button below indicates that:

- You have read the above information
- You voluntarily agree to participate

*

Please choose **only one** of the following:

○ Yes
○ No

Demographic Questions

Which gender do you identify with? *

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '2 [CF001]' (Please select your choice below. Clicking on the "Yes" button below indicates that: You have read the above information You voluntarily agree to participate)

Please choose **only one** of the following:

- Woman
- Man
- Non-binary/Gender diverse
- Prefer not to answer
- Self described

What is your age? *

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '2 [CF001]' (Please select your choice below. Clicking on the "Yes" button below indicates that: You have read the above information You voluntarily agree to participate)

Please choose **only one** of the following:

- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65 or older
- Prefer not to answer

What is your highest academic degree? *

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '2 [CF001]' (Please select your choice below. Clicking on the "Yes" button below indicates that: You have read the above information You voluntarily agree to participate)

Please choose **only one** of the following:

- Bachelor (or equivalent)
- Master (or equivalent)
- PhD (or equivalent)
- Other

Background Question

Do you regularly wear a smartwatch or a fitness tracker with a watch face? *

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '2 [CF001]' (Please select your choice below. Clicking on the "Yes" button below indicates that: You have read the above information You voluntarily agree to participate)

Please choose **only one** of the following:

- Yes
- No

Have you ever used external apps or websites(e.g. Facer, Watchmaker) to change the watch face shown on your smartwatch? *

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '2 [CF001]' (Please select your choice below. Clicking on the "Yes" button below indicates that: You have read the above information You voluntarily agree to participate) *and* Answer was 'Yes' at question '6 [BQ001]' (Do you regularly wear a smartwatch or a fitness tracker with a watch face?)

Please choose **only one** of the following:

- ◯ Yes
- ◯ No, I use one of the pre-installed (default) watch faces

How many times have you changed your watch face in the past? *

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '2 [CF001]' (Please select your choice below. Clicking on the "Yes" button below indicates that: You have read the above information You voluntarily agree to participate) *and* Answer was 'Yes' at question '7 [BQ002]' (Have you ever used external apps or websites(e.g. Facer, Watchmaker) to change the watch face shown on your smartwatch?)

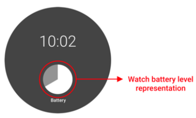
Please choose **only one** of the following:

- ◯ Once
- ◯ 2-5 times
- ◯ 6-10 times
- ◯ More than 10 times

Instructions

Watch faces are the home screen of smartwatches, and you see it at first when glancing or turning on your watch. A watchface typically shows the current **time** together with some **data** such as step count, calories, or watch battery. Here are some examples of watch faces:

In this survey, you will see 5 different ways to show how full your watch battery level is on a very simple watchface. We want to know which design you prefer visually. The following image looks like some of the images you will see. The black round background and the time information(10:02) are just used as context to make the image look more like a watch. What we want you to look at is the representation of the battery level. For example, here the battery level is indicated with a pie chart:



All the designs are in black and white because we do not want you to be influenced by color. So please just focus on how the battery level data is shown to you.

For each data design, you should first specify your level of agreement or disagreement on a 7-point scale for a series of statements. In the last two questions, you need to rank the 5 designs according to your preference and explain why or how you chose the visualization you ranked highest. When answering questions, do not zoom the browser because the images were designed to be roughly the size of a real smartwatch on most screens.
*

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '2 [CF001]' (Please select your choice below. Clicking on the "Yes" button below indicates that: You have read the above information You voluntarily agree to participate)

Please choose **only one** of the following:

- ◯ I understand

On this watch face, battery level is indicated with a bar where the amount of fill indicates the current battery level relative to a maximum of 100%.
*

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '2 [CF001]' (Please select your choice below. Clicking on the "Yes" button below indicates that: You have read the above information You voluntarily agree to participate)

Please choose the appropriate response for each item:

	Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree
This is a beautiful design of watch battery level	○	○	○	○	○	○	○
This is an attractive design of watch battery level	○	○	○	○	○	○	○
This design of watch battery level is pleasing to see	○	○	○	○	○	○	○
This design of watch battery level is nice to see	○	○	○	○	○	○	○
I like to look at this representation of watch battery level	○	○	○	○	○	○	○
This is a sophisticated design of watch battery level	○	○	○	○	○	○	○
This is a comprehensible design of watch battery level	○	○	○	○	○	○	○
In this row, please select "Agree"	○	○	○	○	○	○	○

On this watch face, battery level is indicated with a donut where the amount of fill indicates the current battery level relative to a maximum of 100%.
*

Only answer this question if the following conditions are met:
((CF001.NAOK (/index.php/admin/questions/sa/view/surveyid/714191/gid/6783/qid/75654) == "Y"))

Please choose the appropriate response for each item:

	Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree
This is a beautiful design of watch battery level	○	○	○	○	○	○	○
This is an attractive design of watch battery level	○	○	○	○	○	○	○
This design of watch battery level is pleasing to see	○	○	○	○	○	○	○
This design of watch battery level is nice to see	○	○	○	○	○	○	○
I like to look at this representation of watch battery level	○	○	○	○	○	○	○
This is a sophisticated design of watch battery level	○	○	○	○	○	○	○
This is a comprehensible design of watch battery level	○	○	○	○	○	○	○
In this row, please select "Disagree"	○	○	○	○	○	○	○

On this watch face, battery level is indicated with a gauge where the pointer(left to right) indicates the current battery level relative to a maximum of 100%.
*

Only answer this question if the following conditions are met:
((CF001.NAOK (/index.php/admin/questions/sa/view/surveyid/714191/gid/6783/qid/75654) == "Y"))

Please choose the appropriate response for each item:

	Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree
This is a beautiful design of watch battery level	○	○	○	○	○	○	○
This is an attractive design of watch battery level	○	○	○	○	○	○	○
This design of watch battery level is pleasing to see	○	○	○	○	○	○	○
This design of watch battery level is nice to see	○	○	○	○	○	○	○
I like to look at this representation of watch battery level	○	○	○	○	○	○	○
This is a sophisticated design of watch battery level	○	○	○	○	○	○	○
This is a comprehensible design of watch battery level	○	○	○	○	○	○	○

On this watch face, battery level is indicated with a text, which indicates the current battery level relative to a maximum of 100%.
*

Only answer this question if the following conditions are met:
((CF001.NAOK (/index.php/admin/questions/sa/view/surveyid/714191/gid/6783/qid/75654) == "Y"))

Please choose the appropriate response for each item:

	Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree
This is a beautiful design of watch battery level	○	○	○	○	○	○	○
This is an attractive design of watch battery level	○	○	○	○	○	○	○
This design of watch battery level is pleasing to see	○	○	○	○	○	○	○
This design of watch battery level is nice to see	○	○	○	○	○	○	○
I like to look at this representation of watch battery level	○	○	○	○	○	○	○
This is a sophisticated design of watch battery level	○	○	○	○	○	○	○
This is a comprehensible design of watch battery level	○	○	○	○	○	○	○

On this watch face, battery level is indicated with a pictograph where the amount of fill indicates the current battery level relative to a maximum of 100%.
*

Only answer this question if the following conditions are met:
((CF001.NAOK (/index.php/admin/questions/sa/view/surveyid/714191/gid/6783/qid/75654) == "Y"))

Please choose the appropriate response for each item:

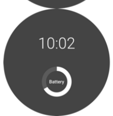
	Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree
This is a beautiful design of watch battery level	○	○	○	○	○	○	○
This is an attractive design of watch battery level	○	○	○	○	○	○	○
This design of watch battery level is pleasing to see	○	○	○	○	○	○	○
This design of watch battery level is nice to see	○	○	○	○	○	○	○
I like to look at this representation of watch battery level	○	○	○	○	○	○	○
This is a sophisticated design of watch battery level	○	○	○	○	○	○	○
This is a comprehensible design of watch battery level	○	○	○	○	○	○	○

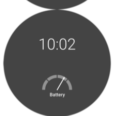
Smartwatch Face Rank - Battery

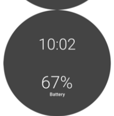
Which watch face you would choose for your own watch?
Please rank the following watch faces according to your preference (from the best to the worst).
*

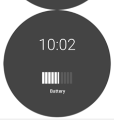
Only answer this question if the following conditions are met:
Answer was 'Yes' at question '2 [CF001]' (Please select your choice below. Clicking on the "Yes" button below indicates that: You have read the above information You voluntarily agree to participate)

Please number each box in order of preference from 1 to 5









Please describe why or how you chose the visualization you ranked highest *

Only answer this question if the following conditions are met:
Answer was 'Yes' at question '2 [CF001]' (Please select your choice below. Clicking on the "Yes" button below indicates that: You have read the above information You voluntarily agree to participate)

Please write your answer here:

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