Evaluating Different Visualization Designs for Personal Health Data

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With the massive development of sensing technology and the availability of self-tracking devices and apps; the interest in personal data collection has widely increased. However, the data representation methods on these tracking devices and apps have many limitations. Our research concentrates on evaluating different data visualization alternatives that could be used to represents the tracked physical activity data (e.g. step count and heart rate) with regards to users' performance when solving visual tasks and their preferences in the proposed visualizations.

Smartphone Apps, Wearable Devices, Health Tracking, Smartwatches Self-tracking, Personal Visualization.

1. INTRODUCTION

Self-tracking is becoming more interesting recently due to the low cost wearable self-tracking devices and the ability to track different personal data using smartphones (Larsen et al., 2013). Many apps, which are available on the major app stores, are developed to help the user collect different types of personal data. For example, capturing data on sports and physical activity (e.g. Fitbit, Jawbone, Runkeeper), sleep (e.g. Sleep Cycle), food and liquid consumption (e.g. MyFitnessPal, Waterlogged), locations (e.g. Moves), time tracking (e.g. Hours) and many others.

The intensive use of these devices and apps and the ability to access information anywhere using the Internet result in a huge amount of personal data such as habits and behaviours (Li, Dey, & Forlizzi, 2011). All of the data collected could be used for different purposes such as self-reflection to help in decision making, increasing self-awareness or changing behaviour in different domains including health and energy (Li et al., 2011).

In this project, we aim to concentrate on a very important aspect of personal data which is health data. Personal health data is beneficial not only to the person himself, but also to others who have interest in the data such as other patients and clinicians (Zhu et al., 2016). It also could be shared with friends and family members. According to (IQVIA Institute, 2017), the number of mobile health-related apps available today in the market has exceeded 318,000 with around 200 apps being added every day. In addition to this increase in health apps, there are around 340 wearable devices worldwide (IQVIA Institute, 2017). These health apps and devices often collect different types of health data, which could be automatically generated by the sensors (such as step count and heart rate) or entered manually by the user (such as nutrition and calories intake). Therefore, they generate large collections of complex health-related metrics. A major challenge in dealing with such large volume of complex data is in interpreting and in extracting useful knowledge about users' personal health.

Information visualization has always played an important role in communication. It offers the methods and tools that could be used to represent the data and to generate information (Mazza, 2009). Since the human visual system has the ability to perceive visual attributes very well (Mazza, 2009), visualization can become powerful in helping people to gain an understanding of the data. Most self-tracking devices and their companion apps/dashboards provide different forms of data representation (e.g. Fitbit bar chart). However, these visualizations do not always fulfil users' needs in the data as presented in (Li et al., 2011). Some users who faced different difficulties in understanding their data, developed customized personal visualization to represent and reflect on their data as discussed in (Choe et al, 2014).

The structure of the paper is as follows. We start with stating the problem and research questions, then we present a background on personal health tracking and visualization followed by a discussion of our research methodology. We then discuss the initial results from the preliminary stages of the research.

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We conclude with a discussion on the main contribution of the research.

2. RESEARCH OBJECTIVE AND QUESTIONS

The essential aim of our research is to evaluate visualization design alternatives to represent multivariate personal and shared physical activity data for non-expert users. The main research questions are as follows:

- RQ1: What are users' preferences in the visualization of personal health data? And what are the limitations of the visualization methods supported by most popular apps and dashboards?
- RQ2: What are the differences between visualization methods that could be used to represent multivariate personal physical activity data in term of users' performance and users' preferences?

In the methodology section, we describe the methods used to answer the research questions.

3. RELATED WORK

The focus of our research lies in the intersection of two research areas: personal health visualization and the evaluation of information visualization techniques. In the following, we present a brief overview of the most related work to our research.

Recent development in wearables and sensing technology facilitates collecting multifaceted data about oneself. An important type of these data is related to health and physical activity (e.g. activity levels, heart rate and sleep), which was supported by wide range of wearable devices like fitness bracelet and smart watches in addition to a variety of apps which are freely available on app stores. The availability of personal health data led to increase people's and patients' awareness and responsibility for their health (Shneiderman et al., 2013). Many research projects have focused on the visualization of these personal data and on users' requirements in visualization designs (Choe et al., 2015; Choe et al., 2014; Epstein et al., 2014; Li et al., 2011).

Different visualization designs are proposed to address different challenges in the field such as overcoming the limitations of statistical charts which are widely used by apps/dashboards. For example, Meyer et al. (2016), explored the challenges of visualizing complex health data on mobile devices. They developed metaphoric and quantitative visual designs to support both long and short-term data representation. The outcomes of this study showed that the users are interested in using more advanced visualizations that could reveal more complex relation in the data and having additional features such as filtering (Meyer et al., 2016). Another example is a study conducted by Fan et al. (2012), who used an informative display to apply the concept of abstract art on Fitbit physical activity data. They developed Spark, an online visualization tool that provides four different designs of abstract representations (spiral, rings, bucket and Pollock) in addition to bar charts and investigated users' experience of using the two types of visualization with their own Fitbit data. The results showed that different visualizations were suitable for different purposes. Fan et al., argued that abstract visualization is more aesthetic and suitable for glanceable display while the bar chart was required for gaining a detailed view or looking for specific information. However, the evaluation was restricted to 6 participants only. Similarly, (Tong et al., 2015) evaluated and compared three types of visualizations which were Fitbit bar chart, Circular Ringmap and Virtual Pet visualization considering different factors such as readability and attractiveness. The result showed that there is no relation between the efficiency of the visualization and the participants' preferences and subjective feedback.

Larsen et al. (2013), focussed on revealing the continuity and the periodic characteristics of self-tracked data by representing Fitbit physical activity data on a spiral, where circles refer to a time span. The interactive visualization proposed helped in discovering the periodic event in the data (Larsen et al., 2013). Huang et al. (2016) proposed a new design for integrating a visualization of Fitbit data as an additional layer with a personal calendar to help people to easily reason about regular and irregular patterns in the visualization.

Other personal health visualization research focused more on abstract representations and used living metaphors to reflect the users' current level of activity, such as UbiFit (Consolvo et al., 2008), which used flowers and garden metaphor to represent user's physical activity data and Fish 'n' Steps (Lin et al., 2006) that used virtual fish to represent each user's step count. The aim of using these living metaphors was to motivate the users to increase their level of physical activity by making them attached to these metaphors. However, it may also encourage negative emotions (e.g. guilt), as discussed in (Lin et al., 2006).

Data visualization is an important aspect in personal health technology design space (Bardram & Frost, 2016). Although there have been many researches discussing the visualization of personal health data and other discuss the effectiveness of different visualization methods such as bar chart and line chart, we aim to focus on the evaluation of the design alternatives for representing different variables of health data including subjective feedback of the users. Our research concentrate on

evaluating the most popular data representations methods provided by health tracking apps and dashboards in term of personal health context. We evaluate the use of both line chart and bar chart in representing three variables of physical activity in the traditional linear format and in the radial format based on clock metaphor.

4. METHODOLOGY

Our methodology to answer research questions is a combination of both qualitative and quantitative research approaches. We employ literature survey, online surveys, autoethnography and a systematic evaluation of the visualizations. In the following, we describe these methods and how they will be applied to answer the questions.

In our literature review, we started from (Huang et al., 2015) survey that explores a number of 50 literature in the field of personal visualization and personal visual analytics to identify research trends and gaps in the fields. We considered the papers cited in this work which are related to personal health visualization and then moved to their citations and the papers cite them. We also search HCI and visualization conference and journals for related work to identify the gaps in personal health visualizations.

Online questionnaires are used in different stages of our research. The first questionnaire is deployed before visualization implementation phase and it aims to understand more about users' requirements and preferences in different visualizations designs for physical activity data. It also includes questions regarding participants tracking behaviour and the tools they use. Other questionnaires will be part of the evaluation study and it will include both demographic questions and questions to collect participants' feedback about the developed designs.

Moreover, we conduct an autoethnography study which we use to review the most popular health and physical activity tracking devices and their companion apps in the visualization they provide to report on the limitations and research opportunity in personal health data representation and sharing.

Our evaluation is based on previous visualization research, which study the effectiveness of different visualization designs through visual task-based evaluation study such as (Borgo et al., 2012; Heer, Kong, & Agrawala, 2009; Srinivasan et al., 2018). We compare the different visualizations by measuring task accomplishment time and accuracy (i.e. error rate) when the user performs a set of tasks on each visualization. The visualizations will be evaluated in accordance with a taxonomy of tasks for multidimensional visualization (Valiati, Pimenta, & Freitas, 2006). In addition, we collect users' feedback about the visualizations pre and post the experiment using questionnaires to qualitatively evaluate the design choices and to compare the users' preferences in the visualizations with their performance. Our participants will be recruited from students and staff in the university across all the colleges and departments.

5. LIMITATION OF OUR METHODOLOGY

Evaluating personal visualization is challenging. There are varied metrics need to be measured to justify design choices in personal visualization space such as how the design fit in users' daily life. According to (Huang et al., 2015) and (Thudt et al., 2017); depending on conventional metrics (i.e. task completion time and accuracy) for evaluating personal visualization is not enough.

In our research, we focus on the effectiveness of different visualization layouts for physical activity data. Therefore, we measure the accuracy and task completion time for comparing the proposed visualizations. This restricts our evaluation to use a fixed dataset for the visualizations and not to be able to conduct the evaluation in a personal context such as using participants' personal health data with the visualizations. However, to strengthen our evaluation, we investigate other metrics related to users' personal preferences in the evaluation.

6. INITIAL RESULTS

In this section, we present a brief summary and outlines of the results we have found from the preliminary stages in our research.

6.1 Results from the questionnaire

This questionnaire was deployed before the development of the visualizations. The aim of this questionnaire is to understand more about users' requirements and preferences in different visualizations designs for physical activity data for personal and for sharing purposes by presenting several designs and collect participants' opinions about the visual representation. We asked the participants about their preference in the widely used traditional statistical charts such as bar/line/pie charts and other abstract representations such as the use of metaphors and abstract art.

The questionnaire was circulated during November and December 2016 and we have collected responses from 84 participants. For all the 84 participants, 53 choose traditional statistical charts, only 1 participant choose the abstract visualization while the rest (around 36%) suggested that both will be helpful. In regard to the preferences in the visualizations of each type, the highest preferred is line chart (57%) and then bar chart (52%) while the

least preferred is Radial pie chart (12%) and pie chart (18%). 6% of the participants have not chosen any preferences. In term of abstract representation, we presented four different design options, which are flowers and garden metaphor, living metaphor, clock and calendar metaphors and abstract art. 41 participants preferred the clock and calendar metaphor which is the highest preferred type of abstract visualization by 49%, 27 participants (32%) choose abstract art, 14 (17%) preferred living metaphors and only 9 participants (11%) preferred flowers and garden metaphors. 17 participants (20%) had no preferences of any of the presented abstract visualizations.

Open-ended questions revealed more about participants' choices such as the main aim of using charts for data. The answers given included various topics, the three main trends we have identified are: (1) Data Comprehension and Gain Knowledge, (2) Aesthetic View and Entertainment, and (3) Personal Preferences with sub-topics in each category. However, the traditional charts were preferred for its familiarity, clarity, its ability to provide a detailed view and because it is easy-to understand. On the other hand, abstract visualization which was reported as it has aesthetic view, it was considered as confusing and ambiguous and could be used for other purposes such as entertainment.

6.2 Results from the pilot study

We conducted a pilot study with 16 participants from Cardiff University. We recruited participants among students and staff in the department of computer science and informatics in the university (7 male and 8 female). We developed eight visualizations for three physical activity variables, which are step count heart rate and active calories. We used bar chart and line chart to represent the data in hourly basis. We apply these charts in traditional linear layout and in radial layout based on a clock metaphor. We also visualize the variables in two different ways. The first is visualizing the three variables to be overlapped with each other by sharing the same visual space and the second method is visualizing them separately where each variable has its own space. The 16 participants were assigned to four groups, where each group sees the visualizations in different order.

The preliminary analysis of the pre-experiment questionnaire data shows limited preferences in the presented visualizations. Four visualizations are preferred in order as the following: 8 participants liked linear stacked bar chart, 4 participants preferred linear overlapped line chart while 4 participants preferred each linear stacked line chart and radial overlapped bar chart. However, the other four types of visualizations have not been chosen by any participants.

Participants' preference after conducting the experiment have changed. The data shows that the most preferred type of the visualizations is linear stacked bar chart as 10 participants preferred it, followed by linear overlapped line chart which was preferred by 6 participants then followed by linear stacked line chart as it was selected by 5 participants. The radial stacked bar chart was the most preferred between the radial layouts, it was preferred by 4 participants while the least was the overlapped bar chart which was chosen by one participants only and the rest two radial visualizations was preferred by two participants for each one.

We aim to continue with data analysis to include the data collected from our software (i.e. tasks' answers and completion time) and then to compare the answers given by each participant with the responses to the tasks during the experiment. This study will be conducted with a larger sample of participants.

7. CONTRIBUTION

The main contribution of my PhD thesis is a systematic investigation of visualization design alternatives for representing multivariate physical activity data. The research goes through several stages starting from initial investigation of users' preferences in the visualization methods of personal physical activity and the identification of the pros and cos of the visualizations provided by the most popular physical activity tracking devices and their companion apps/dashboards to task-based evaluation of different visualization designs. The evaluation includes quantitative analysis of task completion time and error rate as well as qualitative analysis of users' preference and feedback before and after using the visualizations. The output of this evaluation will contribute in identifying design guidelines for designing visualizations that are used to represent physical activity data.

As noted by (Huang et al., 2015), the current visualization designs are formulated by designers who decide on what information to visualize and how to visualize it without involving users or considering their perspective. In this thesis we aim to include users in the evaluation by including participants' qualitative feedback. We also investigate the relationship between users' preferences and the effectiveness of the visualizations. We aim to examine the effect of different visual elements and the options of combining and separating different variables in one visual layout and how it may help the user to find the relationship between different physical activity variables.

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