Visualization Viewpoints

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Expanding Research Methods for a Realistic Understanding of Personal Visualization

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Aided by the recent advances in computing technologies, increasingly more individuals are collecting vast amounts of data about their lives on a daily basis. Automatic logs from both embedded sensors (such as step counters and sleep monitors) and specific applications (such as gathering music listening histories and communication logs) can now be collected more easily than ever. These growing personal data collections pose a great opportunity for people to better understand themselves, set and achieve personal goals, and make positive changes in their lives and their communities.[1]

Personal visualizations, which are relatively new to the visualization community, can make these data collections more easily accessible, understandable, and enjoyable. Such visualizations speak to a broad audience of people who are not usually professional analysts, scientists, or data experts, and they are designed for and used within personal contexts.[1] The goals of personal visualizations may include enhancing self-awareness, promoting self-reflection and reminiscing, facilitating behavior change, fostering prolonged engagement and curiosity, and giving people a sense of ownership of the data and representation. To assess whether these goals are achieved, it is difficult or even inappropriate to use performance metrics such as task completion time and accuracy. Personal visualizations are being developed for a challenging environment; factors such as data ownership and privacy must be considered in tandem with unique design requirements, since the goal is to create enjoyable visualizations, in harmony with individuals' personal tastes. These diverse contexts make it particularly challenging to gain an empirical understanding of personal visualizations.

With this article, we call for attention to realism in empirical investigations of personal visualizations. "Realism of the situation or context within which the evidence is gathered, in relation to the contexts to which you want your evidence to apply" is one of three desirable criteria for study design.[2] Research methods commonly used in visualization often focus on the other two criteria: generalizability (maximizing the range of people to whom the results are applicable, often by controlling the participant sample) and precision (sufficiently controlling external variables so as to isolate a specific effect and supply a degree of confidence). In an ideal world, we could design studies that maximize all criteria. In practice, however, trade-offs have to be made. For example, increasing the precision necessitates more control, but in turn decreases realism.

Our intention is not to downplay the importance of measuring performance and testing hypotheses in a statistically meaningful way via controlled

Published by the IEEE Computer Society

experiments. Instead, we strive to raise awareness of less common methods in the visualization community and encourage researchers to consider them as options when planning a study. Qualitative and formative studies that shed light on the contexts and attitudes surrounding personal visualizations are as necessary as evaluating the impact of existing personal visualization systems and prototypes. When studying personal visualizations, it is important to allow people to interact with their own data, within the visualization's intended environment. Furthermore, because the use of personal visualizations often requires commitment and self-motivation, how a person feels about the visualization is as important as how easy it is to read and understand.

Other disciplines can serve as a rich source of inspiration for developing suitable methods—from formative to evaluative. For instance, the social sciences and design research offer methods for measuring engagement, in-situ observations, and eliciting affective feedback that are already widely used and being continuously refined. In this article, we suggest a few example empirical methods that visualization researchers can use as a starting point to explore how people interact with personal visualizations. By embracing research methods from other fields, the visualization community can develop the full potential of the growing and exciting field of personal visualization, making visualizations more accessible to the general public.

Goals of Personal Visualizations

The common goals of the personal visualizations we describe here illustrate the importance of realism when studying their need, use, and success.

Many personal visualizations aim to support *self-reflection*, "the meditation or serious thought about one's character, actions, and motives" (see en.oxforddictionaries.com/definition/us/self-reflection). Using visualizations can help people understand themselves and their behavior, from which they can develop or strengthen their sense of self. Supporting self-reflection involves providing insights into past behaviors, generating hypotheses about one's life, and confirming or disproving these hypotheses, sometimes without aiming at self-evaluation or self-enhancement. Visualizations can be a powerful tool for gaining such insights. For example, SleepTight improves the person's awareness of sleeping patterns through self-monitoring (see Figure 1).[3] To assess personal visualizations for self-reflection, we should try to discover whether the visualizations allow people to formulate and investigate hypotheses that interest them, to understand themselves better, and to integrate the information they obtain into their views of themselves.

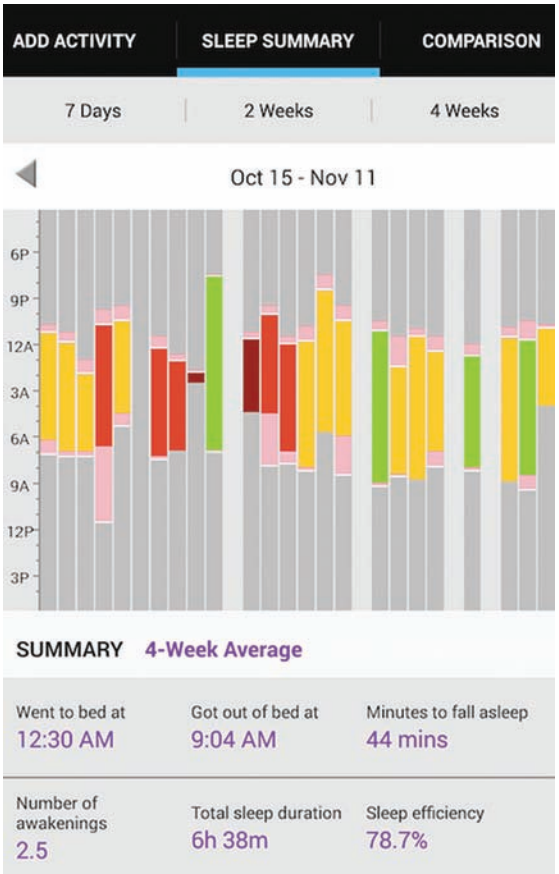

Figure 1. SleepTight personal visualization.[3] SleepTight improves the awareness of sleeping patterns through self-monitoring.

Some personal visualizations strive to support *reminiscing*—the pleasurable recollection of one's past—which is a particular form of self-reflection. People engage in this enjoyable activity alone or with family and friends to form a positive view of their lives and deepen their relationships. Studying whether a visualization helps people reminisce requires understanding if the revealed patterns spark recollections of the past and how well the representation matches the person's memory.

Promoting *behavior change* is another common goal of personal visualizations that goes beyond supporting self-reflection or reminiscing. It involves monitoring and assessing one's actions and putting the gained personal insights into action to improve one's behaviors. Visualizations that support behavior change can positively affect people's health and wellness, productivity, and environmental impact. However, studying if a behavior change has occurred requires a study design that situates people in their natural environment with their own data and that observes their behavior over a prolonged time period. In addition, to foster the long-term adoption of personal visualizations, they need to be integrated into and fit within people's everyday lives. To ensure this, it is crucial to

learn about the context for which the visualization is designed, especially in the early design phase. This type of study benefits from researchers being immersed into the contexts for which the visualizations are intended.

Not all personal visualizations aim to drastically change people's view or behavior. Sometimes a goal of personal visualizations can be providing *moments of pleasure* from small insights about one's life. In this context, visualization designers often strive to make visualizations engaging and capable of sparking people's curiosity. To understand if this goal is achieved, it is useful to study the experience and affective response of the people using the visualizations.

Other personal visualizations aim to support *the presentation of self* using personal data. In this context, it is desirable to make the visualization feel like the intended depiction of one's life. Providing means to make the representation feel more personal (such as by customizing the style and representation) could give the data owner a sense of ownership over its representation. Unlike with traditional visualizations, it can be desirable to include an element of subjectivity when creating compelling stories about one's life. To study if a visualization can adequately support self-presentation, studies need to elicit qualitative responses from both data owners and viewers.

Challenges for Studying Personal Visualizations

Empirical research in personal visualization comes with unique challenges, which highlight the importance of introducing novel research methods and adapting proven methods from other disciplines.

To study personal visualizations with regard to their common goals, performance metrics are often insufficient. Measuring performance in terms of task completion time and accuracy does not provide a deeper understanding of affective responses, specific behaviors, or the impact on people's daily lives. Although efficiency and accuracy sometimes matter in personal visualizations, we need to find additional metrics that can be applied in realistic settings and help to determine whether personal visualizations are successful.

To understand if a visualization supports self-reflection or reminiscing, it is crucial to let people interact with a visualization of their own data. Using test datasets, which are commonly used to evaluate visualizations, would only produce hypothetical results in studies about self-reflection or reminiscing. Alternatively, leveraging participants' existing personal data or asking participants to collect their own data before the study might result in more realistic and valuable feedback. However, this requires a greater commitment from study participants and thus may hinder recruitment. Furthermore, this sampling method—recruiting those who already have data and are willing to provide it—can lead to a selection bias.

Privacy concerns further limit the number of people who are willing to provide their data for study purposes. Because personal data often contains sensitive information, some people might be reluctant to share it even anonymously. Even after participants agree to share their data for study purposes, visualizations can reveal intimate and sensitive information that participants might not be aware of. Because the main role of visualization is to help people gain insights, researchers should make participants aware of the risks and provide a way for participants to share only certain data and insights.

The audience of personal visualizations is diverse and thus has different levels of visual and data literacy. Although some people with an interest in data analysis might have substantial knowledge of different visualization techniques, others might only understand simple standard visualizations. When designing personal visualization studies, researchers must carefully consider this diverse audience and test participants' abilities to understand both data and visual representations in order to obtain meaningful results.

Some personal visualizations aim to help people make positive changes through feedback, data exploration, and analysis. Such visualizations ideally have a direct observable impact on particular aspects of people's lives. However, measuring a visualization's effect on people's actual behavior is challenging because behavioral change is a long-term and complex process. Understanding whether a visualization has a prolonged impact on a person's daily life and whether it has the potential to fit within a person's lifestyle and value system requires field deployment studies over a long-term period. Although these types of studies are common in the human-computer interaction (HCI) and ubiquitous computing communities, they are still rare in the visualization community.

Adapting Methods from Other Fields

We argue that, in personal visualization studies, realism is often more central than either generalizability or precision when attempting to understand individuals' behaviors and feelings toward the visualizations. As a starting point for researchers who want to design studies to inform or evaluate the design of personal visualizations,

we provide a few examples of empirical methods from HCI, psychology, and design research. We do not argue that any one of these methods is perfect or generally better than others. Instead, our goal is to discuss how these methods can help assess specific goals and reduce barriers and problems when studying personal visualizations. For each example, we briefly introduce the method, discuss why it can be useful in the empirical investigation of personal visualizations, and point out where the method might be less suitable. In addition, we encourage researchers to develop new methods specific to their study objectives and adjust existing methods to suit the context of their study.

Elicitation Interviews

Introspection is a research practice in cognitive psychology that aims to capture participants' subjective lived experiences.[4] One specific method associated with this practice is the elicitation interview technique. Researchers have suggested that this technique can help evaluate information visualizations when the research goals are to capture deep interpretation, personal contextualization of a representation, and dialogues with the data.[5] In an elicitation interview, the participant's attention is guided toward one single experience. The interviewer first leads participants into an introspective state by encouraging them to recollect sensual stimuli that occurred during the experience as if it were happening in this moment. Participants are then asked to describe how the experience progressed over time. After the temporal sequence has been recalled, the interviewer iteratively asks deeper questions to reveal the key episodes within the experience.

We believe that introspective research practices can provide valuable insights into people's subjective experiences with personal visualizations. Elicitation interviews can encourage participants to relive and describe moments of self-reflection or deep engagement with their data. The focus on the what and how of the experience rather than the why minimizes the effect of retrospective rationalization that can be problematic when experiences are described retroactively. The elicitation interview method can be applied in all stages of the design process, from an early ideation phase to an evaluative phase with a fully developed system. However, because the method focuses on the affective response during a single instance of a specific experience, excluding the participants' reasoning and opinions, the technique is less suitable for understanding why such technologies are integrated into people's lives.

Cultural and Technology Probes

Bill Gaver and his colleagues introduced cultural probes as an inspirational design method to stimulate the ideation process of technology designers.[6] Probes are usually one or multiple artifacts that are introduced into real-life contexts as a means to prompt discussion that can lead to design insights. It is a way of collecting qualitative data and establishing a relationship with participants that can turn into a deeper understanding of their context.

The HCI community has since adapted the original design method in various ways to produce more focused results.[7] Technology probes, for instance, introduce new technology prototypes as a probe, allowing researchers to collect subjective or emotional feedback on their use. This method gives researchers the opportunity to provide a concrete artifact to contextualize people, yet some aspects of the design are still wide open and invite discussion. Alice Thudt and her colleagues applied this method in the context of personal visualization to study visual mementos created from personal movement data (see Figure 2).[8] They deployed their technology probe on the web together with a free-form questionnaire to collect both subjective feedback and mementos created by participants. The probe method allowed the authors to show a proof of concept for their system and provided inspirational data that provoked ideation for future research.

An important advantage of the probe method is its versatility, which makes it applicable for many study objectives and different stages of a design process. The results from the method can provide qualitative data on how people are using personal visualizations in their own environments over a prolonged time period. They can also help us better understand the habits and environments of a specific target audience and provide inspiration for future research. Participants can decide what and how they share with researchers, which can help mitigate privacy concerns. Data provided by probes is open-ended and sometimes ambiguous and messy, however, which makes the technique less suitable for obtaining reproducible results or answers to more specific research questions.

Diary Studies

Diary studies can provide data about people's use of and attitudes toward personal visualizations over an extended time period.[9] In this method, researchers ask participants to fill out a diary about their activities and/or feelings. The diary can either contain specific questions in log forms to gather situational feedback on a technology or be

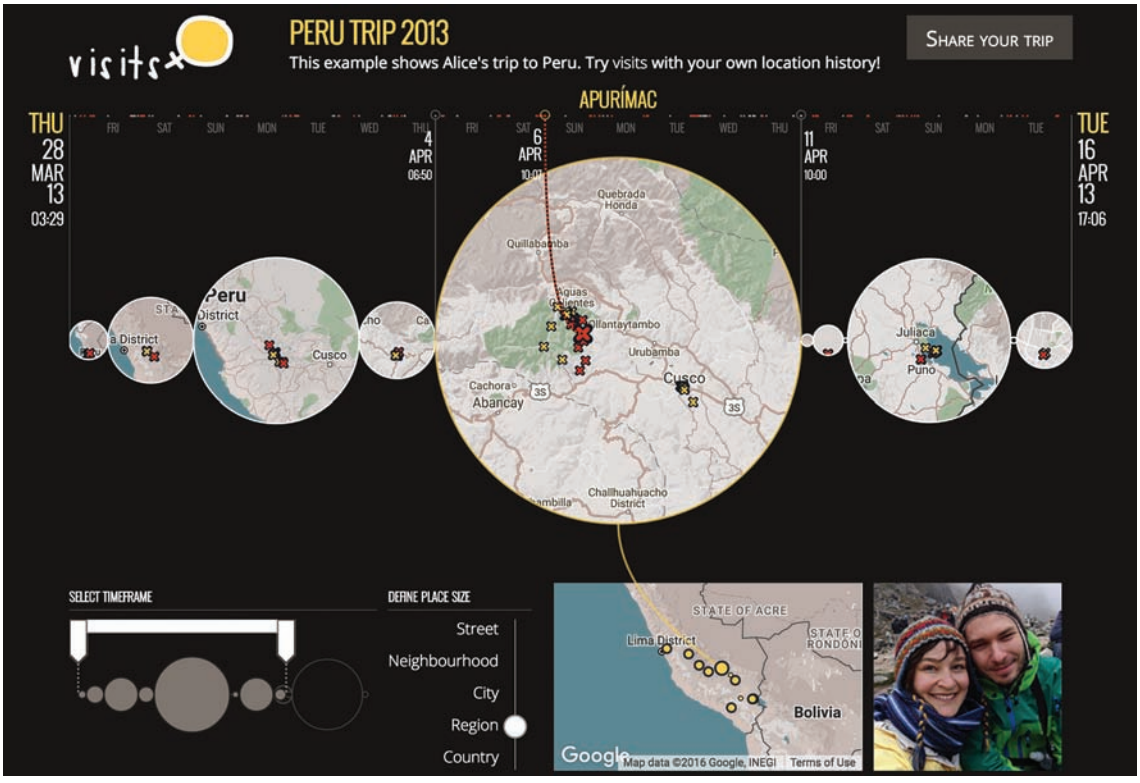

Figure 2. Visual memento created in visits.[8] The system allows creating mementos of personal movement for reminiscing and personal storytelling and was evaluated using a technology probe method.

used more freely to capture notes and photos as memory prompts for follow-up interviews. Diary studies have been widely adopted in the user experience (UX) community. A study on understanding analysts' use of visualizations in the workplace by Purvi Saraiya and her colleagues is one example of applying this method to visualization.[10]

Diary studies are promising methods for evaluating personal visualizations—for instance, to shed light on how people gain insights from their personal data and how they use a visualization to fulfill their goals and needs. They allow researchers to collect contextualized feedback from participants' natural settings without the presence of researchers. Participants can work with their own data without revealing sensitive details to researchers. However, these studies require commitment and prior training of participants to gather rich and regular diary entries. Therefore, dairy studies particularly lend themselves to studying personal visualizations that people already use regularly.

Analysis of Public Data

Data that are already being publicly shared online can be a source of insights for personal visualization research. One such source is the Quantified Self (QS) blog (quantifiedself.com), where recordings of in-person Meetup talks and conferences have been shared since 2008. The speakers talk about their firsthand experiences with self-tracking methods and tools using a show-and-tell format. The recorded videos contain a series of stories on what they did, how they did it, and what they learned, often presented with self-created visualizations.

Analyzing a collection of these presentation videos, researchers have identified common pitfalls of self-tracking,[11] types of data-driven insights people found from their personal data,[12] and visualizations and annotations that lay individuals created to convey these insights.[12] By leveraging publically available data such as QS Meetup talk videos, we can learn about real-world experiences of a focused group of people without having to impose a privacy burden because they voluntarily gave a talk to share their stories with a broader audience. At the same time, however, those who share their data might be a self-selected group of people and might not accurately represent the perspectives of the general public.

Discussion

Personal visualizations have great potential to open up the benefits of visualizations to everyone in their everyday lives. The unique characteristics of personal visualizations combined with the personal data they contain and the contexts in which they are being used call for diverse empirical methods. In particular, the diverse goals of personal visualizations that often differ from those of visualizations designed to support data experts in analyzing large amounts of data motivate the application of a broader set of methods.

As a first step, we suggest being open to careful adaptations of existing methods from other

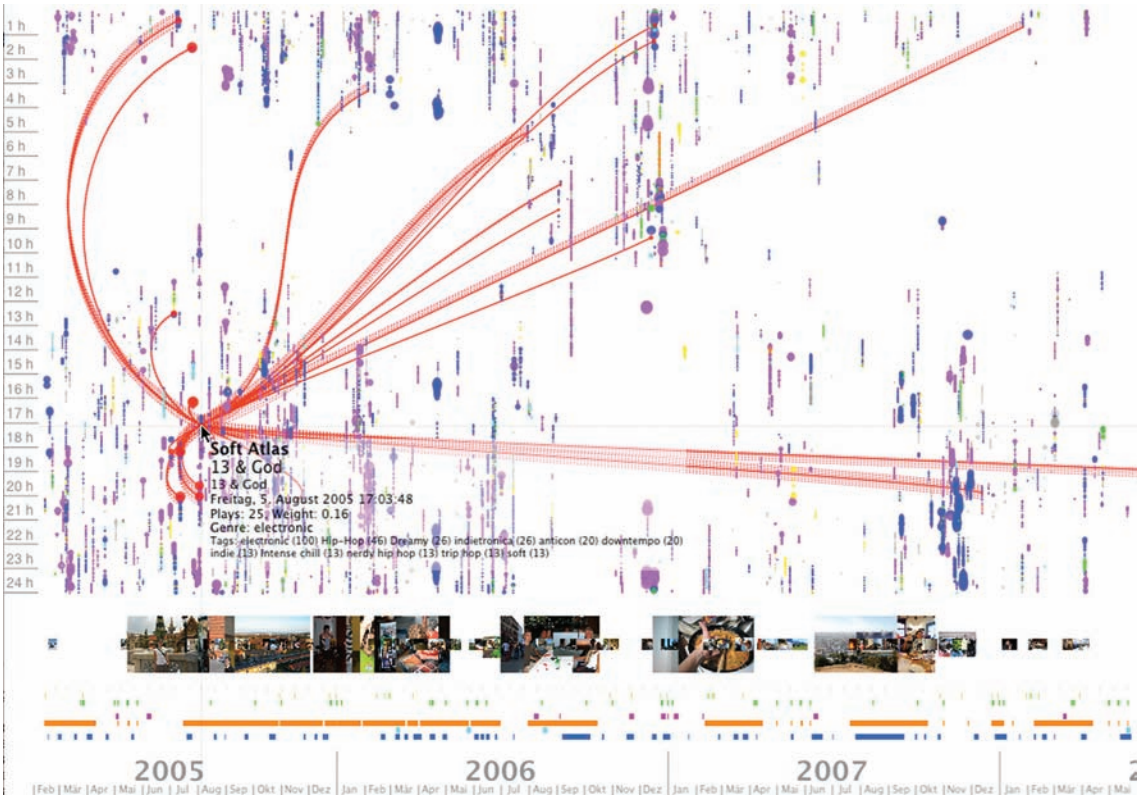

Figure 3. LastHistory visualization.[14] The system facilitates the analysis of music listening habits and was evaluated through a lab study combined with an online survey. (Courtesy of D. Baur)

fields. We have presented just a few recommendations here: elicitation interviews, cultural and technology probes, diary studies, and public online data analyses. We strongly encourage looking into fields such as social sciences, design, and the more closely related HCI for a wealth of ideas of possible empirical approaches. Other areas of visualization research share similar challenges with personal visualization or have their own unique challenges and could therefore also benefit from employing and adapting a broad set of empirical methods. In security-sensitive areas, for instance, it is also a major challenge to collect suitable data for evaluation. The articulation of challenges in other areas of visualization and the benefit of adopting other research methods in those areas deserve further attention.

We argue that realism is crucial when studying personal visualizations. The emphasis on realism makes it particularly difficult to design studies that produce generalizable results. Some researchers have combined methods aimed at generalizable results while still using sufficiently realistic setups to study personal visualizations. For example, Daniel Epstein and his colleagues conducted an online survey on Mechanical Turk, in which 141 participants were able to try personal visualizations with their own data accessed via the Fitbit API.[13] Dominikus Baur and his colleagues combined a lab study with an online survey to assess their visualization of music listening histories (see Figure 3).[14] They were able to collect responses from a large number of people who downloaded and used the application in a realistic setting and elicit more in-depth qualitative data from a small group of recruited participants in the lab. As a research community we need to use and explore such new approaches to more realistically assess personal visualizations.

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