Assessing User Engagement in Information Visualization

Ya-Hsin Hung
Purdue University
West Lafayette, IN 47907 USA
hung17@purdue.edu

Paul Parsons
Purdue University
West Lafayette, IN 47907 USA
parsonsp@purdue.edu

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Abstract
Engagement is an important aspect of user experience. While some researchers have investigated user engagement in the context of information visualization, there is still a lack of scholarship on the topic. In this paper we briefly explore the role and significance of user engagement in information visualization, and discuss challenges in its characterization and assessment. We present VisEngage, a self-assessment questionnaire that provides insight into 11 different characteristics of user engagement. We report the results of an online pilot study that was conducted using VisEngage, and reflect on its potential utility for visualization researchers and designers.

Author Keywords
Information visualization; User engagement; Self-assessment questionnaire.

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H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

Introduction
Information Visualization (InfoVis) research has historically placed primacy on utilitarian aspects of visualizations. As a result, performance and usability have been emphasized as the factors relevant to assessing suitability or success-

fulness of visualizations [42]. While the broader HCI community has emphasized non-utilitarian aspects of human-computer systems for many years now (e.g., those related broadly to *user experience*), InfoVis scholarship has only recently moved in this direction. For instance, recent contributions have explored topics such as memorability, fun, engagement, and enjoyment [4, 5, 30, 42, 43]. Although the value of such research has been questioned (see [42]), it is likely that experience-related concerns will only increase in the coming years, as visualizations are becoming increasingly prevalent in everyday, non-work contexts. Consequently, there is a need for more research and scholarship within InfoVis on broader aspects of the user experience.

In this paper we focus specifically on *user engagement*. While seemingly an important aspect of user experience, user engagement lacks a clear, agreed-upon definition in InfoVis [30, 42]. Furthermore, little research has focused on developing guidelines and instruments for assessing user engagement. We briefly explore the role and significance of user engagement in InfoVis, and discuss challenges in its characterization and assessment. We present VisEngage, a self-assessment questionnaire that provides insight into 11 different characteristics of user engagement, and report the results of an online pilot study that was conducted using VisEngage. Finally, we reflect on the potential utility of VisEngage for visualization researchers and designers and discuss planned future work.

Related Work

A small number of researchers have recently begun to explore the notion of engagement in InfoVis. Mahyar et al. [30] argued for viewing engagement at multiple levels, and have proposed a preliminary taxonomy for evaluating user engagement based on Bloom's taxonomy. Saket et al. [42] argue for going beyond usability and performance in InfoVis evaluation, and have provided an overview of recent work related to user experience. Others have examined engagement indirectly—e.g., looking at whether storytelling in InfoVis engages users [6], and how aesthetic concerns engage users [28]. At this point, research on engagement in InfoVis is still in its infancy. Definitions and assessments have largely been borrowed and adapted from other disciplines. Although scholarship on engagement exists in other technology related fields ([35, 45, 46, 3]), InfoVis deserves its own treatment due to its specific characteristics not necessarily present or prevalent in other disciplines—e.g., the abstract nature of data and information, visual encoding and representation, cognitive and perceptual issues, and interaction.

Characterizing User Engagement

Engagement is a complex construct—it is abstract, not directly observable, and composed of multiple parts. Complex constructs can be difficult to define, as they cannot be directly accessed and can be measured only via an observable phenomenon in which they are manifest [27].

In attempting to understand the nature of engagement, we have examined literature from multiple disciplines including psychology, education, games, and HCI, all of which characterize engagement differently. For instance, from a psychology perspective, engagement is often discussed in relation to flow, positive psychology, fulfilment, and motivation (e.g., [44, 12]). In education, the concept of student engagement has received much attention, and is usually discussed in terms of motivation, achievement, and interpersonal relationships (e.g., [26, 14]). Within the context of gaming, engagement is believed to be a generic indicator of game involvement [8], and some researchers think an engaging experience is encouraged by the sensory appeal of the system and the level of feedback and challenges

a user receives from the system [36, 35]. In HCI, several theoretical frameworks have been proposed [32]. User engagement has been viewed in the context of flow and fluid interaction, leading to satisfying and pleasurable emotions related to curiosity, surprise, and joy [45]. It has also been defined as the emotional, cognitive, and behavioural connection that exists between a user and a resource in time or possibly over time [3]. User engagement is also believed to be the positive interaction quality of the user experience, and has been associated with being captivated and motivated to use a website [23]. Sometimes it is treated as user's level of involvement with a product [40]. Additionally, terms such as flow [15, 11], immersion [35, 9], and playfulness [25, 2, 1] have been mentioned in related research areas, some of which are close to the concept of user engagement. Because engagement is of interest to researchers from many disciplines, each having its own priorities and concerns, it is likely impossible to reach an all-inclusive definition of user engagement. As O'Brien [34] notes, the scope of engagement must be determined before constructing a useful definition. After reviewing the above literature, while also examining particular characteristics of InfoVis, we propose the following preliminary factors to shape the scope of user engagement in InfoVis:

- **Intention**: Users should possess an initial commitment to view or interact with a visualization.
- **Autonomy**: Users should want to view or interact with a visualization un-coerced (e.g., not as a job requirement).
- **Purpose**: Users should form intentions on non-utilitarian grounds (e.g., for pleasure or personal interest).
- **Time**: Users should spend more than a few seconds viewing or interacting with visualizations to have a meaningful experience.
- **Outcome**: Users should gain more than a simple piece of information (e.g. a single variable from a simple chart) from their experience with a visualization.

The above factors delineate an initial scope for studying user engagement in InfoVis. At this point, we do not attempt to propose a formal definition; rather, we identify abstract characteristics that contribute to the construct of engagement, and propose more concrete traits that can be used in the assessment of user engagement. This idea is elaborated in the following section.

Assessing User Engagement

Several approaches for assessing engagement in various disciplines have been proposed [22]. For example, in the gaming community, the Immersive Experience Questionnaire (IEQ) [20, 19] and the Gaming Engagement Questionnaire (GEQ) [8] have been proposed to evaluate immersion and engagement respectively. Models and frameworks relating to engagement have been proposed for online services and web interfaces [3, 23]. Questionnaires and surveys in information science and technology have also been proposed (e.g., [36, 33]). Related constructs, such as flow [13, 29] and playfulness [24, 25], have received considerable efforts at measurement and assessment.

Constructs such as engagement cannot be measured directly. Although various physiological indicators can be measured directly, such as blood pressure [31], heart rate [47], and nervous system activity [21], these methods can be considerably costly and lengthy, limiting their scalability and practicality. Furthermore, considerable interpretation is required to make causal connections to subjective phenomena [48]. Some behavioural indicators (e.g., mouse clicks and movements, page visits, and time spent) have been

successfully used as indicators of users' subjective experiences [10, 18, 35, 36, 40].

One of the most popular methods of assessing psychological constructs is self-reporting [39]. Advantages of self-reporting methods include interpretability, information richness, and practicality [37]. Aside from common assessment challenges, the main disadvantage for self-assessments is credibility, as self-reports are subject to various inaccuracies, even when subjects try their best to be accurate [37]. Because of the numerous advantages of self-reporting methods, and their practicality for conducting pilot studies, we decided to develop and employ a self-report questionnaire that can be used to assess user engagement with visualizations. We elaborate on the questionnaire in the following section.

User Engagement Questionnaire: VisEngage

We developed a self-assessment questionnaire for user engagement called VisEngage. Based on prior research on ideal characteristics of online questionnaires (e.g., [16, 17]), we had the following requirements in mind:

- It should require only 10-15 minutes to complete
- The number of factors should be approximately 10
- Each factor should contain multiple items that can be assessed using a Likert scale
- Each factor should generate a single score

Because engagement is a complex construct, we had to identify a number of its constituent characteristics that could be used for assessment purposes. Inspired by Lucero et al.'s work [35], we reviewed approximately 150 papers in related disciplines such as website analysis, game design, education, psychology, and HCI, and compiled a list of potentially relevant characteristics. Since some characteristics appeared repeatedly, we calculated their frequency. In total, we identified 57 characteristics. Many of these were too broad or vague for our purposes (e.g., affect, entertaining). Others were too narrow and only relevant in specific contexts (e.g., brutality, eroticism). Additionally, many were synonymous and we merged them.

In the end, we identified 11 engagement characteristics that had the highest frequency in the literature and were most relevant to engagement in InfoVis: **Aesthetics, Captivation, Challenge, Control, Discovery, Exploration, Creativity, Attention, Interest, Novelty, and Autotelism**. We identified 22 items (2 for each) that are more concrete than the abstract characteristics and could be used in a self-assessment questionnaire. We developed the items into 22 questions that participants could easily answer, the answers to which could reveal something about the underlying characteristics of engagement. For each item, participants provide their response on a seven-point Likert scale, ranging from strongly disagree (1) to strongly agree (7). VisEngage is intended to be given to participants immediately after using a visualization. Six of the questionnaire items are listed in the margin; letters of the alphabet indicate the sequence of characteristics from 1 to 22 (A=1, B=2, etc.).[1]

VisEngage Example Items

Aesthetics:
A. While using this interactive chart, I found its look and feel to be pleasing.
B. The layout of this interactive chart is clear and balanced.

Captivation:
C. While using this interactive chart, I felt absorbed to the extent that I was not aware of my surroundings.
D. While using this interactive chart, time seemed to pass quickly.

Discovery:
I. While using this interactive chart, I learned something that I had not known before (e.g., a new fact, concept, or piece of information).
J. While using this interactive chart, I learned and figured out how to use it along the way.

Pilot Study

To explore the utility of a self-assessment user engagement questionnaire, we conducted an online pilot study using Amazon Mechanical Turk (MTurk). We also used the Qualtrics online survey platform and the Mouseflow web analytics service. We employed three visualizations in the experiment, each of which was selected from Tableau's Public gallery: Record Breaking Coasters [38], Analysis of Queen [41], and Women in Computer Science [7]. By

[1] For more details please visit the VisEngage website: https://yahsin.github.io/VisEngage/

comparing behavioral indicators (e.g., how long a subject's cursor is within the visualization area) and scores from the questionnaire, we could identify any correlations between these two measurements.

Our experiment included three trials, where each trial comprised a visualization; three task-related questions, the answers to which could be found within the visualization; and 24 questions (22 VisEngage questionnaire items and two open-ended questions). The order of trials was randomized. During each trial, participants' interaction data, including total time spent and the length of time a subject's mouse cursor was within the visualization area, was collected.

	Avg Time Spent in Viz
Trial 1	64.47 (std=25.53)
Trial 2	47.40 (std=18.63)
Trial 3	43.22 (std=17.73)
	Avg Engagement Score
Trial 1	123.92 (std=17.047)
Trial 2	123.20 (std=16.12)
Trial 3	104.5. (std=23.521)

Table 1: Average time spent within the visualization area (top) and average engagement score (bottom) among the three trials.

Results and Analysis

A total of 40 participants were initially recruited through the MTurk platform. To remove random responses, we ruled out 5 participants who completed the questions in under 20 seconds. Mouse movement data for some participants was lost due to glitches with the Mouseflow platform. Of the remaining 27 participants, 12 were female and 15 were male, and ages ranged from 20 to 75 (M=37.73). We collected the amount of time a subject's cursor was within the visualization area of a page (in seconds) and engagement scores from the questionnaire items (in points). The engagement score was based on subjects' responses using a seven-point Likert scale with even weighting. A general statistical analysis is shown in Table 1. Trial 1 had the longest time spent within the visualization and the highest engagement score; Trial 2 had a shorter time spent and a similar engagement score to Trial 1. Trial 3 had the lowest of both variables.

With a one-way repeated-measure ANOVA analysis, we found a significant effect of Trial on Score ($F(2,52)=19.13$, $p<0.01$, partial $\eta^2=0.43$), which indicates a significant difference in participants' engagement scores among the three trials. A pairwise comparison revealed significant differences between Trial 1 and 3 ($p<0.01$), and between Trial 2 and 3 ($p<0.01$). For time spent, we found a significant difference in participants' time spent within the visualization among the three trials ($F(2,52)=11.86$, $p<0.01$, partial $\eta^2=0.32$). A pairwise comparison revealed significant differences between Trial 1 and 2 ($p<0.01$) as well as Trial 1 and 3 ($p<0.05$). However, linear regression modeling of engagement scores and time spent within visualization areas shows low correlation ($R^2=0.24$, $F(1, 79)=4.62$, $p<0.05$). To convey general trends of the three trials, we created three bar charts that represent the average score of all 22 items in the questionnaire, from item A to V (see Figure 1). By simply eyeballing the chart, we can see that items M and N, which deal with the creativity characteristic of engagement, are considerably lower than the others. We also see that

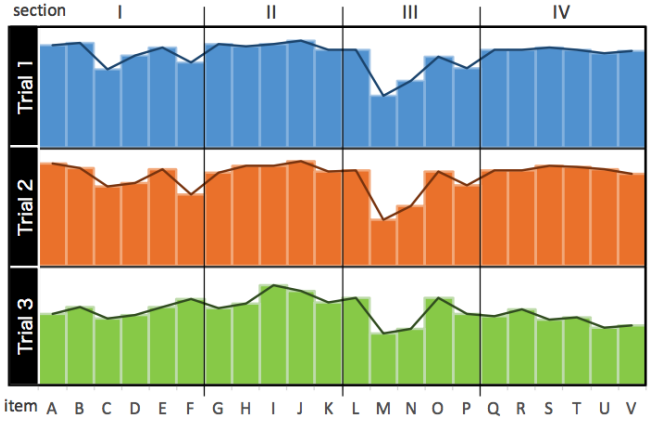

Figure 1: Average scores of each item across the three trials. Bar length represents the score for an item. Sections have been superimposed for discussion purposes.

Figure 2: A screenshot of one survey page, including one interactive visualization [41] and three of the corresponding questions.

the chart shape of trial 3 is quite different from others, especially in sections I, II and IV (we have superimposed these sections on the chart for discussion purposes). The general trend in Trials 1 and 2 is quite similar—however, we still can identify differences in sections I and IV.

Discussion and Future Work

In this paper, we discussed the importance of user engagement in InfoVis and elaborated on the difficulty of its characterization and assessment. We summarized related work in InfoVis and other relevant areas. We also presented our self-assessment user engagement questionnaire called VisEngage, and described its development and intended use. We reported the results of a pilot study that was conducted using VisEngage.

Three limitations of this pilot study should be noted. First, since we required participants to use the three visualizations in the experiment, some of our scope-related factors (intention, autonomy, purpose) may not have been met authentically. Results of the study could be influenced by this. Second, the complexity of the three visualizations in the pilot study was fairly low, due to the assigned length of the experiment as well as the unknown backgrounds of the subjects. As a result, engagement characteristics such as creativity and captivation may be lower than they could be in with more complex visualizations. Third, because the study was conducted online, we could not observe participants' physical behaviors such as eye movements, facial expressions, or body language. Previous research has shown that such behaviors can be relevant in indicating inner subjective activity, and could thus be relevant in assessing user engagement.

For future work, we plan to conduct a laboratory study that can overcome a number of limitations inherent in online studies. We plan to supplement our VisEngage questionnaire with methods such as eye-tracking, verbal protocol, and facial expression analysis, with the aim of developing a richer and more holistic understanding of user engagement. We will also attempt to mitigate the known difficulties of creating authentic experiences in laboratory settings.

We plan to explore the utility of grouping related questionnaire items into meaningful orderings, and then visualizing the results as in Figure 1. The current ordering of items has no inherently meaningful arrangement. If the arrangements were more meaningful, results would generate different shapes that allow visualization designers to perceptually assess the aspects of user engagement for which their visualizations are high or low. For example, a "U" shape could imply that a visualization is engaging in terms of aesthetics and ease of understanding, yet poor in terms of user control. If this idea is viable, a visualization designer could quickly evaluate a set of visualizations based on the shape of the generated chart, then dig into the details of any particular ones of interest.

A final note should be made that our set of characteristics is not exhaustive or final, and is likely to be updated in the future. Our hope is that researchers will expand on and improve this work, and that VisEngage will promote more scholarship on the topic of user engagement in InfoVis.

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