Eurographics Conference on Visualization (EuroVis) (2015)
J. Kennedy and E. Puppo (Editors)

Short Papers

Towards Understanding Enjoyment and Flow in Information Visualization

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Abstract

Traditionally, evaluation studies in information visualization have measured effectiveness by assessing performance time and accuracy. More recently, there has been a concerted effort to understand aspects beyond time and errors. In this paper we study enjoyment, which, while arguably not the primary goal of visualization, has been shown to impact performance and memorability. Different models of enjoyment have been proposed in other fields; yet there is no standard approach to evaluate and measure enjoyment in visualization. In this paper we attempt to relate the flow model of Csikszentmihalyi to Munzner's nested model of visualization evaluation and previous work in the area. We suggest that, even though previous papers tackled individual elements of flow, in order to understand what specifically makes a visualization enjoyable, it might be necessary to measure specific elements in particular ways.

1. Introduction

Within visualization, traditional usability and user experience research has focused on two aspects: measuring performance time and accuracy. For example, four out of five papers in the evaluation track published at InfoVis 2014 measured performance time and accuracy to compare different visualization techniques [BDJ14, CDF14, SSKB14, FIB*14]. Although several recent papers study memorability [BARM*12, IXTO11, BVB*13], other aspects such as enjoyment or engagement are not as developed.

This focus on time and accuracy can be explained in part by how easy it is to tell how quickly or accurately a participant performs a task, especially in contrast to aspects that are harder to define, much less measure. Further, one might argue that providing enjoyment is not a primary goal in visualization [vW05]. Still, it is likely worthwhile to understand the impact of factors such as enjoyment on performance; for example, positive mental states appear linked to better problem-solving performance in general [Fre98], and in InfoVis in particular [HSF*13].

Bateman et al. [BMG*10] asked participants to rate the enjoyability of charts using a Likert scale, and found that participants enjoyed embellished charts ("chartjunk") significantly more than plain ones (these counterintuitive results were recently replicated by Li et al. [LM14]). Assuming these results hold in general, natural research questions include: Are there specific factors of enjoyment at play here? Can we increase enjoyment *without* chartjunk? How do we connect the evaluation of visualizations to the current study of enjoyment in the literature?

One of the most well known model for understanding and measuring enjoyment in psychology is the flow model by Csikszentmihalyi [Csi90]. He first studied people who invested a great deal of time and effort on challenging activities, such as rock climbing and chess playing. The results revealed that various activities were described similarly when they were going well: as Csikszentmihalyi writes, "the way a long-distance swimmer felt when crossing the English Channel was similar to the way a chess player felt during a tournament, or a climber progressing up a difficult rock face".

In visualization, Munzner's nested model [Mun09] is well-known for understanding evaluations. In this paper, we discuss how specific factors of the flow model *interact with* different levels of Munzner's model, and how previous work has indirectly measured some of these factors. In this way, we hope that our characterization of these interactions will guide future research questions and guide experimental designs.

We begin with a brief summary of the flow model and identify elements that capture the experience of flow. In Section 3 we review several studies in other fields which have used flow model to either design a new model or assess user enjoyment. In Section 4 we discuss how the nested model relates to specific parts of flow, and, in particular, how one flow element appears fundamentally different from the others, and how this potentially impacts visualization evaluation. We conclude with some possible recommendations for evaluation studies in visualization that try to understand enjoyment.

	Why? problem / domain	What? data / operation	How? encoding / interaction	How Fast? algorithm	references
Challenge		✓	✓		Hullman et al. [HAS11]
Focus			✓		—
Clarity	✓	✓			Brehmer and Munzner [BM13]
Feedback				✓	Liu and Heer [LH14]
Control			✓		Kondo and Collins [KC14]
Immersion			✓		van Dam et al. [VDLS02]

Table 1: *In this paper, we relate enjoyment* factors *in Csikszentmihalyi's flow model (rows) to visualization design and evaluation, using specific* levels *of Munzner's nested model (columns). Check marks denote* interactions*: if visualizations change in particular levels, then resulting changes in enjoyment should only be attributable to the factors corresponding to checked cells in its column. Conversely, concerns about specific enjoyment factors need to be evaluated only at the levels corresponding to checked cells in the respective rows. The "references" column, while making no attempts at comprehensiveness, shows examples of previous work in visualization which appear to be related to specific elements of the flow model.*

2. Flow

Csikszentmihalyi conducted a series of experiments in different countries in which he asked people to explain how and when they achieved the highest level of enjoyment when performing some activity [Csi90]. As Csikszentmihalyi writes, "Regardless of culture, social class, gender or age, the respondents described enjoyment in very much the same way. *What* they did to experience enjoyment varied dramatically — the elderly Koreans liked to meditate, the teenage Japanese liked to swarm around in motorcycle gangs — but they described *how* it felt when they enjoyed themselves in almost identical terms." [Csi90] He identifies, among others, the following factors as encompassing the experience of flow:

- Challenge: the activity must be challenging and require skill
- Focus: it should be possible to concentrate on the task
- Clarity: it should be possible to concentrate on the activity *because it has clear goals*
- Feedback: it should be possible to concentrate on the activity *because it provides immediate feedback*
- Control: participants should feel a sense of control over actions
- Immersion: participants should lose the concern for self (this is sometimes described as being "in the zone")

Very different experiences, when engaging and enjoyable, elicit feelings described in similar ways. We speculate that enjoyable, engaging visualizations should elicit comparable descriptions.

3. Previous Work

The flow model has been applied by researchers in other fields to assess enjoyment [PA04, RC05] and to create new models [SW05, VCS02]. A multi-year study of student experiences in two different educational settings (Montessori and traditional) found that Montessori settings [RC05] helped students to achieve flow experiences more frequently [RC05]. Vass et al. [VCS02] combined several theories, including the flow model, for the development of problem solving environments that support creativity. The flow model has also been used in a framework for constructing engaging commercial websites [Jen00] and to assess enjoyment in an interactive music environment [PA04].

Sweetser et al. [SW05] combine various heuristics into a model of enjoyment in games, GameFlow, that is based on flow model and adds a new "social interaction" element. Elmqvist et al. defined *fluid interaction* in the context of information visualization: "Fluidity in visualization is a concept characterized by smooth, seamless and powerful interaction; responsive, interactive and rapidly updated graphics; and careful, conscientious, and comprehensive user experiences." [EVMJ*11] A fluid information visualization interface has three properties: it promotes flow, supports direct manipulation, and minimizes gulfs of action. Although Elmqvist et al. [EVMJ*11] suggest that *interactions* should be designed to promote flow, they do not discuss how each of the elements of the flow model can be applied to information visualization in general. They also do not describe how to map the flow elements to visualization tasks or how to measure each of the elements.

4. Adapting Flow for Information Visualization

In this section, we discuss how each individual element of flow model can be linked to InfoVis, how these elements correspond to levels of Munzner's model, and how previous work has indirectly measured some of these flow elements. Of course, the only absolutely correct way to decide whether or not to mark a cell in Table 1 would be done by investigating every possible task, abstract, encoding, and algorithm, and measuring whether differences in each layer cause specific changes in the enjoyment factors of the flow model. This is obviously impossible in practice. Instead, we look to the infovis literature, Csikszentmihalyi's descriptions of the flow model, and Munzner's nested model paper to make these characterizations *a priori*, knowing that they are necessarily incomplete and subjective.

Challenge: Generally speaking, enjoyment occurs when the challenge in an activity matches the skills of the participant. [Csi90]. For example, Alper et al. [ABR*13] compared node-link diagrams with matrix representations to assess which representation best supports weighted graph comparison tasks. They showed that participants who were not familiar with the matrix representation had more difficulty performing the tasks than when the graphs were represented by node-link diagrams. Such results support the idea that challenges in a visualization should match the skills of participants. In Munzner's model, the challenges in a visualization appear to necessarily relate to either the abstract *operations* available (the "What?" layer) — some operations might make the task comparatively hard or easy — or the *encoding* being used (the "How?" layer). A bad characterization of the problem domain might make the visualization *unclear* (see below), but it will not make it *hard*, and the same argument holds for the performance of the encoding algorithm. In terms of explicitly making visualizations more or less challenging, the work of Hullman et al. about visual difficulties is recently the best-known [HAS11], in connection to Bateman et al.'s study on visual embellishments, and subsequent studies by Li et al., Borgo et al. and Ghani and Elmqvist. [BMG*10, BARM*12, GE11, LM14]. We defer a further discussion of this point to Section 6.

Focus: Enjoyable activities require complete attention on the task at the hand. Visualization design has a significant perceptual impact. As advocated by Tufte, the visualization should make it possible to concentrate on the important information [Tuf83]. This aspect of enjoyment is broken down below into "clear goals" and "immediate feedback", both of which make good sense in the context of visualization. In our literature search, we were unable to find papers that specifically discuss user focus during visualization evaluation; feedback and goals, on the other hand, are widely discussed. As it relates to Munzner's nested model, we see Focus being affected only by the interaction/encoding being used, but confess that since we could not find any reference in the literature to a specific study appearing to measaure or characterize focus, this classification is particularly speculative.

Clarity: Enjoyment occurs because the user understands exactly what the task's goals are, and what they are working towards. The clarity of a goal, perhaps surprisingly, is not directly related to the encoding of a visualization or to the data used to generate it. Instead, it is related to the problem and domain in which the user is working. Clarity, at least on the surface, appears to be in contradiction to Challenge, since the clearer a goal is, the "easier" it is to achieve it. But in fact, these two concerns operate on different levels, and this becomes clear when we map them to the nested model. Consider, for example, the abstract task of finding a path between two nodes of a graph. Node-link diagrams with a reasonable layout make it clear what to do and how to do it (follow paths from the source to the target); with an adjacency matrix representation, the task is less clear [GFC04]. But the *goal* is likely to have been described as "find a connection between actors Kevin Bacon and Harrison Ford", and that is independent of the encoding or the data being used. If we were to describe the goal differently, then it is conceivable that the very same visualization *and task* would have different levels of enjoyment. This is an important point we turn back to in Section 6. Clarity appears to relate to the outermost level in Munzner's nested model, namely the problem/domain characterization aspect, and possibly to the decision of which data to use in a visualization (the "What?" layer).

Feedback: Enjoyment happens because the task undertaken provides immediate feedback. Feedback appears to be exclusively associated with the *innermost*, "How Fast?", level in Munzner's model. Liu and Heer [LH14] have studied how latency influences the exploratory behavior of users. Their results indicate that increasing latency decreases performance and causes modifications in exploration strategies. An intriguing possibility is to study the degree to which these changes in exploration strategies come from disengagement or frustration. We note that alternate feedback mechanisms, especially when the user's visual field is already occupied, was also been considered [SYT*14].

Control: When achieving flow, one experiences a sense of complete control over one's actions. Feedback relates to the immediate acknowledgment of an action having happened. Control, on the other hand, relates to the action doing *what one expected it to*. A visualization system should make it possible to translate intentions into visualization behavior and provide a feeling of control. Here we highlight the recent DimpVis system, where direct manipulation of the visual marks are translated into the data query that would best generate an output with the manipulated configuration [KC14]. In the context of Munzner's model, Control appears to interact exclusively with the "How?" layer. In other words, the way we *encode data* and *design interactions* affects the amount of control (and *only* the amount of control) perceived by the user.

Immersion: Participants lose their sense of self and become "lost" in the activity. Although immersion is frequently discussed in leisure activities such as gaming [JW03, SW05], achieving immersion through multisensorial stimulation has long been a goal of virtual reality systems in scientific visualization [VDLS02]. With the ubiquity and dropping prices of virtual-reality equipment, it would appear to be possible to design visualization tasks than can be completed in immersive and non-immersive systems, and then compare participant reports. Similarly to Control, Immersion appears exclusively connected to the "How?" layer. For example, in a recent experiment, Saket et al. showed that participants took significantly longer to explore map-based visualizations than node-link visualizations of the same data [SSKB15]. At the same time, results of earlier experiment show that the extra time taken to explore the map-based visualizations does not seem attributable to the visualization being harder to read. [SSKB14]. Hence, we speculate that this difference might be due to different amounts of immersion.

5. Measuring Flow in Visualization

Although there is no single holistic method to measure these elements, several studies apply self-reporting methods (e.g., Likert scale questionnaires and Product Reaction Cards [Mer14]) to measure some of these elements. Self-reporting is a widely used method, especially for understanding emotions [HSF*13]. In particular, although self-reporting methods can be questionable, it has been shown that people are capable of giving numerical or graphical indication of their emotions [PTTVG03].

For example, Sweetser et al. [SW05] used the Likert scale to measure the strength of each individual element of their GameFlow model which is derived from the flow model. In another study, Merčun [Mer14] indicates how the product reaction card method can be applied to extract participants comments and thoughts on different visualizations. Other methods beyond the Likert scale and reaction cards, such as the HCI-Q method [OWR13], might be also useful for evaluating presence of the elements of flow.

Recommendations: While it remains unclear how to design specific measurement methodologies for enjoyment in visualization, the current best model for enjoyment in psychology has several relatively well-defined aspects. In future studies that evaluate engagement in visualization, we recommend authors to elicit responses along these different elements. As we have found in the literature, studies specific to one technique or system have touched various aspects of flow, but in order to paint a more complete picture of what ultimately leads to engagement and enjoyment, we ideally need information on all aspects suggested by Csikszentmihalyi [Csi90].

6. Discussion and Limitations

Undoubtedly, there will be difficulties in measuring elements of enjoyment. We want to highlight one potentially important concern in comparing different studies. As it relates to visualization, Clarity comes not from the technique, data, or performance, but rather comprehension of the task being performed. In this sense, in order to compare Clarity across visualizations, it seems essential to precisely control the task performed. However, the task typically comes from the task list created by the experimenter, and this information is rarely published along with the study. This, of course, is similar to the problem of *survey question wording* [SP81]. Does a difference in enjoyment ultimately arise from the relative difference in Clarity between the tasks? This confounding factor seems to require a change in how we report our studies.

	Intensity vs. enjoyment	
	Other Fields	InfoVis
Challenge	 [LPFK13]	?
Focus	?	?
Clarity	?	?
Feedback	 [SW05]	 [LH14]
Control	?	?
Immersion	?	?

Table 2: *For some specific elements of flow, there is evidence that optimal enjoyment occurs with* moderate *intensity levels. This appears to be in contradiction to some published work in visualization [LH14]. Question marks indicate areas authors were unable to find published work.*

While evidence suggests that optimal enjoyment occurs with moderately challenging activities [LPFK13] and moderate feedback [SW05, LPFK13], we do not have enough evidence to draw conclusions about other elements of the flow model. We illustrate the current situation in Table 2.

7. Conclusion and Future Work

In this paper, we connected Csikszentmihalyi's flow model of enjoyment to Munzner's nested model of visualization evaluation. Regardless of the many hurdles mentioned above, we believe it is important to explore different elements of enjoyment in the context of visualization. Our main recommendation is that since "enjoyment" encompasses many different elements, in order for visualization researchers to initiate a systematic study of enjoyment in visualization, evaluations must control as many specific flow elements as possible: Challenge, Focus, Clarity, Feedback, Control, Immersion. We are planning to study enjoyment in the context of node-link and map-based visualizations and will study each flow element specifically; nevertheless, we hope other readers will find our discussion, analysis, and especially the myriad unresolved research questions, relevant and interesting.

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