Questionnaires assessing usability of audio-visual representations

Niklas Rönnberg[1], Camilla Forsell[1]

[1]Linköping University, SE-581 83, Linköping, Sweden

Abstract

In this position paper we argue for the need of using standardized questionnaires for assessing usability in audio-visual representations. By using standardized measures of usability, comparability and validity of research studies in this field will be improved. However, it is not clear which questionnaire that is most suitable for assessing usability in audio-visual representations, neither when assessing the modalities individually or the combination. We present a variety of different questionnaires available, and argue for the need of combining different measures as well as developing new.

Keywords

User-centered evaluation, Questionnaires, Usability, Visualization, Sonification, Audio-visual representations

1. Introduction

By using audio-visual analytics, the best of visualization and sonification can be combined to create a strong and informative data analysis. In this position paper we argue for the need of standardized evaluation methods, specifically questionnaires, for audio-visual analytics that consider visualization and sonification (or auditory displays) separately as well as the combination of these two modalities. The lack of standardized evaluation methods imposes serious constraints on the possibility to conduct evaluation studies and on the results. These concerns are not new and have been raised before in relation to visualization [1], but with this position paper we follow up on this reasoning with a focus on audio-visual data analysis.

A challenge in audio-visual analytics is that both modalities, should be assessed in combination, as the outcome of such data analysis might be equally affected by both modalities. However, the modalities should also be assessed individually to ascertain insight and knowledge in how they, separately, affect the process. Also, data analytics tools are often interactive (see for example discussions in [2, 3, 4, 5, 6]), consequently interaction should also be taken into consideration in evaluation.

There are benefits of using standardized questionnaires in evaluation studies for information visualization and sonification. Evaluation studies in both visualization and sonification borrow theory and methods from other disciplines, such as the research area of human-computer interaction (HCI), interaction design, or cognitive ergonomics. These methods were not developed to be used for evaluation in information visualization or sonification, and consequently not for the combination of these. As a result, many questionnaires do not address aspects of use and experiences that are relevant to study in audio-visual analytics. This means that evaluators, from study to study, are adapting existing methodology to fit their needs or have to develop new approaches and schemes for assessing the usability of their work. This in turns may lead to challenges in judging the reliability and the validity of individual studies and doubtful study outcomes (see for example discussions in [7]). When study outcomes become questionable and when different studies use different evaluation methods, it becomes hard to compare results between evaluation studies. This makes it difficult to find general patterns between different tools, techniques, and approaches, and to keep building on previous results.

The lack of standardized methodology to rely upon when conducting evaluation studies makes it difficult to produce credible and comparable results and it may also lead to researchers avoiding conducting evaluation studies at all. This means that promising audio-visual design ideas might be rejected since convincing evidence of usability is not presented, or that less useful ideas are presented and promoted. We believe that standardized questionnaires considering usability of all aspects of audio-visual analytic tools (i.e., visualization, sonification, the combination of these, as well as the interaction) would be a much needed and valuable contribution to the growing research field of audio-visual analytics. The opportunity of presenting this paper at the WAVA22 (AVI 2022 workshop on audio-visual analytics) and discussing this proposed work with the workshop participants, could initiate the process to develop and establish a set of such standardized instruments in the community.

WAVA: AVI 2022 Workshop on Audio-Visual Analytics, June 07, 2022, Rome, Italy

niklas.ronnberg@liu.se (N. Rönnberg); camilla.forsell@liu.se (C. Forsell)

https://liu.se/en/employee/nikro27 (N. Rönnberg); https://liu.se/en/employee/camfo15 (C. Forsell)

0000-0002-1334-0624 (N. Rönnberg)

2. Measuring usability

To obtain a relevant measure of usability, the concept of usability needs first to be defined. According to the ISO9241-11 standard [8], usability is a measure of quality in terms of the extent to which a specified user can achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use. Usability has also been defined as being composed of concepts such as learnability, memorability, subjective satisfaction, and error rates [9]. In the ISO9241-11 standard, memorability and error rates are included in the effectiveness aspect while learnability is included in efficiency.

When measuring usability, it is, in many cases, important to address all three aspects: effectiveness, efficiency, and satisfaction, and these aspects can be measured with both objective and subjective measures. Subjective measures are not limited to only referring to the satisfaction aspect, but objective measures (i.e., effectiveness and efficiency) can also be evaluated subjectively [10]. Objective and the subjective measures do not always correlate. As an example, when a user is more engaged in a task, time is perceived to pass more quickly [11, 12, 13]. This means that the objective and subjective measures should be considered independently and investigated separately, when necessary, as these measures might result in different conclusions [14].

Visualization and visual analytics, as well as sonification are well-established scientific fields, with extensive work carried out both on auditory and visual representation of data. Visualization is more than pretty pictures [15] and the overall purpose of visualizing data is insight and not pictures [16]. When an information visualization technique is implemented in a system, usability is hence crucial [2, 17]. Similarly, sonification is more than just the transformation of data into sounds. The purpose of sonification is to communicate data [18], thus, usability is equally important in this field, considering as an example perception of auditory data representations and precision vs. perception of music [19, 20, 21, 22]. The work on audio-visual analytics is sparse compared to visualization and sonification, even if there is an immense potential for audio-visual analytics environments [23].

In visual data analysis dynamic human interaction is essential for exploring the data [3, 4, 2], and this has also been suggested to be the case for sonification [5, 6]). Interaction design is about creating conditions for operation and use of digital designs [24] and using interaction in data analytics affects perception and experience of both visualization and sonification. Therefore, we would like to argue that interaction is an important part of an audio-visual analytics tool [25] and usability aspects of interaction could consequently be an important aspect to be assessed in the evaluation.

3. Questionnaires for assessing usability

As mentioned above, to assess the usability of a representation, both objective (quantitative) and subjective (qualitative) measures are needed. Questionnaires can provide data about subjective experiences of satisfaction and aesthetic experiences of visualization and sonification, but also about effectiveness (i.e., the experienced correctness of answers given) and efficiency (i.e., the experienced swiftness of the answers given). This information can also be obtained via e.g., interviews or think-aloud methods, however questionnaires are easier to administer and often less time consuming. Furthermore, questionnaires can assure reliability since they are consistent to all participants in a user study. This also increases reproducibility and comparability between studies. Most often evaluators borrow questionnaires and evaluation methods from other research fields, as mentioned above, measuring task load, user experience, or user engagement [26, 27].

There are a number of standard measures of usability (see for example [28, 29]), such as the System Usability Scale (SUS) [30] for exploration of usability of a system, the Questionnaire for User Interface Satisfaction (QUIS) [31] which elicits user opinions and evaluates user acceptance of a computer interface, the Software Usability Measurement Inventory (SUMI) [32] offering a measure of software quality from the end user's point of view, the NASA Task Load index (NASA TLX) [33] which is a subjective assessment tool rating perceived workload to assess a task, system, or team's effectiveness or other aspects of performance, the After-Scenario Questionnaire (ASQ) [34] which assesses the difficulty level a user perceives a task in a usability test, the Post-Study System Usability Questionnaire (PSSUQ) [34] that measures users' perceived satisfaction of a website, software, system or product, and the Computer System Usability Questionnaire (CSUQ) [34] measuring user satisfaction with system usability. All of these are in general good and useful to assess, at least, parts of an audio-visual representation.

User experience, as part of usability, builds on the satisfaction dimension of usability [8]. User experience assesses aspects like user emotions, perceptions, responses, adaptability, desirability, and value. There are different standard questionnaires for assessing user experience, such as the Usability Metric for User Experience (UMUX) [35] measuring an application's perceived usability in regard to the ISO9241-11 definition of usability, the UMUX-Lite [36] which is a shorter and faster version of UMUX, and the standardized questionnaire for the Component model of User Experience (meCUE and meCUE2.0) [37, 38] which is based on the analytical

component model of user experience [39] exploring perception of product characteristics (usefulness, usability, visual aesthetics, status, commitment), users' emotions, and consequences (product loyalty and intention to use).

Other questionnaires that assess relevant aspects are related to immersive experience, gaming experience, and user engagement, such as Immersive Experience Questionnaire (IEQ) [40] that measures the subjective experience of being immersed while playing a video/computer game, the Gaming Engagement Questionnaire (GEQ) [41] assessing levels of engagement specifically elicited while playing video games, and the User Engagement Scale (UES) [42, 43] measuring users' experienced aesthetic appeal, focused attention, novelty, perceived usability, felt involvement, and endurability. Even if these measures might be perceived as somewhat unrelated to evaluation of audio-visual representations, they still contribute to a better overall understanding of how a user perceives, uses, and experiences such representations.

All the above-mentioned questionnaires may be of use when evaluating audio-visual representations and analytics tools, however, they were not developed specifically tailored for visualization or sonification. Consequently, there is a need for instruments that cover the unique aspects of visualization and sonification, together with interaction.

3.1. Questionnaires for visualization and sonification

To this date there are no, at least to the authors' knowledge, standardized questionnaires proposed for specifically evaluating visualization. Also, it has been suggested that standardized measurements for information visualization might be difficult to apply due to the diversity of the field [44]. The benefits of standardized questionnaires are evident, and we believe and suggest that one way of accomplishing this is to develop a number of questionnaires that separately assess aspects such as mapping strategies, perception, experience of data values, experience of insights, where some questionnaires could assess the modalities separately and others the combination.

There are some differences between visualization and sonification [45] that need to be considered when evaluating sonification, and which would motivate having specifically designed questionnaires for sonification, or at least complement questionnaires with sonification specific questions. Visual representations are primarily spatial while auditory representations in sonification are temporal. This suggests that typically visualization consists of static elements, while sonification has more dynamic elements. Visualization has more focused attention, letting a user focus on individual visual objects, while sonification rather has distributed attention providing more overview information. Visualization is good to use for representing structures while sonification might be good for representing processes. A visual representation can be experienced and explored in a non-linear fashion, while auditory representations are rather perceived linearly. These differences suggest that there is a need for specialized approaches for evaluating these modalities with questionnaires.

In sonification, there are a variety of relevant aspects that would be of interest for evaluation, such as data to sound mappings strategies, comprehension, and aesthetic aspects, and questionnaires can be an effective way to address these [46]. However, there are very few sonification only questionnaires proposed. The Auditory Interface User Experience test (the BUZZ) is one example of this [47]. The BUZZ consists of eleven items, divided into sections about perception and content interpretation, feedback on meaning and interpretation, enjoyment, and comprehension of the auditory mappings. This questionnaire was inspired by the evaluation of peripheral displays, particularly on perception and content interpretation [48]. However, few studies have used the BUZZ questionnaire, and the BUZZ has not yet been standardized and validated on a large scale.

It might not be feasible to cover all dimensions of usability of interest in one questionnaire [10], however, we nevertheless argue that there is a need for new standardized questionnaires for audio-visual data analysis, considering both visualization and sonification, as well as interaction and aesthetics. We believe that a combination of questions and statements from some of the abovementioned questionnaires together with new needed ones, could provide a good and relevant basis for evaluating audio-visual representations. Thus, the existing questionnaires need to be carefully investigated in terms of coverage of important aspects and the need for new questions/statements. This work, exploring the most suitable combinations, would not only lead to useful tools for evaluation, but also provide interesting research into visualization, sonification, and interaction while exploring and developing a new questionnaire considering reliability, validity, and sensitivity [34, 49].

3.2. Assessing aesthetics in audio-visual representations

In this position paper, we would like to bring forward that aesthetics is an important, but rather often disregarded, aspect to evaluate in both visualization and sonification. An aesthetically pleasing visualization, or a visually appealing representation is perceived in a better way for a user, it tells a story better, and communicate information better than an poorly designed representation (see for example discussions in [50, 51, 52, 53]). The aesthetics of audio-visual representations, and the perception and appreciation of this, can be considered as part of the aspect

of satisfaction in the ISO9241-11 definition of usability. However, we believe that aesthetics of an audio-visual representation should be assessed in more depth than the current standardized questionnaires allow for.

As the purpose of visualization is to support a user in analyzing and communicating data, the aesthetics [54] and the design of visualization [55] should be assessed when evaluating [56, 57]. Aesthetics might be especially important to assess in sonification [58, 59, 60]. If sonification is perceived as unpleasant, a user will not listen to or use sonification regardless of how well it represents the data [59]. Therefore, a listener's experience of pleasantness and enjoyment, the aesthetics of the sonification, should be considered when designing sonification [60]. It seems plausible to assume a similar aspect of visualization. In sonification, there seems to be two directions for design, either with a more artistic approach or with a data empirical approach [58], and there seems to be a trade-off between these directions where an increase in perceived pleasantness tends to decrease data representation accuracy (see for example discussion in [61]. It could be possible that a similar trade-off between visual pleasantness and precision exists also for visualization.

The Desire for Aesthetics Scale (DFAS) [62] explores how important aesthetics are to a user, which could be relevant to explore for audio-visual representations, and the Centrality of Visual Product Aesthetics (CVPA) [63] is a scale measuring the level of importance that visual aesthetics hold for a particular consumer in the relationship with products. Both these measures could answer if the user experiences a need for an aesthetic design for an audio-visual representation, for a given task in a given situation. Such an insight would guide researchers towards understanding the need for further evaluation including aesthetic measures.

Aesthetic perception and judgement involve feelings, and not only cognitive processes. The Aesthetic Emotions Scale (AESTHEMOS) [64] are a measure of aesthetic emotion in domains such as painting, literature, music, and design, and could provide new insights into audio-visual representations. This measure covers a variety of measurement such as aesthetic emotions (e.g., the feeling of beauty and fascination), epistemic emotions (e.g., interest and insight), and emotions indicative of amusement (humor and joy). The Aesthetic Experience Questionnaire (AEQ) [65], consists of four artistically related dimensions (i.e., perceptual, emotional, cultural, understanding) and two flow dimensions (i.e., proximal conditions, experience). The scale of affect [66] is a subjective rating scale based on the circumplex model of affect [67] and can be used to assess emotional qualities in, for example, sonification [61]. Finally, the BUZZ questionnaire also has some statements considering aesthetic aspects of the auditory display, i.e., ranking of the perceived pleasantness of the sonification.

4. Towards a research agenda

Even if we have presented a variety of measures that are often used to evaluate both visualization and sonification, we nevertheless argue that these measures are not enough. Many of the older questionnaires contains questions or statements that might not be relevant for a modern visualization, sonification, or audio-visual analytics tool, such as "*I think I would need the support of a technical person to be able to use this system*" in the SUS or "*How physically demanding was the task*" in the NASA TLX. Furthermore, there are aspects in visualization and sonification that are not addressed in some of these standardized measures, such as appreciation of the visual or sound design, how well the visualization or sonification represents the data, or understanding of visual or auditory metaphors, to mention a few.

We argue that there is a need for a systematic approach that includes the community for suggesting new measures that assess the usability of audio-visual representations. This systematic approach should review existing questionnaires for finding the most appropriate and important questions and statements, and for this, the involvement of the community is essential. Such a review should be the basis for decisions on what is useful in existing questionnaires, and what is missing and should be included. Based on this, a new questionnaire can be proposed consisting of sections that address visualization, sonification, and interaction, as well as the combined audio-visual representation. This questionnaire must be fully evaluated, validated, and used, for being useful when assessing usability in audio-visual representations.

5. Concluding remarks

In this position paper we bring forward the need for a standardized approach for evaluation in audio-visual analytics and the need for a set of standardized questionnaires that can be used to evaluate the modalities individually as well as in combination. The long-term objective of our proposed work in this area is an established set of standardized questionnaires providing evaluators with recognized and valuable tools for conducting evaluation in their research work. It would also support reviewers and other researchers, and help them feel confident when judging outcomes of work presenting evaluation studies.

With this position paper we aim to encourage and inspire the audio-visual analytics community to engage in this proposed work and to take part in the research and development process needed to create these standardized questionnaires. To present and discuss the need of this work and the efforts and process it will require at the WAVA22 (AVI 2022 Workshop on Audio-Visual Analytics) would be an excellent starting point.

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