# "It's Just a Graph" – The Effect of Post-Hoc Rationalisation on InfoVis Evaluation

Rosa van Koningsbruggen
Bauhaus-Universität Weimar
Germany
rosa.donna.van.koningsbruggen@uni-weimar.de

Eva Hornecker
Bauhaus-Universität Weimar
Germany
eva.hornecker@uni-weimar.de

## ABSTRACT

A growing body of work in InfoVis explores its user experience (UX), however, emotions remain underexplored. Our study reveals barriers for investigating personal connection and emotional reaction to visualisations. This provides an explanation for why the role of emotions so far received little attention in InfoVis. Twenty-four participants viewed two traditional data visualisations, answered UX questionnaires for each, and were interviewed about their experience. Our findings show that traditional visualisations are seen as 'just a graph', that represents neutral information. Participants referred to aesthetics, legibility, and usability, instead of the actual topic. Moreover, to make sense of the data, emotions have to be separated from it. We found four possible explanations underlying this belief and argue that a form of post-hoc rationalisation takes place, which obscures people's initial connections and affective responses to visualisations. Based on these findings, we discuss implications for future research on the UX of visualisations.

## CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in visualization**.

## KEYWORDS

User Experience, Role of Emotions, Post-Hoc Rationalisation, InfoVis

**ACM Reference Format:**
Rosa van Koningsbruggen and Eva Hornecker. 2021. "It's Just a Graph" – The Effect of Post-Hoc Rationalisation on InfoVis Evaluation. In *Creativity and Cognition (C&C '21), June 22–23, 2021, Virtual Event, Italy*. ACM, New York, NY, USA, 10 pages. https://doi.org/10.1145/3450741.3465257

## 1 INTRODUCTION

Concerned with visually representing abstract data [16], Information Visualisation (InfoVis) plays an increasingly important role in the everyday lives of non-experts, with visualisations that focus on storytelling [56], personal reminiscing [61], edutainment [28], and much more; resulting in a wide range of visualisations, from more complex interactive visualisations, to artistic ones, to classic data visualisations, such as bar graphs. While InfoVis research traditionally focused on assessing usability and effectivity [54, 66], a growing body of work explores User eXperience (UX) [53]. Through a method of deep interviewing (micro-phenomenological/elicitation interviews), Hogan et al. [29] investigated the experience of interpreting classic data visualisations (graphs). Here they found that people reported connecting to them on a personal and emotional level, and empathised with the data. From other fields, such as Human-Computer Interaction (HCI) and cognitive science, we know the importance of emotions. In particular, the ability to evoke emotional responses and engagement is seen as a strength of data physicalisation [66]. However, emotional experience and affect have not received much attention yet within InfoVis [34, 66]. Only very recently does InfoVis consider emotional engagement as contributing to the value of data representations, e.g. [6, 14, 34, 46].

We conducted interviews with twenty-four participants about their experience of two data visualisations. Our study reveals that people tend to be biased towards seeing visualisations as neutral and requiring an emotionless reaction, and thus rationalise their experience. We found that these data visualisations are seen as 'just a graph', which portrays objective information. Moreover, participants reported separating their emotions from the data, as emotions should not play a role in understanding objective information. When encountering data visualisation in a user study, people disassociate the content from the representation and focus on its legibility or aesthetics. This makes it hard to gain access to people's emotional responses to visualisations.

These findings are in stark contrast to Hogan et al.'s observations [29] and indicate that post-hoc rationalisation takes place, a process where initial emotional responses to traditional data visualisations are rationalised and obscured. We found four possible explanations for this post-hoc rationalisation, which hint that participants could (1) consciously remove their subjective experience to be as analytical as possible, (2) subconsciously forget and supress any emotional connection, as such rationalising their process, or (3) believe emotional response do not interest the researchers. We therefore argue that dedicated methods, such as the micro-phenomenological interview technique, are required to uncover responses which normally tend to be rationalised post-hoc, are not noticed, or which might be suppressed from memory. We further argue that non-traditional data representations, such as data physicalisations or artistic InfoVis approaches allow people to notice their affective responses, as we have not yet formed stereotypes about them and are not used to analyse these types of data representations. Our work thus helps to explain why emotions are underexplored in InfoVis and why other studies have not been able to find similar insights as studies using the micro-phenomenological interview.


*C&C '21, June 22–23, 2021, Virtual Event, Italy*

ACM ISBN 978-1-4503-8376-9/21/06…$15.00
https://doi.org/10.1145/3450741.3465257

# 2 THEORETICAL BACKGROUND

## 2.1 User Experience, Emotions, and InfoVis

In the past, a design was regarded successful when it met all usability goals [48, 49]–such as being effective, efficient, and easy to learn [13, 27]– and emotions were seen as hindering rational reasoning and decision making [4, 38, 52]. Nowadays, the narrow focus on usability is not enough: design should account for user experience (UX) as well [36, 53]. Past research shows that it is difficult to formulate an exact definition of UX, e.g. [3, 24, 55], and that different approaches exist [21, 55]. However, a recurring theme is that UX expands the focus from solely exploring practical goals (also known as pragmatic qualities, do-goals), to exploring non-utilitarian aspects of design –such as beauty, affect, engagement, and enjoyment– as well (hedonic qualities, be-goals) [23]. This multidimensional perspective [41, 63] aims to ensure that a design is meaningful, valuable, and fulfils human needs [3, 25, 40]. Regarding emotions, we have learned that they play a crucial rule in human decision making processes [10, 39]. Furthermore, emotions influence our attention, as such affecting memorability and learning [64], and determine our behaviour, often being more powerful in doing so than our brain's logical and rational processes [60].

A similar evolution can be seen in InfoVis, which historically focussed on evaluating usability, often via quantitative methods [54]. The main emphasis of what makes a successful visualisation was placed on performance: creating visualisations with the primary goal to effectively communicate the represented data [53]. However, there is increasing awareness that usability is not enough. As described by Faisal et al. [17], InfoVis is a subjective experience, which requires methods that allow us to explore and evaluate UX. This can be seen in the BELIV workshop, which explores new evaluation methods for InfoVis. Aspects such as enjoyment and engagement are increasingly considered important to evaluate [22, 32, 53, 54]. Moreover, there is work on the creation of UX guidelines for visualisations, for example healthcare visualisations [57]. Another trend is usage of qualitative methods on data visualisations [17, 54], for instance: reaction cards [45], the microphenomelogical interview [8, 29, 50], expert reviews [62], observation techniques [16], and focus groups [44]. Another area explores what insights and knowledge people obtain from visualisations, and how to evaluate these. For example, Stasko [59] proposes value-based evaluation, which besides usability, takes the generation of insights, conveying the essence of data, and creation of confidence into account. Wang et al. [66] recently proposed enhancing this model with other factors, such as social and affective engagement. Furthermore, previous research found that people's reaction to visualisations depends on their perspectives and experience, making data a personal matter [33, 51]. Lastly, there has been research exploring how insights relate to the user's mental model [5, 16], and research that shows people not only critically assess the visual qualities and content of InfoVis, but the context as well [31].

For long, emotional experience and affect have not received much attention in InfoVis. InfoVis research that does explore this, has been very recent, e.g. [6, 14, 29, 34, 46], or stems from related fields, such as data physicalisation [66]. As stated by D'Ignazio and Klein [12], emotion and affect are purposefully excluded from data visualisations. However, this does not make emotions useless to data representations [12, 29, 34, 66] and does not mean that they are not present in the design or perception of data visualisations. The work of Hogan et al. [29], and Kennedy and Hill [34] shows that emotions play a role in the assessment of both traditional and more artistic Infovis. Moreover, emotions are one of the key strengths of data physicalisation, data storytelling [66], and data visceralisation [37]. Since these related fields do utilise and research the role of emotions and studies found that they play a role in InfoVis [29, 34], it is an open question why InfoVis has paid little attention to them.

## 2.2 Standard UX Evaluation Methods: the AttrakDiff, UEQ, and PANAS

The most common methods for investigating UX are standardised questionnaires [42]. One of the initial goals for our study was to identify which questionnaires might be best suited for assessing visualisations. Only few studies so far have used standardised questionnaires to evaluate the UX of InfoVis, e.g. in [19, 47], and it is yet unknown what insights we gain with these questionnaires. Such questionnaires are cheap to deliver, easy to use, and reliable [11, 20]. For our study, we selected three commonly used questionnaires, namely the AttrakDiff [26], UEQ [35], and PANAS [67]. The AttrakDiff and UEQ explore the attractiveness, hedonic, and pragmatic qualities of a product through semantic differentials. On a 7-point scale, users select which word of the opposing word pair best describes the product. As emotions play a role in the assessment of data [34, 66], we chose the PANAS questionnaire to assess the emotional aspects. It consists of two 10-item scales: one for positive valence and one for negative. Each item has to be rated on a 5 point Likert-scale.

# 3 STUDY DESIGN

Our study consisted of two parts: the first part was an online survey, where participants had to engage with two standard data visualisations, filling out the AttrakDiff, UEQ, and PANAS after each. Having completed the survey, participants took part in a semi-structured interview about their experience with the visualisations and questionnaires. Since the study was online, it could be filled out when and wherever it suited them.

The initial aim of our study was to explore what insights regarding UX are gained with standardised questionnaires. We hoped that standardised questionnaires would offer a cheap, quick, and reliable way to gain insights, unlike the amount of training and effort that micro-phenomenological interviews require. However, during analysis, it became clear that the interview data offers more insights, which is why we focus on the qualitative data in our Results section.

For our study, possible participants received a link to the online survey created with SoSci [58]. Participants were recruited via convenience sampling and snowballing, with emphasis on recruiting people with different occupancies, from outside the HCI and research community. In order to take part, participants had to be aged eighteen years or older, be able to read English, have access to the Internet, and should not have a visual impairment. In total, twenty-four participants were recruited, with an average age of 35.21 years (SD = 15.05). Ten participants identified as female and fourteen as male, all had a European nationality, of which twenty-one Dutch.

By opening the aforementioned link, participants were directed to the survey, which started at the consent form, that participants had to agree to. Once opted in, participants got to see the first visualisation. The visualisations were accompanied with the following instruction: *"Please take your time studying the information until you feel confident you understand the visualisation. Once you feel you are done studying the visualisation, you can move on to fill out the questionnaires"*. Then, participants could move on to the questionnaires. In total, two data visualisations (see Figure 1) had to be reviewed and three questionnaires filled out for each.

The data visualisations were chosen as they are similar to those used by Hogan et all. [29], and we believed that they present information which people can relate to and would probably find interesting, but which is not too sensitive or controversial. Furthermore, they have similar information density -meaning it takes roughly the same amount of time to comprehend-, use commonly used formats, and were retrieved from reputable organisations [9, 15]. The order of visualisations and questionnaires was counterbalanced: reverse counterbalancing [1] of the UEQ and AttrakDiff, as well as complete counterbalancing [2] of these two questionnaires and visualisations. This resulted in eight possible versions of the online survey. Participants were assigned to one of the versions at the start, with each version being assigned to three participants.

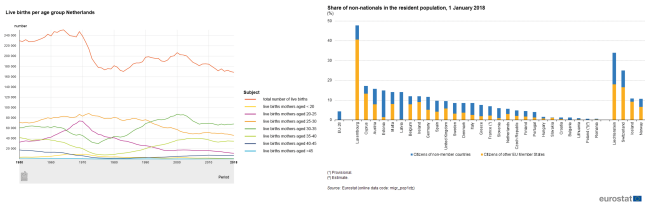


**Figure 1: The data representations used for this study. Left, the number of live-births per age group in the Netherlands, retrieved from [9]. Right, the share of non-nationals in the resident population, retrieved from [15].**

Once both visualisations were analysed and all questionnaires had been filled out, participants reached the contact page. Here they could enter their preferred medium for the follow-up interview (phone call, Skype, Teams, video call via WhatsApp, and Zoom) and schedule a timeslot. The longest time between filling out the survey and the interview was nine days, and the shortest directly after filling out the survey. To help participants refresh their memory, they were sent a booklet with the graphs and questionnaires. The booklet was only given at the start of the interview, to prevent participants from overanalysing the material. During the interview, participants were asked: (1) whether and how they related to the data visualisations, (2) how they approached the visualisations, (3) if and how the visualisations influenced how they answered the questionnaires, (4) how they experienced the questionnaires, (5) what they believed the aim of the questionnaires was, (6) what the questionnaires helped them to realise or look for, (7) which questionnaire they believed was the most applicable, and (8) if there were items or elements which did not make sense. With the participant's consent, the interview was audio recorded, so it could be transcribed and analysed using thematic analysis [7].

The thematic analysis was conducted by two researchers, following an inductive approach. Both researchers individually familiarised themselves with the transcripts and each researcher independently selected initial codes and themes, based on a primary open coding approach. These were then brought together and iterated upon by the two researchers, a process which resulted in a revised set of 104 codes and ten themes. A coding sample can be found with the supplemental materials. During this iteration, the themes received an initial naming. After a period of reflection, the researchers returned to the analysis and performed the final iteration, in which they distinguished between the major and minor themes, finalised the naming, and created a thematic map (see Figure 3), to capture how the six themes and four subthemes interdepend.

Prior to the real study, a pilot test with four people was conducted, to check our protocol and find out whether the PANAS questionnaire should be first or last. This was done as the PANAS focusses on valence, instead of the attractiveness, and hedonic and pragmatic qualities, as done by the AttrakDiff and UEQ. Having the PANAS as the first questionnaire would ensure minimal time between experiencing and recalling the felt emotions. However, the PANAS was also the most abstract and hence the most difficult to respond to. Therefore, the PANAS was put last in the series of questionnaires given out.

## 4 RESULTS

The focus of this paper lies on the insights from interviews on how the visualisations were perceived, analysed, and possibly rationalised. Prior to each quote, the participant number is indicated with *P*. Six interviews were conducted in Dutch, the native language of most participants. Selected quotes have been translated as literal as possible and are indicated with a *'-D'* after the participant number. The other interviews were conducted in English.

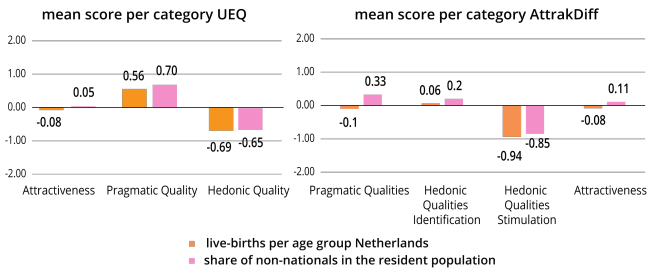


**Figure 2: Mean score per category in UEQ (left) and AttrakDiff (right). The bars on the left (coloured orange) show mean scores for live-births in the Netherlands and the bars on the right (coloured pink) the scores for the graph on the share of non-nationals in the resident population.**

### 4.1 The Questionnaires

Four participants preferred the AttrakDiff, four the UEQ, for two participants either the UEQ or AttrakDiff would work well, and two preferred the PANAS. The others did not have a preference. The UEQ and AttrakDiff were preferred for their terms, which fitted

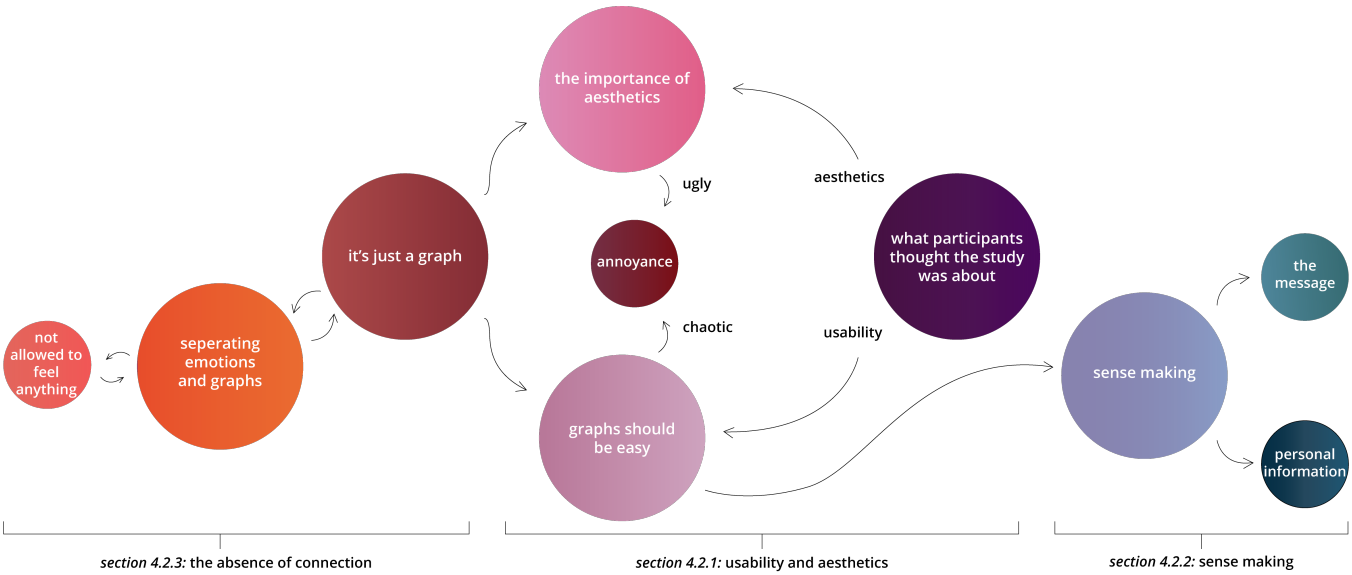


**Figure 3: Overview of how the themes (the six bigger circles) and subthemes (the four smaller circles) from the thematic analysis interdepend. Double arrows mean that the themes interplay, a single arrow indicates a one-sided relation. Beneath, the corresponding text section of the themes is indicated.**

the graphs. Contrary, the PANAS questionnaire was experienced as 'too emotional' (P8): *P24: "The PANAS questionnaire in its entirety didn't make a lot of sense to me. [...] Because I associate graphs to be very technical and functional"*. This is also reflected in the scores: almost all terms score around 1 and 2, on a five-point Likert scale. The maximum average score is 3.1, for the term *'interesting'*. Other terms which scored above 2 are *'alert'*, *'attentive'*, and *'active'*.

While the difference between the PANAS and other questionnaires was clear, fifteen participants did not notice a difference between the AttrakDiff and UEQ. It thus seems that both questionnaires were suitable. However, the UEQ had more applicable terms: *P13: "I felt like the statements in the UEQ questionnaire also fit more with the graphs than the AttrakDiff"* and participants mentioned its focus on usability: *P24: "the UEQ. Definitely, because it is about usability, which I associate with graphs"*, stating that this makes it a better fit.

Results for AttrakDiff and UEQ show that the visualisation of the share of non-nationals in the resident population scores slightly higher in all categories (see Figure 2). Both visualisations scored low on hedonic qualities and were not seen as attractive. In the AttrakDiff, the graphs were scored as *'technical'*, *'isolating'*, *'conventional'*, *'unpredictable'*, *'separates me from people'*, *'unimaginative'*, *'cautious'*, *'conservative'*, *'dull'*, *'demanding'*, and *'ordinary'*. UEQ terms with a negative score were *'annoying'*, *'dull'*, *'boring'*, *'conventional'*, *'usual'*, *'unpleasant*, *'demotivating'*, and *'conservative'*. Overall, the questionnaire scores align with the descriptions participants gave during interviews, as can be seen in Figure 4. Plots of all the questionnaire results can be found with the supplemental materials.

## 4.2 Thematic Analysis of the Interview Data

The thematic analysis of our interviews resulted in six themes. These themes and how they correlate, can be seen in Figure 3. From our analysis, we found that participants thought the study would be about usability and aesthetics, and that the visualisations were seen as abstract and objective. Participants rarely referred to the actual topic of the visualisations. Instead, they focussed on the design, legibility, and usability. If these elements were regarded chaotic or ugly, it resulted in annoyance towards the visualisation. Besides being abstract and objective, the visualisations were seen as 'just a graph' that should fulfil its purpose of explaining data. Participants expressed feeling as if they are not allowed to feel anything and stated that in order to make sense of the data, emotions have to be separated from it. This absence of emotional connection was reflected in participants not relating to the PANAS questionnaire, which was considered 'too extreme'. Methods that were used to make sense of the visualisations, were looking for the message they portrayed or for personal information. The latter was rarely found, which could explain why the visualisations were seen as 'just a graph'. In this section, we will discuss these themes in depth. For clarity, we have grouped the themes in three clusters: (1) usability and aesthetics, (2) sense making, and (3) the absence of connection.

### 4.2.1 *Usability and Aesthetics.*

Participants focussed on easiness and aesthetics of the visualisations, arguing that these are most important: *P4: "For me it is most important that the graphs are logical and easy to interpret, professional and a little bit stylish"*, as they determine what you think of a visualisation: *P15: "I think I reacted more emotionally to the choice of colours [...] and the fact that it is difficult to read, then the fact that it is a chart"*. Beneath, we highlight three themes for this topic:

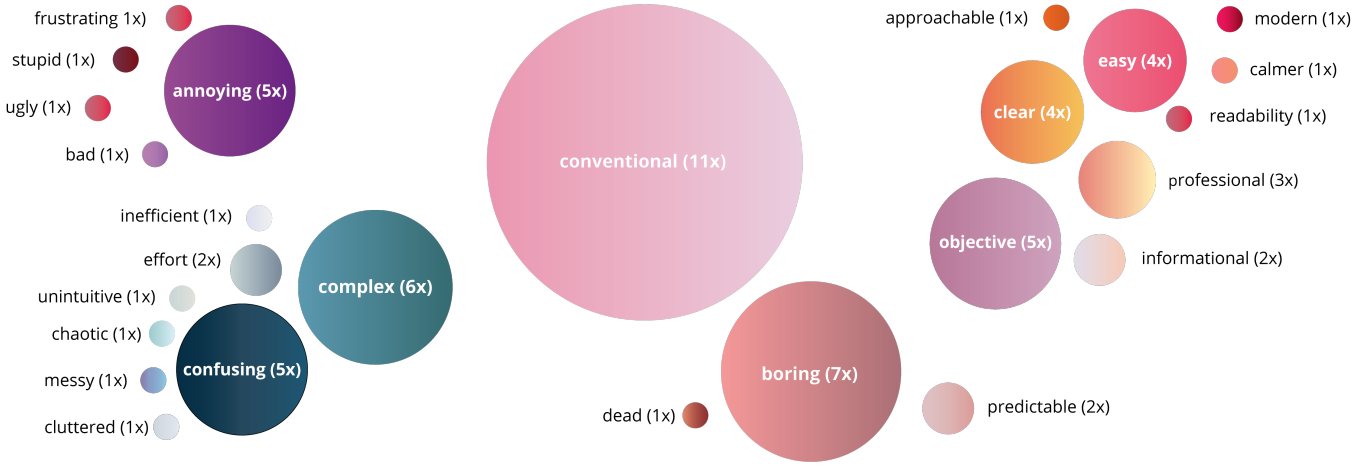


**Figure 4: Overview of the terms used to describe the data visualisations. On the left are the negative terms and on the right the positive terms. Conventional has been placed in the middle. The dimensions of the circles represent how often a term was mentioned, the exact number of times is stated next to the term. The distance between the circles indicates similarity between terms: a small distance indicates high similarity.**

**1. What participants thought the study was about.** Despite using questionnaires which assess hedonic and emotional aspects, and asking participants to analyse the visualisations until they understood the information, seven participants thought the study was about 'how graphs look', while three extended this to usability and aesthetics (and used these terms), as illustrated by these quotes: *Interviewer: "What did you think are the differences between the questionnaires?" P5: "[…] what's the best way to show data in a graph."* and *Interviewer: "What did you think was the aim of each questionnaire?" P21: "[…] Which aspects were good about a graph and which aspects were maybe, could be improved"*. This resulted in decreased interest in the message of the visualisations: *P1-D: "Yeah, that graph, I don't really care what it is saying"*. Another confessed to having focused on the content of graphs, since they thought the study was about visualisation as such, and explained they were used to doing so, because of exams: *P12-D: "I really thought: "ah, the questions will be about the details", but it of course wasn't an exam."* This reason was stated by one other: *P1-D: "It reminded me a bit of the CITO-exam"* (the final examination in the Netherlands). However, most participants commented extensively on the graphic design of the graphs, use of colour, and whether they preferred a certain style.

Interestingly, the UX questionnaires reinforced the above mentioned focus on aesthetics: *P22: "But then the questionnaires made me really think about not the information that they tried to convey, but more about how the information was portrayed."*

**2. The importance of aesthetics.** Besides believing the study was largely about aesthetics, aesthetics also played an important role in how the visualisations were perceived. Participants described the graphs as *'conventional'* (P4, P7, P17), *'boring'* (P10, P23), and *'not creative'* (P23). An overview of all the terms used to describe the visualisations and how often they were used, can be seen in Figure 4. Although some had a preference for one of the visualisations, they were both described using the same or similar terms. Therefore, Figure 4 focuses on the terms used for both visualisations. Despite this, it was a debated topic: some participants mentioned that aesthetics influence how likely they are to look at a visualisation: *P4: "If it is not attractive, I am not going to look into it"*, and influence whether you relate: *Interviewer: "You got to see two visualisations and did you relate to them?" P15: "How do you relate to a chart? I think it is a question of taste, if I prefer […] column charts, or line charts"*. Moreover, it was questioned whether traditional information representations (such as bar charts) are the best way to present your data: *Interviewer: "What did the questionnaire make you realise or look for?" P17: "[…] If you have something new to present, is then the conventional method the best way?"*

On the other hand, some participants wondered if it is possible at all for a graph to be beautiful: *P3: "How can a graph be stylish?"* and *P24: "I don't think they ever are very beautiful."*, or even stated that aesthetics do not matter: *P17: "I am not that much interested in 'does it look attractive?', I just want to understand it"*.

**3. Graphs should be easy.** This brings us to the third cluster: what did matter to most participants was whether they understood the message of a visualisation: *P24: "I associate usability with graphs"*. In order to facilitate this, eight participants mentioned that visualisations should be easy: *P3: "Easy to learn, if you have to take 5 minutes to even understand what the graph is showing, that it is a waste of time"*. If a visualisation was easy to analyse, it received a positive rating: *P9-D: "I found the second one a lot easier, so I have rated the second one a lot more positive"*. Whereas a negative rating was given, if it was hard(er) to analyse: *P23: "both were horrible. Both of them for me were like a 1 out of 10 in intuitiveness and creativeness and […] a 1 out of 10 on easy to interpret"*.

Interestingly, when the easiness or aesthetics did not align with the participants' standards or mental model, it resulted in frustration and annoyance: *P20: "And then I found it that I didn't understand it the way I thought I would, and I got frustrated and kind of angry at the graph"*. One participant stated that this has a negative effect on

how you perceive the visualisation and the insights you take away from it : *P3: "If it is an annoying graph, which they were, then you are getting frustrated. And there is the change that you are making errors, because it is so frustrating and not easy to read."*

#### 4.2.2 Sense Making.

We also looked at how participants described their sense making process of understanding the graphs. This uncovered various strategies with two main approaches. Seventeen participants mentioned following the classic approach of looking at the title, axis, and legend. Two people asked themselves questions about the data, five mentioned *'concentrated looking'*, and two looked for things that stood out (such as crossover points). A few participants tried to find their own viewpoint in the visualisation, checked numbers, interpreted percentages, tracked the lines, or tried to find more information. All this was done in order to *P13: "Get a grasp"* and *P22: "[Understand] what it is telling"*. Most participants expressed they thought the visualisations had a message, and expressed wondering what 'it' (the graph) was telling them: *P20: "What is it telling me?"* and *P4: "Can I relate the information to the message it gives?"*

On the other hand, eight participants mentioned looking for or needing something personal, in order to make sense of or relate to the visualised data. Two participants looked for information that related to them and three realised that you could relate to graphs through filling out the questionnaires, but only three participants found a personal relation: *P19: "when I look at my family or friends [...] I can understand where it is coming from"*.

Despite our expectation that people could relate, especially to data on birth rates, the majority reported not finding a personal connection, so that the visualisations and portrayed information remained distant: *P13: "they do show demographics of people, but that didn't really relate to me in a sense that I actually envisioned people or a group of people or people I know."* and *P3: "They were just graphs and they were not anything related to me personally, so it was quite objective."*

#### 4.2.3 The Absence of Connection.

As mentioned above, some participants thought it would require something personal in order to relate to the data. Without it, visualisations remain 'just a graph' that portrays objective information. Our opening question for the interviews was *'did you relate to the graph?'*. This was asked as the graph gives access to the data. Strikingly, ten participants overheard and did not respond to this at all, instead six discussed whether they liked or disliked the aesthetics, and four started to discuss usability aspects. Furthermore, four participants explicitly said that they could not find a personal relation *P3: "I have no emotional bonding to the data"*. While in Hogan et al.'s study [29], which uses similar simple data visualisations, almost all participants created personal connections in order to analyse and contextualise graphs (e.g. placing personal or family events on the timeline, thinking of a relative as an example for a data case), only three of our participants mentioned being able to relate to the data and two of these said they looked for their own home country in the graph about the share of non-nationals.

Overall, eighteen participants did not connect to the information represented by the visualisations and explained separating their emotions from the objective data. Although participants mentioned not feeling anything themselves and deemed having to think about it unusual, they did wonder how it would be for others: *P7: "I guess ashamed makes sense if you don't get it and you feel ashamed of your inability to understand."* and *P4: "It might make you think more about: 'Oh, what would others, that have maybe a worse education, how do they feel about these graphs?'"*. Yet this concern for what others might feel, again only relates to usability aspects and the visualisation's purpose of explaining data. We discuss two themes which elaborate on these notions:

**1. It's just a graph.** When asked what the visualisations made participants realise, what items of the questionnaires did not make sense, how participants experienced the questionnaires, and whether they related to a visualisation, several participants stated that the visualisations were just a graph: *P3 & P13: "It is just a graph"*, *P23: "just dead graphs, just lines on a paper"*, and *P3: "Just data in a line"*. These graphs were seen as functional: *P24: "I associate graphs to be very technical and functional"*, and not meant to be interesting: *P7: "A very, very conventional visualisation that is just not meant to be interesting [...] just meant to get a point across"*. They are simply there: *P2: "A graph is not ashamed or shamed or whatever for me. It is just, it's just there"*. Besides, the visualisations were labelled as factual: *P7: "This is very factual"* and clear: *P8: "They are just clear pictures"*, providing you an objective overview: *P20: "An objective kind of overview of information"*. Graphs are associated as technical and functional (P24), objective (P20), and purposeful (P17). According to participants, this facilitates clinical analysis: *P17: "You can make a rather clinical analysis"*.

Since the visualisations were seen as 'just a graph' and as factual, all they should do is fulfil their purpose: *P15: "They should do what they are meant to do: explain data in a way that makes it more understandable"*. Note how this connects to the focus on usability or legibility that many participants emphasised. Even the user is not important, as stated by two: *P17: "You never think about the user experience. This is how the graphs are build."* and *P23: "Why does it matter if I can relate or cannot relate to the graph?"*.

**2. Separating emotions and graphs.** The fact that the visualisations were seen as 'just a graph' could play a role in why eighteen participants mentioned not connecting to the visualisations and represented data. Participants stated that they did not relate or feel, and could not imagine doing so, as stated by *P15: "How do you relate to a chart?"*, *P3: "Emotions and graphs is not something I relate"*, and *P24: "I don't think graphs are very human, ever"*. Related statements occurred during various parts of the interview, after different questions. For example, when asked what elements of the questionnaires did not make sense, P10 responded on the PANAS questionnaire: *P10: "I didn't really feel so much, to be honest"*. This was shared by nine others, who stated that the PANAS asked for feelings that do not suit the visualisations: *P6-D: "Of multiple terms, I just could not imagine anyone having that feeling with these visualisations"* and *P23: "A feeling that I [...] never thought I could feel with a graph"*.

Here participants regarded the information of the graph as separate from the graph itself. A reason for the emotional disconnect was given by seven participants, who indicated that in order to make sense of visualisations, feelings and the portrayed information are separated from the visualisation: *P3: Emotions and graphs is not something I relate. [...] I feel like the emotions come maybe from the actual data instead of the graph?"* and *P16: "The graph itself doesn't annoy me, the topic kind of annoy (sic) me"*. Participant

20 phrased this separation the clearest: *P20: "I separate or try to separate how I feel and, and the objective information on the graphs".*

Going even further, participants implied that you are not allowed to feel or connect emotionally, when analysing data visualisations: *P5: "Kinda weird if you feel that if you are looking at a graph".* Stating that it is not something you normally do: *P7: "Maybe a bit difficult questions, to say how you feel about a graph. It is not something you usually are expected to say."* and remained something you do not do: *P12-D: "with the second one, I didn't necessarily think about my feelings. Even though I knew those questions would come".* Even if people experienced an affective reaction to the data conveyed, they did not think this was relevant to our study or to visualisations. Thus, possibly, studies exploring people's reactions to visualisations do encounter the implicit expectation of participants that researchers are interested in the visualisation itself (e.g. its aesthetics and usability), not their response to the data. For three participants, the questionnaires in retrospect made them realise that there are ways to connect to visualisations: *P11-D: "I answered this, but actually, when I think about it, there is indeed something happening with my feelings when looking at those infographics."* and *P20: "I stopped focussing on the objective base and I really just listened to how it made me feel".*

## 5 DISCUSSION

The findings of this study might indicate why InfoVis research so far has not shed light on the role of emotional connection and affect for engaging with data visualisations. In this section, we discuss our findings, hypothesise why only studies using the micro-phenomenological interview have found emotional connections to traditional data visualisations, provide suggestions for future work, and discuss the limitations.

### 5.1 Emotions and Data Representations

Our main finding is the emotional disconnect which participants appeared to experience when analysing the visualisations. Participants kept focussing on the usability and aesthetics, which was reflected in the preferred questionnaire: the UEQ. Besides, the visualisations were described as 'just a graph', which represents objective information. In order to analyse them, one needs to separate emotions from the objective data. These statements align with the origins of visualisation, which can be traced back to the Enlightenment [18, 43]. According to the logic of the Enlightenment, emotion obstructs judgement [34]. From our results, it seems that we try to analyse data visualisations as objectively and clinically as possible, and believe we need to discount our possible connection and feelings. Moreover, two participants mentioned that having to answer questions about visualisations reminded them of exams, where you have to analyse the information carefully in order to answer the question correctly. This could be another reason for why participants focussed on being analytical. Nonetheless, these findings are contradictory to previous work with the micro-phenomenological interview technique. Studies using this technique show that people do connect to data represented by visualisations on an emotional and personal level, relating them to their own lives and experiences [29, 50]. This contrast in findings reveals that questionnaire study approaches are not sufficient to get beyond the participants bias, e.g. feeling they should not feel emotional about graphs, and the post-hoc rationalisation of their experience, as we will further explain in the final paragraph of this section.

Next, both in our study and the work of Hogan et al. [29], participants had a dialogue with the visualisations. As described by Hogan et al. [29], participants discussed what 'it' (the visualisation) and 'they' (the makers of the visualisations) wanted to tell them. However, in our study, the dialogue was limited to 'it', with participants wondering what the visualisation was telling them, not what the makers might want to tell. Moreover, Nowak et al. [50] describe that participants connected to the *"humans-behind-the-dots"*. This was absent in our study, where participants did not wonder what the consequences of the data would be to the humans behind it.

The differences in findings highlighted above, could be explained through post-hoc rationalisation: a common side-effect of introspective interview techniques. The micro-phenomenological interview was designed to minimise such biases, by guiding participants to recall their lived-experience [65]. This would explain why we only found hints of certain results, instead of the richer experiences described by Hogan et al. [29] and Nowak et al. [50]. We found four possible explanations for why post-hoc rationalisation would take place: (a) participants expressed separating their emotions from the objective data, (b) stated that it is weird to feel something when analysing data, (c) described feeling not being allowed to emotionally connect to visualisations, and (d) thought that our study only concerned their reaction to the visualisations (regardless of the content) and that their reaction to the portrayed data was irrelevant. These reasons hint that (1) participants consciously remove what they believe is subjective, in order to be able to analyse the data, or (2) that they subconsciously forget and suppress memory of emotional engagement and personal relation, in effect rationalising their analysis process, or (3) think it does not interest the researchers. This would explain why emotions have not yet received a lot of attention in InfoVis, as they are obscured through post-hoc rationalisation.

The work of Hogan et al. [29] reveals how much is going on in terms of emotional connection to (simple) data visualisations. As indicated by our own study, such connections tend to be obscured by post-hoc rationalisation or participants believing a study concerns mostly Usability and Aesthetics. This makes it difficult for researchers to gain full insight into what is going on when reviewing, looking at, or analysing visualisations. It is therefore important to explore methods and approaches that shed insights into how emotions might play a role -even if people ignore these. Of course, for some areas it is beneficial to use visualisations that do not evoke emotional connection, e.g., safety-critical work. However, in others this might be desirable, for example when trying to communicate the impact of certain phenomena. In *both* cases, we need to know more about the role of emotion.

### 5.2 Future Directions

Our findings indicate that UX questionnaires are mostly suited to assess usability and aesthetics of traditional visualisations, but do not go deeper. This highlights the need for dedicated methods able to remove the bias of post-hoc rationalisation. Our work reveals both the strength of the micro-phenomenological interview (which

uncovered what our more traditional user study approach could not) and the limitations of the used visualisations. Based on these findings, we have summarised directions which we believe are important to further research.

Firstly, we think it is fruitful to deepen our understanding of using the micro-phenomenological interview technique in InfoVis. Future work should include studies which compare the micro-phenomenological interview to other UX-methods, and that have participants do both UX questionnaires or interviews and a micro-phenomenological interview for a direct comparison. Furthermore, it would be interesting to see how the micro-phenomenological interview can be used for different kinds of data representations, such as physicalisations, sculptures, or artistic visualisations, and the insights it brings to light. Lastly, since the micro-phenomenological interview is not easy to use, we should explore whether there are other techniques which provide us with similar deep insights.

Further, we believe the emotional disconnect from the data visualisations could be a disadvantage. As stated by Norman: *"only through our emotions do we unravel problems, as the human emotional system is intertwined with our cognitive abilities"* [49]. If people feel positive towards an object, they are inclined to explore it creatively, in order to solve problems it might present [8]. Since the only reported emotions that participants felt towards the visualisations were frustration and annoyance, it seems this prohibits us from exploring and analysing the information fully. This was also stated by participants, who mentioned losing interest when they disliked the aesthetics or if it took more than five minutes to understand the visualisation. These findings might indicate an advantage for artistic visualisations and data physicalisations, of which people have not yet formed a stereotypical image, possibly allowing them to bond and empathise with the data. The work of Kennedy and Hill [34] already shows that emotions play a crucial role in more artistic visualisations. Therefore, we believe it is important to keep exploring these directions and evaluate whether these representations allow us to connect with the data, as done by Hogan and Hornecker [30], and Kennedy and Hill [34]. Moreover, we think it would be valuable to conduct such a study, where the micro phenomenological interview is used to assess artistic data visualisations, in order to explore whether people bond deeper to this type of representation.

### 5.3 Limitations

This study has several limitations, of which the first is the online setup. The benefits of this were that participants could do the study whenever it suited them and participants with different geographic locations could be asked to participate. However, a disadvantage of this was that the interview did not always directly follow after filling out the questionnaires. In order to help participants recall the visualisations and questionnaires, they were given a refresher at the start of the interview. However, the passing of time –which ranged from directly after filling out the questionnaire to nine days later– could have influenced results. Secondly, some participants filled out the questionnaires on their mobile phone. Two participants mentioned that they had to scroll more, which created a feeling of annoyance, completely separated from the aesthetics of the visualisation or the topic. Something which could have influenced the participants' questionnaire answers and preferences. Lastly, despite our effort to get a varied sample, most participants have finished a higher education, and all but one felt comfortable reading and analysing data visualisations. Both elements which could have influenced our results.

## 6 CONCLUSION

The presented work describes an argument for why emotions have received little attention in InfoVis research. In this study, twenty-four participants had to review two traditional data visualisations and fill out the AttrakDiff, UEQ, and PANAS questionnaire for each. Our study shows that participants saw the visualisations as 'just a graph' and separated their emotions from the data, when analysing it. Our contribution focusses on the argument that post-hoc rationalisation takes place during the evaluation of data visualisations, for which we have found four reasons: (a) participants tried to separate their emotions from the objective data, (b) stated that it is weird to feel something when analysing data, (c) described feeling as if they are not allowed to emotionally connect to visualisations, and (d) thought that our study only concerned their reaction to the visualisations (regardless of the content) and that their reaction to the portrayed data was irrelevant. Based on these findings, we recommend future research to further explore the effect of the micro-phenomenological interview, what other methods can be used to circumvent post-hoc rationalisation, and data representations which allow people to emotionally connect to the portrayed information.

## ACKNOWLEDGMENTS

We want to thank our participants for their time and effort. This work was conducted on a grant from the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) –420584617 / HO3901/4-1.

## REFERENCES

[1] American Psychological Association. [n.d.]. personality – APA Dictionary of Psychology. https://dictionary.apa.org/reverse-counterbalancing
[2] American Psychological Association. 2018. epiphenomenon – APA Dictionary of Psychology. https://dictionary.apa.org/complete-counterbalancing
[3] Javier Bargas-Avila and Kasper Hornbæk. 2012. Foci and blind spots in user experience research. *Interactions* 19, 6 (11 2012), 24–27. https://doi.org/10.1145/2377783.2377790
[4] Allison Barnes and Paul Thagard. 2003. Emotional decisions. , 7 pages. http://cogprints.org/619/1/Emot_Decis.html
[5] Michelle A. Borkin, Azalea A. Vo, Zoya Bylinskii, Phillip Isola, Shashank Sunkavalli, Aude Oliva, and Hanspeter Pfister. 2013. What Makes a Visualization Memorable? *IEEE Transactions on Visualization and Computer Graphics* 19, 12 (12 2013), 2306–2315. https://doi.org/10.1109/TVCG.2013.234
[6] Jeremy Boy, Anshul Vikram Pandey, John Emerson, Margaret Satterthwaite, Oded Nov, and Enrico Bertini. 2017. Showing People Behind Data. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. ACM, New York, NY, USA, 5462–5474. https://doi.org/10.1145/3025453.3025512
[7] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3, 2 (1 2006), 77–101. https://doi.org/10.1191/1478088706qp063oa
[8] Damla Cay, Till Nagel, and Asim Evren Yantac. 2020. Understanding User Experience of COVID-19 Maps through Remote Elicitation Interviews. In *2020 IEEE Workshop on Evaluation and Beyond - Methodological Approaches to Visualization (BELIV)*. IEEE, 65–73. https://doi.org/10.1109/BELIV51497.2020.00015
[9] CBS. 2018. StatLine - Geboorte; kerncijfers. https://opendata.cbs.nl/statline/#/CBS/nl/dataset/37422ned/line?ts=1589282698552
[10] Antonio Damasio. 1994. *Descartes' error: Emotion, rationality and the human brain*. G.P. Putnam's Sons, New York. 344 pages. https://archive.org/details/descarteserrorem00dama/page/n11/mode/2up

[11] Díaz-Oreiro, López, Quesada, and Guerrero. 2019. Standardized Questionnaires for User Experience Evaluation: A Systematic Literature Review. *Proceedings* 31, 1 (2019), 14. https://doi.org/10.3390/proceedings2019031014

[12] Catherine D'Ignazio and Lauren F. Klein. 2020. *Data Feminism.* The MIT Press, New York. 328 pages. https://doi.org/10.7551/mitpress/11805.001.0001

[13] Alan Dix. 2009. Human-Computer Interaction. In *Encyclopedia of Database Systems.* Springer US, Boston, MA, 1327–1331. https://doi.org/10.1007/978-0-387-39940-9{_}192

[14] Tommaso Elli, Uta Hinrichs, Adam Bradley, Zachary Hills, Christopher Collins, and Karen Kelsky. 2020. Tied in Knots: A Case Study on Anthropographic Data Visualization About Sexual Harassment in the Academy. In *2020 IEEE VIS Arts Program (VISAP).* IEEE, 29–44. https://doi.org/10.1109/VISAP51628.2020.00010

[15] Eurostat. 2018. Non-EU citizens: 4.4 % of the EU population in 2018 - Product - Eurostat. https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20190315-1?inheritRedirect=true

[16] Sarah Faisal, Paul Cairns, and Ann Blandford. 2007. Challenges of Evaluating the Information Visualisation Experience. In *Proceedings of the 21st BCS HCI Group Conferenc*, Devina Ramduny-Ellis and Dorothy Rachovides (Eds.), Vol. 2. British Computer Society, Lancaster, 4.

[17] Sarah Faisal, Brock Craft, Paul Cairns, and Ann Blandford. 2008. Internalization, qualitative methods, and evaluation. In *Proceedings of the 2008 conference on BEyond time and errors novel evaLuation methods for Information Visualization - BELIV '08.* ACM Press, New York, New York, USA, 1. https://doi.org/10.1145/1377966.1377973

[18] Michael Friendly. 2008. A Brief History of Data Visualization. In *Handbook of Data Visualization.* Springer Berlin Heidelberg, Berlin, Heidelberg, 15–56. https://doi.org/10.1007/978-3-540-33037-0{_}2

[19] Stefan Gradl, Markus Wirth, Tobias Zillig, and Bjoern M. Eskofier. 2018. Visualization of heart activity in virtual reality: A biofeedback application using wearable sensors. In *2018 IEEE 15th International Conference on Wearable and Implantable Body Sensor Networks (BSN).* IEEE, Las Vegas, 152–155. https://doi.org/10.1109/BSN.2018.8329681

[20] Guillaume Gronier, Carine Lallemand, and Adélaïde Chauvet. 2015. Mesurer la formation de la première impression d'une interface à l'aide du test des 5 secondes. In *8ème conférence de Psychologie Ergonomique (EPIQUE 2015).* Aix-en-Provence. https://www.list.lu/en/research/scientific-publication/mesurer-la-formation-de-la-premiere-impression-dune-interface-homme-machine-a-laide-du-test-des-5/

[21] Tobias Grundgeiger, Jörn Hurtienne, and Oliver Happel. 2020. Why and How to Approach User Experience in Safety-Critical Domains: The Example of Health Care. *Human Factors: The Journal of the Human Factors and Ergonomics Society* XX, X (1 2020), 12. https://doi.org/10.1177/0018720819887575

[22] Steve Haroz, Robert Kosara, and Steven L. Franconeri. 2015. ISOTYPE Visualization. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems.* ACM, New York, NY, USA, 1191–1200. https://doi.org/10.1145/2702123.2702275

[23] Marc Hassenzahl. 2004. The interplay of beauty, goodness, and usability in interactive products. *Human-Computer Interaction* (2004). https://doi.org/10.1207/s15327051hci1904{_}2

[24] Marc Hassenzahl. 2008. User experience (UX): Towards an experiential perspective on product quality. *ACM International Conference Proceeding Series* (2008), 11–15. https://doi.org/10.1145/1512714.1512717

[25] Marc Hassenzahl, Andreas Beu, and Michael Burmester. 2001. Engineering joy. *IEEE Software* 18, 1 (2001), 70–76. https://doi.org/10.1109/52.903170

[26] Marc Hassenzahl, Michael Burmester, and Franz Koller. 2003. AttrakDiff: Ein Fragebogen zur Messung wahrgenommener hedonischer und pragmatischer Qualität. In *Mensch & Computer.* J.Ziegler & G. Szwillus (Eds.), Stuttgart, 187–196. https://doi.org/10.1007/978-3-322-80058-9{_}19

[27] Marc Hassenzahl and Noam Tractinsky. 2006. User experience - a research agenda. *Behaviour & Information Technology* 25, 2 (3 2006), 91–97. https://doi.org/10.1080/01449290500330331

[28] Uta Hinrichs, Holly Schmidt, and Sheelagh Carpendale. 2008. EMDialog: Bringing Information Visualization into the Museum. *IEEE Transactions on Visualization and Computer Graphics* 14, 6 (11 2008), 1181–1188. https://doi.org/10.1109/TVCG.2008.127

[29] Trevor Hogan, Uta Hinrichs, and Eva Hornecker. 2016. The Elicitation Interview Technique: Capturing People's Experiences of Data Representations. *IEEE Transactions on Visualization and Computer Graphics* 22, 12 (2016), 2579–2593. https://doi.org/10.1109/TVCG.2015.2511718

[30] Trevor Hogan and Eva Hornecker. 2013. Blending the repertory grid technique with focus groups to reveal rich design relevant insight. In *Proceedings of the 6th International Conference on Designing Pleasurable Products and Interfaces - DPPI '13.* ACM Press, New York, New York, USA, 116. https://doi.org/10.1145/2513506.2513519

[31] Jessica Hullman, Nicholas Diakopoulos, Elaheh Momeni, and Eytan Adar. 2015. Content, Context, and Critique. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing.* ACM, New York, NY, USA, 1170–1175. https://doi.org/10.1145/2675133.2675207

[32] Ya-Hsin Hung and Paul Parsons. 2017. Assessing User Engagement in Information Visualization. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, Vol. Part F1276. ACM, New York, NY, USA, 1708–1717. https://doi.org/10.1145/3027063.3053113

[33] Tobias Kauer, Arran Ridley, Marian Dörk, and Benjamin Bach. 2021. The Public Life of Data: Investigating Reactions to Visualizations on Reddit. In *CHI Conference on Human Factors in Computing Systems (CHI '21).* 12. https://doi.org/10.1145/3411764.3445720

[34] Helen Kennedy and Rosemary Lucy Hill. 2018. The Feeling of Numbers: Emotions in Everyday Engagements with Data and Their Visualisation. *Sociology* 52, 4 (2018), 830–848. https://doi.org/10.1177/0038038516674675

[35] Bettina Laugwitz, Theo Held, and Martin Schrepp. 2008. Construction and evaluation of a user experience questionnaire. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* 5298 LNCS (2008), 63–76. https://doi.org/10.1007/978-3-540-89350-9-6

[36] Effie Lai-Chong Law, Virpi Roto, Marc Hassenzahl, Arnold P.O.S. Vermeeren, and Joke Kort. 2009. Understanding, scoping and defining user experience. In *Proceedings of the 27th international conference on Human factors in computing systems - CHI 09.* ACM Press, New York, New York, USA, 719. https://doi.org/10.1145/1518701.1518813

[37] Benjamin Lee, Dave Brown, Bongshin Lee, Christophe Hurter, Steven Drucker, and Tim Dwyer. 2020. Data Visceralization: Enabling Deeper Understanding of Data Using Virtual Reality. *IEEE Transactions on Visualization and Computer Graphics* x, x (2020), 1–1. https://doi.org/10.1109/TVCG.2020.3030435

[38] Pierre Livet. 2010. Rational choice, neuroeconomy and mixed emotions. *Philosophical Transactions of the Royal Society B: Biological Sciences* 365, 1538 (1 2010), 259–269. https://doi.org/10.1098/rstb.2009.0177

[39] George Loewenstein and Jennifer S. Lerner. 2003. The Role of Affect in Decision Making. In *Handbook of Affective Science.* Oxford University Press, New York, 619–642.

[40] Marianne Lykke and Christian Jantzen. 2016. User Experience Dimensions. In *Proceedings of the 2016 ACM on Conference on Human Information Interaction and Retrieval.* ACM, New York, NY, USA, 81–90. https://doi.org/10.1145/2854946.2854965

[41] Sascha Mahlke. 2007. Aesthetic and Symbolic Qualities as Antecedents of Overall Judgements of Interactive Products. In *People and Computers XX — Engage.* Springer London, London, 57–64. https://doi.org/10.1007/978-1-84628-664-3{_}5

[42] Camila Loiola Brito Maia and Elizabeth Sucupira Furtado. 2016. A Systematic Review About User Experience Evaluation. In *5th International Conference, DUXU 2016*, Vol. 9746. Springer, Cham., Toronto, 445–455. https://doi.org/10.1007/978-3-319-40409-7{_}42

[43] Lev Manovich. 2011. What is visualisation? *Visual Studies* 26, 1 (3 2011), 36–49. https://doi.org/10.1080/1472586X.2011.548488

[44] Riccardo Mazza and Alessandra Berre. 2007. Focus Group Methodology for Evaluating Information Visualization Techniques and Tools. In *2007 11th International Conference Information Visualization (IV '07).* IEEE, 74–80. https://doi.org/10.1109/IV.2007.51

[45] Tanja Merčun. 2014. Evaluation of information visualization techniques. In *Proceedings of the Fifth Workshop on Beyond Time and Errors Novel Evaluation Methods for Visualization - BELIV '14.* ACM Press, New York, New York, USA, 103–109. https://doi.org/10.1145/2669557.2669565

[46] Luiz Morais, Yvonne Jansen, Nazareno Andrade, and Pierre Dragicevic. 2020. Showing Data about People: A Design Space of Anthropographics. *IEEE Transactions on Visualization and Computer Graphics* (2020), 1–1. https://doi.org/10.1109/TVCG.2020.3023013

[47] Kawa Nazemi, Dirk Burkhardt, David Hoppe, Mariam Nazemi, and Jörn Kohlhammer. 2015. Web-based Evaluation of Information Visualization. *Procedia Manufacturing* 3 (2015), 5527–5534. https://doi.org/10.1016/j.promfg.2015.07.718

[48] Don Norman. 1998. *The Design of Everyday Things.* MIT, New York. 272 pages.

[49] Donald A. Norman. 2004. Emotional design. *Ubiquity* 2004, January (1 2004), 1–1. https://doi.org/10.1145/985600.966013

[50] Stanislaw Nowak, Lyn Bartram, and Thecla Schiphorst. 2018. A Micro-Phenomenological Lens for Evaluating Narrative Visualization. In *2018 IEEE Evaluation and Beyond - Methodological Approaches for Visualization (BELIV).* IEEE, 11–18. https://doi.org/10.1109/BELIV.2018.8634072

[51] Evan M. Peck, Sofia E. Ayuso, and Omar El-Etr. 2019. Data is Personal. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems.* ACM, New York, NY, USA, 1–12. https://doi.org/10.1145/3290605.3300474

[52] Rosalind W. Picard. 1997. *Affective Computing.* The MIT Press, New York. 306 pages.

[53] Bahador Saket, Alex Endert, and John Stasko. 2016. Beyond usability and performance: A review of user experience-focused evaluations in Visualization. *ACM International Conference Proceeding Series* 24-October (2016), 133–142. https://doi.org/10.1145/2993901.2993903

[54] Bahador Saket, Carlos Scheidegger, and Stephen Kobourov. 2016. Comparing Node-Link and Node-Link-Group Visualizations From An Enjoyment Perspective. *Computer Graphics Forum* 35, 3 (2016), 41–50. https://doi.org/10.1111/cgf.12880

[55] Dominique L. Scapin, Bernard Senach, Brigitte Trousse, and Marc Pallot. 2012. User experience: Buzzword or new paradigm? *ACHI 2012 - 5th International Conference on Advances in Computer-Human Interactions* February 2015 (2012), 336–341.

[56] Edward Segel and Jeffrey Heer. 2010. Narrative visualization: Telling stories with data. *IEEE Transactions on Visualization and Computer Graphics* 16, 6 (2010), 1139–1148. https://doi.org/10.1109/TVCG.2010.179

[57] Duaa Shaalan and Shaidah Jusoh. 2020. Visualization in Medical System Interfaces: UX Guidelines. In *2020 12th International Conference on Electronics, Computers and Artificial Intelligence (ECAI)*. IEEE, 1–8. https://doi.org/10.1109/ECAI50035.2020.9223236

[58] SoSci GmhB. [n.d.]. SoSci Survey - the Professional Solution for Your Online Survey. https://www.soscisurvey.de/

[59] John Stasko. 2014. Value-driven evaluation of visualizations. *ACM International Conference Proceeding Series* 10-Novembe (2014), 46–53. https://doi.org/10.1145/2669557.2669579

[60] Robert Sylwester. 1994. How emotions affect learning. *Educational Leadership* 52, 2 (1994), 60–65. http://www.ascd.org/publications/educational-leadership/oct94/vol52/num02/How-Emotions-Affect-Learning.aspx

[61] Alice Thudt, Dominikus Baur, Samuel Huron, and Sheelagh Carpendale. 2016. Visual Mementos: Reflecting Memories with Personal Data. *IEEE Transactions on Visualization and Computer Graphics* 22, 1 (1 2016), 369–378. https://doi.org/10.1109/TVCG.2015.2467831

[62] Melanie Tory and Torsten Möller. 2005. Evaluating visualizations: Do expert reviews work? , 8–11 pages. https://doi.org/10.1109/MCG.2005.102

[63] Paul van Schaik and Jonathan Ling. 2008. Modelling user experience with web sites: Usability, hedonic value, beauty and goodness. *Interacting with Computers* 20, 3 (5 2008), 419–432. https://doi.org/10.1016/j.intcom.2008.03.001

[64] Sara Värlander. 2008. The role of students' emotions in formal feedback situations. *Teaching in Higher Education* 13, 2 (4 2008), 145–156. https://doi.org/10.1080/13562510801923195

[65] Pierre Vermersch. 2014. *L'entretien d'explicitation.* ESF, Strasbourg Cedex. 100 pages. https://doi.org/10.14375/NP.9782710127055

[66] Yun Wang, Adrien Segal, Roberta Klatzky, Daniel F. Keefe, Petra Isenberg, Jorn Hurtienne, Eva Hornecker, Tim Dwyer, Stephen Barrass, and Theresa-Marie Rhyne. 2019. An Emotional Response to the Value of Visualization. *IEEE Computer Graphics and Applications* 39, 5 (9 2019), 8–17. https://doi.org/10.1109/MCG.2019.2923483

[67] David Watson, Lee Anna Clark, and Auke Tellegen. 1988. Development and Validation of Brief Measures of Positive and Negative Affect: The PANAS Scales. *Journal of Personality and Social Psychology* 54, 6 (1988), 1063–1070. https://doi.org/10.1037/0022-3514.54.6.1063