

Trustworthiness of visualizations of mobility-induced CO₂ emissions

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Abstract

In the face of global warming, CO₂ emissions have to be reduced. Everybody can contribute by making CO₂ aware decisions. But what decisions are good? Next to texts and figures, visualizations are an important communicative tool to encapsulate information in a way that is understood quickly and potentially changes consumer behavior. To have an impact, they have to evoke the trust of the recipient. In this qualitative study we address the mostly neglected topic of how individuals come to trust visualizations. We conducted interviews with eight subjects to compare trustworthiness of two visualizations of CO₂ emissions of different means of transportation. Either using a bar chart or a chart that depicts differently sized clouds. We analyzed the answers by categorizing different criteria. Overall, the bar chart was considered trustworthier. We argue that trustworthiness of visualizations follows a complex process, which considers different criteria that interact with each other. The criteria with the most influence trustworthiness are: completeness of information, necessity of information, neutrality, reading accuracy and plainness of the graph. Lastly, trust might follow a U-shaped curve when plotted over the density of graph-features.

1 Introduction

The concept of trust has gained pivotal relevance. Trust is to be found in all areas of life as well as a research subject in many scientific disciplines. For corporations, trust plays a major role, predominantly concerning the assessment of their trustworthiness. The products or the services offered by a corporation which (potential) customers do not consider trustworthy, will have little success in the marketplace. Furthermore, a corporation's communication needs to prove trustworthy. A corporation that communicates false facts or false information is perceived as less trustworthy (Reinmuth 2006).

In the digital age, the internet has become an important medium of information, upon which most corporations have reacted by offering products, services and information on their own website (Bauer 1998). A popular way of conveying information is using visualizations.

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Those which are supposed to convey scientific facts, need to be perceived as trustworthy by the addressee. Otherwise, they are considered useless, misleading, or manipulative and (if they have been created by a corporation) they can have negative effects on the global trustworthiness of the corporation.

The German national railway is the largest provider of mobility services in Germany. Both in passenger and goods traffic, the railway is the most energy-efficient and least CO₂-intensive means of traffic in many cases (Ostermayer 1999). In recent years (until 2008), greenhouse gas emissions in the field of transportation continue to increase, necessitating a call to action to reduce those emissions (Tober 2013). An additional vector to reduce CO₂ emissions, the electrification of road traffic, also requires the population to be sensitive to the issue of global warming. Visualizations can support this process of sensitization by providing a clear visual representation of the amounts of CO₂ produced by the different means of traffic. In order for such representations to change mobility behaviour, the recipients need to assess them as trustworthy.

2 Theoretical background

Visualizations are a common way to present facts and information and they can be used for an efficient analysis as well as for achieving certain communicative goals (Schumann & Müller 2000). This study focuses on the communication of an environmental problem which is to be communicated to people as effectively as possible, ideally resulting in a change of behaviour. A visualization can support this by attracting attention, by anchoring the core message and by making complex contents comprehensible (Thiele 2000).

Whereas visual presentations are not a new area of research, quality and effectiveness of a visual presentation are often neglected. Also, little is known on which visualization method is the most suitable for a certain problem and how it can be sensibly used in a specific situation. Using unsuited visualizations can lead to misinterpretations and difficulties in comprehension that affect the decision of the viewer and result in missing the communicative goal. Thus, a visualization needs to present facts perceptibly so the viewer is able to identify and understand them without difficulties. “The quality of a visualization is defined by the degree to which it reaches its communicative goal.” (Schumann & Müller 2000).

The concept of trust is very complex and multi-layered. Due to the multitude of research disciplines, there is no universally valid definition of the term “trust” to be found in literature. Nevertheless, there is consensus that trust reduces complexity, always carries certain risks and depends on the relationship of the interaction partners (Matejkova 2009, Luhmann 2000, Bierhoff & Buck 1984, Schlenker et al. 1973). Trust is usually applied on interaction partners which means mutual communication (Dzcyk 2005). Nevertheless, certain aspects of trust research can be transferred to static communication between a visualization and the viewer of a visualization. In communication science, trust research predominantly takes place as credibility research and focuses on the influence of changes of opinion, not on crite-

ria which contribute to trustworthiness (Kohring 2010). For this reason, this work has to rely on other disciplines.

There are two aspects to be distinguished: The *subject of trust* (the person who trusts) and the *object of trust* (the person who is trusted) (Dzeyk 2005). According to Mayer et al. (1995), the decision to trust an object of trust is based both on the subject-of-trust's capability to trust as on the object-of-trust's properties. Usually one focuses on three of those properties: 1) The ability that allows the object to influence others in a certain area (competence, expertise), 2) the extent to which the subject supposes good intentions of the object (benevolence), and 3) whether the object sticks to certain principles that the subject accepts (integrity) (e. g. polite manners). Integrity has the greatest effect on trust building at the beginning of the relationship of two parties, whereas benevolence only gains importance over the course of time (Mayer et al. 1995). Hence, one can assume that the assessment of the trustworthiness of the diagrams especially draws on aspects of integrity.

In this study, the question is pursued how and on the basis of which criteria recipients judge the trustworthiness of visualizations, in our case visualizations of CO₂ emissions.

3 Method

As there has not yet been much research on trust with the particular focus on visualizations, a qualitative approach was chosen. Qualitative interview procedures do not aim on checking pre-fixed hypotheses, but on gaining new substantive insights into the subject (Hohl 2000). Also, interviews have the advantage that the researcher is able to adjust themselves to particular situations and the varied subjectivities of the respondents. This method allows for an in-depth look into the views of the subjects and how they reach their conclusion (Hohl 2000).

The guided interview was divided into three parts. First, a scenario was introduced: Subjects were asked to imagine wanting to travel from Cologne to Paris. Before they began their journey, they should inform themselves about the CO₂ emissions of the different means of transportation (train, car, plane), for what they find an informative diagram on the Internet.

The subjects were then asked to describe in which case they generally identify a diagram as trustworthy and on the basis of which criteria they value that trustworthiness. Afterwards, they were asked to sketch a diagram they would trust and explain why they chose that certain diagram. Following, two diagrams from the website of the Deutsche Bahn AG were presented, illustrating the CO₂ emission of different means of traffic (train, car, plane). The first diagram was a classic bar chart, while second one showed differently sized clouds (see figure 1). Both diagrams depicted the same information on emissions. The car is presented as the least eco-friendly option, while the train is the eco-friendliest one with the least emissions.



Figure 1: The two diagrams the subjects were presented in the interview: The bar chart (left) shows three bars of different color representing the emission of (f.l.t.r.) a train, a car and a plane. The cloud diagram (right) indicates the same data on emissions using differently sized clouds, the smallest of which is colored green while the other two are grey. Diagrams were obtained from the website of the Deutsche Bahn AG (2015).

The subjects had to decide which one appeared more trustworthy and why. To test what kind of influence the source of the diagrams had on the appraisal, it was finally revealed that the diagrams originated from the Deutsche Bahn AG.

In order to get a wide range of views and personal impressions, subjects of different age, gender, knowledge and mobility behaviour were chosen. Eight interviews were conducted with persons from 17 to 70 years, three of which were female. Except for two subjects, all of them had an academic background. The interviews were recorded and transcribed. The material was reviewed and topical fields were marked. The statements were then categorized by iteratively revisiting the classification criteria and categories and finally grouped into main categories.

4 Results

The first part of the research question, that is, how do subjects appraise the trustworthiness of the visualizations, showed that the bar chart was recognized as more trustworthy than the cloud graph. However, the cloud diagram was not always evaluated as not-trustworthy but the opinions on it were more diverse. With six sketches, the bar chart was the most frequent type of diagram drawn by the subjects. A pie chart and a line graph were each drawn once.

From the criteria used to appraise the trustworthiness of the diagrams, five categories were formed: *Origin of the diagrams*, *content*, *situation of reception*, *design* and *appraisal*.

Origin of the diagram. This category contains the criteria *method of data collection*, *source* and *up-to-datedness of the data*. The source was mentioned by all subjects and can further be differentiated into the *sponsor*, the *institution collecting the data*, and the *graphic designer*. Scientific and independent institutions, such as university institutes and Stiftung Warentest (the leading German institution for product testing) were considered more trustworthy than those institutions that were suspected to have an agenda. The method of data collection was

also important for most participants in order to be able to judge the data. “It’s more about where the information comes from and how they have been ascertained”, “The underlying things like data and assumptions within the diagram are not comprehensible and therefore you cannot really say anything about the truth content of these diagrams”.

Content. The criteria *metadata*, *units* and *consequences of carbon dioxide emission* were summarized as the category *content*. *Metadata* refers to additional information that explains the data in the diagram. Some subjects also mentioned that indicating measurement units in a graph is important. On the other hand, showing consequences of behavior in a diagram decreases the trustworthiness, as mentioned by two subjects: “Well, what I personally do not like is when they say: ‘If you go to Cologne by plane, fifty baby seals will die’”.

Situation of reception. The *situation of reception* was only mentioned by very few subjects, who named criteria like the *website* the diagrams were published on, more precisely its author, design, and the existence and length of *explanatory texts*. They also mentioned that their judgment would depend on psychological factors like with what kind of *motivation* and *interest* they were visiting the site for.

Design. This category contains the visual criteria *motives*, *visual qualities of the stream of data*, *color* and *annotations*. With regard to the *visual qualities of the stream of data*, subjects considered a *three-dimensional depiction of the bars* as less trustworthy. The *order* in which the bars were arranged was thought to imply the intention of the author which could both have an increasing or decreasing effect on the trustworthiness, depending on the context: “If I were an opponent of cars I might put this one [the bar of the car] in front and here [at the end] the bus [...]. I would optimize it a bit and depict it in an increasing or decreasing order”. As for the color design, blue appeared to be trustable whereas red was said to lower the trustworthiness. Most of the subjects felt that the green cloud tried to manipulate them, whereas the colors of the bar chart did not maliciously influence them. The effect of the labeling was on the one hand deduced from the drawings of the subjects, on the other hand were some items directly mentioned. From this analysis, it was followed that the labeling of the axis is important in general, especially the units: “Well, if there are only numbers which don’t have a unit or so, then it doesn’t make sense to me and then I don’t trust them”. Placing the label directly beside the data was chosen by almost every subject and one subject directly mentioned it as a criteria.

Evaluation. This category unites all criteria that were used to appraise the graph in general. The criteria with the most influence on trustworthiness are: *completeness of information*, *necessity of information*, *neutrality*, *reading accuracy* and *plainness of the graph*. The subjects often criticized that there were not enough information to fully comprehend the diagrams: “[...] if something [...] important is left out [...], I can throw it away”. Too much information was also criticized because the subjects supposed manipulative aims or incompetence of the originator. Thus, the criteria *completeness* and *necessity* of information complement each other: There should neither be too much information nor too little. Furthermore, neutrality was important to the subjects. A factual diagram which did not suggest a certain opinion was judged as more credible than a graph which let the subjects feel manipulated in any way: “The green and the grey are very suggestive. [...] This forces me to feel like I’m a bad person if I want to go by car”. The reading accuracy was often named as a reason for the

bar chart to be more trustworthy than the cloud diagram. Subjects felt they were able to check whether the chart was correct or not: “There [in the cloud graph] I can’t control whether the proportions of the illustration are correct or not”.

5 Discussion

The most noticeable finding in comparing the two diagrams is the overall preference for the bar chart. The association of this type of diagram could be observed in the verbal statements of the subject as well as in the frequency of this type of diagram in their initial drawings. Within the small sample group and for the context in question, the bar chart can be considered the prototype of a trustworthy diagram. Differences between the bar diagram and the cloud diagram could be seen in how uniformly the subjects judged the diagrams. The appraisals on the cloud diagram differed more strongly from one another, which suggests that the type of the diagram is not the only factor influencing the trustworthiness.

An overall pattern that could be observed across subjects and criteria was that there appears to be a certain amount of information and design elements that are considered appropriate. Deviating from it by staying under or exceeding it, diminishes trust among the subjects. Too little information was interpreted as a lack of competence in the graphic designer or as an intentional withholding of information. Interestingly, subjects also expressed less trust when they felt like they were presented with too much information, which was said to result in a lack of clarity. Two subjects explicitly opposed the depiction of the consequences of CO₂ emissions arguing that they felt manipulated and influenced in their judgment. They attributed a narrow function to the diagrams which were expected to enable the recipient to properly compare the amount of CO₂ of the three means of traffic, that is, *inform* them (“[...] that is actually the purpose of diagrams, they are to visualize differences”). The subjects resolutely opposed any information that suggested or even seemed to make the decision for them. Once a diagram exceeded its expected purpose of informing them, the subjects suspected the companies involved were trying to enforce their own goals. The design also diminished trust when judged as exaggerated. Qualities like objectivity, simplicity and clarity were described as appropriate for the design of a diagram and mainly attributed to the bar chart.

Furthermore, the criteria differ from one another in their function in the process of appraisal. One might expect that each criterion is considered separately and then included in the appraisal on the trustworthiness. In contrast, many criteria appear to be dependent on others. In particular, the source of the diagram influenced the appraisal of other aspects of the diagram. One subject judged the color of the smallest cloud as acceptable at first (“[...] it is quite obvious that the green one is in fact the most ecofriendly alternative”). When the Deutsche Bahn AG was revealed as the company providing the diagram, he changed his mind: “In that case, I am wondering again about the choice of color, for example that the Bahn is green and the car and the train are gray. In that case, the source of the data would have to be considered.” Whether and to what extent perceived flaws such as the choice of color diminished the trustworthiness of the diagram was affected by the information on the institution providing it. Another thing to be noted is that the subject, in consequence wants to consider another

criterion as reassurance, namely the source of the data. The uncertainty caused by revealing the company made him continue the judgment process using additional criteria.

To summarize, the appraisal of trustworthiness of visualizations is a complex, varyingly extensive, usually multistep process of conclusion. Viewers consider several criteria that have different functions and can interact with each other.

The results of this study represent a first attempt at understanding trustworthiness of visualizations. As it solely relies on qualitative data obtained from eight subjects, the findings are neither complete nor generalizable. The questions in the interviews focused on the qualities of visualizations that increased or decreased their trustworthiness. Future studies should include external factors which are likely to also affect the judgment process as pointed out at the beginning of this article. Also, one subject repeatedly addressed details of the situation of reception (i.e. where is the diagram found, with what text). To prevent ambiguities, the scenario should give more details on the situation of reception. Alternatively, it could be staged, meaning subjects are sat down in front of a computer screen and access the diagrams themselves. This methodological change would allow for a better understanding of how subjects judge situational factors. Another thing left aside in this study are individual differences of the recipients, such as age, gender, education, knowledge, interest, willingness to trust, or attitude towards to the environment. In order to learn about their effects on trust, future studies should include them.

Future research should aim at understanding the complex process of judgment and the different functions of the criteria used. Qualitative interviews allow for a repeated inquiry and are therefore a key technique. Particularly when studying visualizations, it seems to be a suitable technique to also have subjects produce a sketch. An advantage of this approach as an addition to verbal statements is that subjects do not need to have a rich visualization-related vocabulary. This advantages especially apply to groups of subjects who are not used to communicate about visualizations due to their education or profession. Quantitative studies should follow, testing not only for main effects, but also for interactions between one or more factors to understand the dependencies of criteria and other factors.

The key findings of this study were not found in the initial literature review. This indicates a need of a separate theory on the trustworthiness of information visualization incorporating their perceived function and attributes of the visualization, the context of reception and characteristics of the recipient. Trust – in Luhmann's understanding – as a way to reduce complexity undoubtedly has an important function in decision situations in mobility and other domains. However the complexity of this judgment process behind it should not be neglected.

The results indicate that the current trend towards infographics embellished with many iconic and design elements should not be adopted unquestioningly. As they are considered more esthetic and comprehensible, they may be appropriate for example when the audience's interest has yet to be aroused. However, if the visualization is expected to facilitate a decision process of an already interested recipient, other criteria seem to apply.

The following preliminary conclusions on how to design such diagrams can be drawn: Cues signaling trustworthiness should be used, but in such way that they appear to be coincidental and not deliberately created, which would again decrease trustworthiness. Bar charts are the prototype of a diagram that puts several data points into relation. The source of the data and the diagram is an indispensable element which should always be easily visible and should reference an independent institution. Colors, icons and other design elements should be used cautiously giving the visualization an appearance of objectivity and simplicity.

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