

DESIGNING EFFECTIVE DATA VISUALISATIONS FOR ENVIRONMENTAL CRISIS AWARENESS: THE IMPORTANCE OF LOCAL DATA

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Abstract

This paper explores the use of data visualisation to communicate effectively about the risks posed by environmental issues, and the importance of representing local data. Previous studies have shown that data visualisation of local environmental data is an effective way to communicate ideas and influence people about environmental issues. This study investigated how to apply this for the purposes of environmental campaign groups to persuade people to take action around environmental issues. Two visualisations were designed and evaluated for a local campaign group. Human centred design approaches and heuristics were used to support the design process. The visualisations were evaluated with members of the public through a survey. They were found to be effective for persuading people from a wide range of backgrounds to take more personal and political action around environmental issues. The study found that environmental campaign groups can communicate their message effectively by creating simple visualisations of local data that has a clear, direct impact on people. Human centred design approaches were successful for producing visualisations that had the desired impact and heuristics were an effective method for supporting the design process for an inexperienced designer. The process used in this study for analysing and transforming weather data could be replicated for other local areas to uncover compelling messages for the general public. Visualisations could be made more effective by pairing them with clear evidence that actions an individual takes can make a meaningful contribution, although more research needs to be done to explore how to do this effectively.

Keywords: education, data visualisation, climate change, environment, flood, pollution

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Introduction

Climate change presents local actors with a particular challenge: while the grave risks that it poses globally to all of humanity are clear, mitigation requires local action, which can discourage individuals from taking any significant and urgent action to mitigate environmental issues.

To ensure such an active response to climate change, an awareness of the risks it poses is essential, and so is clear communication. This study explored, with the support of Extinction Rebellion Sheffield (XR Sheffield), the use of local data visualisations to better persuade people to take action on environmental issues. Local data has been shown to be effective for changing beliefs and attitudes about the environment (Herring et al., 2017). This study confirms the strength of this approach in the design of effective visualisations that can successfully persuade people to take personal and political action to tackle environmental issues.

Two visualisations were designed and evaluated for use by Extinction Rebellion Sheffield. Human centred design approaches and heuristics were used to support the design process. The visualisations were evaluated with members of the public through a survey. The visualisations were found to be effective for persuading people from a wide range of backgrounds to take more personal and political action around environmental issues. The study found that environmental campaign groups can communicate their message effectively by creating simple visualisations of local data that has a clear, direct impact on people. Human centred design approaches were successful for producing visualisations that had the desired impact and heuristics were an effective method for supporting the design process for an inexperienced designer. The process used in this study for analysing and transforming weather data could be replicated for other local areas to uncover compelling messages for the general public. Visualisations could be made more effective by pairing them with clear evidence that actions an individual takes can make a meaningful contribution, although more research needs to be done to explore how to do this effectively.

Theory and method

Literature review

A well designed visualisation can help with effective communication around environmental issues. Pandey et al. (2014) show that data is more persuasive when presented graphically rather than in tabular form. Data visualisation has been shown to be effective for changing beliefs in the context of climate change specifically. All participants in a study showed strong changes in beliefs and attitudes after interacting with a site that showed the impact of climate change at local scales (Herring et al., 2017). Newell et al. (2016, p3) explain why data visualizations can be powerful tools for engaging people in the fight against climate change:

They can convey a message using multiple senses, engage people on an emotional level and provide a degree of salience to the information presented. [...] visualizations can transmit the severity of certain impacts, [...] and impress upon stakeholders (and the broader public) the imperative to act.

There is plenty of literature available to inform the design of data visualisations, much of which is applicable to environmental campaigns. There is widespread agreement in the literature that design decisions should be informed through user centred design and the design should be tailored to the purpose of the visualisation. (de Folter et al., 2014; Sedlmair et al., 2012; Dasgupta et al., 2015; Grainger et al., 2016). There is still limited empirical evidence of how different individuals and groups interpret different visualisations of climate data (Daron et al., 2015), so it is important to do empirical testing.

Simplicity, conveying information clearly and aesthetics are important (De Folter et al., 2014; Newell et al., 2016; Dasgupta et al., 2015; Grainger et al., 2016; Valkanova et al., 2015). Designers should use graphic design principles to draw the reader's attention to salient information, lower cognitive load,

enhance pattern detection and perceptual inference, and solve problems more efficiently (Grainger et al., 2016). The data should be transformed appropriately to balance reducing clutter against loss of information. Data transformation can reveal information that would be hidden from the user in untransformed data, or take great effort on the part of the user to uncover (Wen and Zhou, 2008). It is appropriate to support the audience's understanding of the visualisation with explanations such as a caption, particularly when audiences may not be skilled interpreters of graphical information (Glazer, 2011).

Effort should be directed to make sure the evidence is trustworthy and authoritative (Cialdini, 2007). To be convincing, it is essential to make it personally relevant for the target audience (Ibrahim et al., 2013). To this end, it has to be made vivid and emotive (Ibrahim et al., 2013). Most importantly, the data selected for visualisation should relate to local issues, which readers feel strongly connected to (Herring et al., 2017).

Research design

To test these principles, two visualisations were designed and evaluated for a local campaign group (Extinction Rebellion Sheffield) using user centred design techniques. Design research was chosen as an accompanying methodology because it takes advantage of the potential to generate knowledge from the design process itself. This knowledge was captured by documenting and analysing the design process. The literature review summarised above provided heuristics to support the design process, and the initial design was informed by capturing the requirements from Extinction Rebellion volunteers. The visualisations were evaluated with members of the public through a survey. This was followed by data analysis and redesign.

The two simple visualisations centre on local air pollution (figure 1) and on local flooding (figure 2), two issues that are extremely well-known in Sheffield, and for which data is available that leaves little doubt that it is a major environmental issue for the city. The process involves accessing appropriate weather data, identifying long term climate trends, and from those trends finding extreme weather events, and pairing salient data patterns with stories and images that show a clear impact. The visualisations and surveys were distributed online and 117 respondents took part.

Details of research activities

1) Artifact analysis

A thematic analysis of XR's policy documents and XR Sheffield's social media output was carried out to improve the interviewer's knowledge of the context and elicit tacit requirements that may not emerge during an interview.

2) Interview with two members of XR Sheffield's media and messaging team

The analyst asked questions to understand more about the context of use and the needs of the campaign group. Examples of relevant data visualisations were shared with the interviewees and discussed to elicit further requirements around what data to visualise, visualisation style and what messages to communicate, as well as facilitating co-generation of design ideas.

3) Product backlog

This captured the requirements elicited from the interview. Results from the artifact analysis were discarded because they didn't reveal anything that wasn't in the interview.

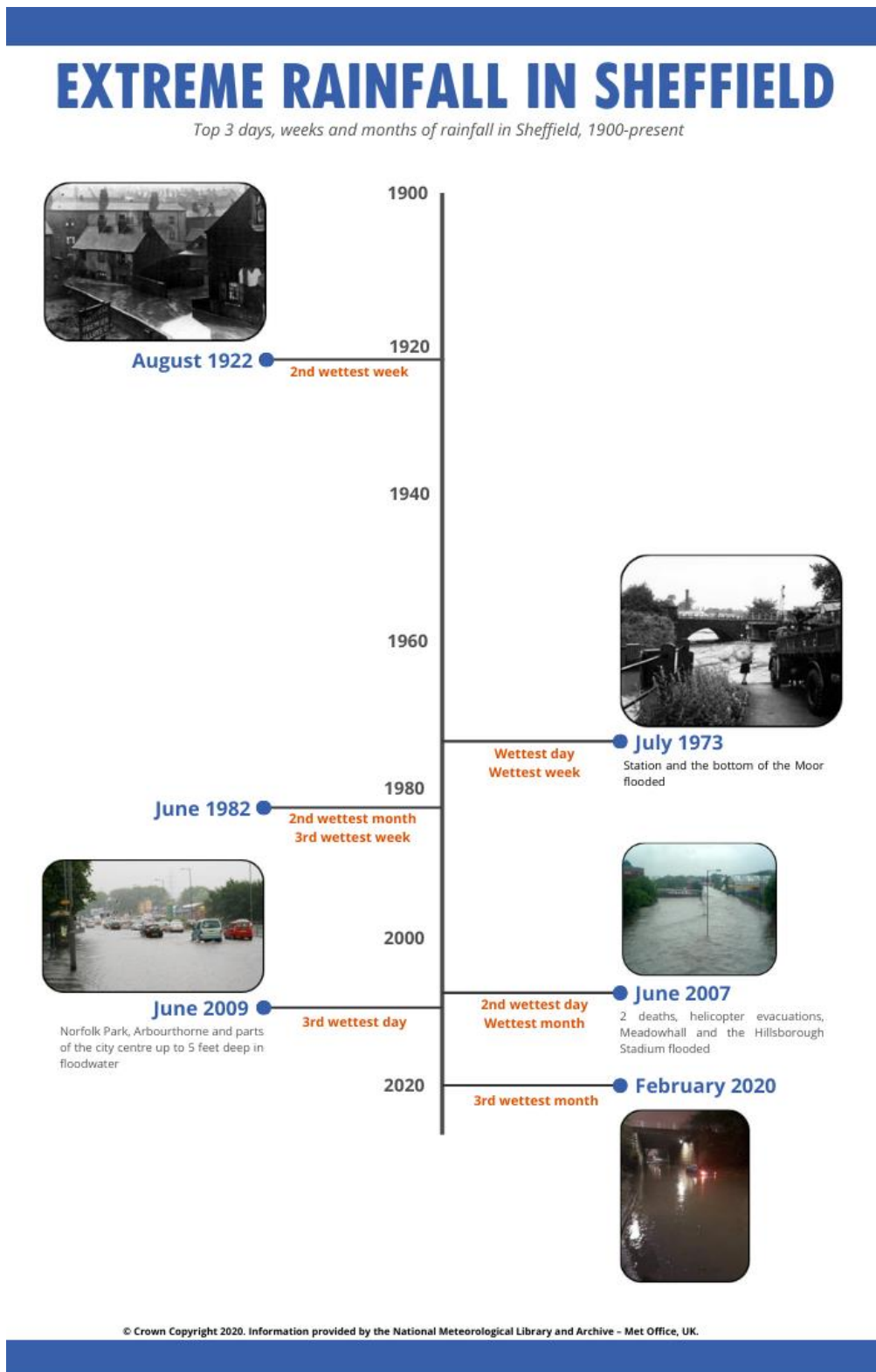
4) Production and evaluation of multiple prototypes

Prototypes were produced and evaluated against the product backlog, a heuristic checklist produced based on the literature review and casual feedback with members of the public. This was followed by further development of prototypes and evaluation. The design process was documented to capture the knowledge generated. Two fully developed visualisations emerged from the design process.

Figure 1: Visualisation of the consequences of air pollution in Sheffield.
The full version includes references for the data used



Figure 2: Visualisation of flooding in Sheffield



5) *Final evaluation - survey*

The desired impact of the visualisations was a change in willingness to take action about environmental issues, ideally in the form of political action. One of the two visualisations was randomly assigned to survey participants. The survey measured attitude change by asking questions before and after exposure to the visualisations.

Results and discussion

The results unequivocally confirm the importance of local data to directly impact and effectively influence people on the environment: 73% of survey respondents said seeing the visualisations had changed their minds about the environmental issues, at least to some extent; and 49% of respondents stated they will take additional personal and/or political action around environmental issues as a result of seeing the visualisations. When taking into account the local connection of respondents to Sheffield, the importance of local data becomes clear in persuading people from a wide range of backgrounds to take more action around environmental issues, as is apparent from Table 1.

Table 1: The stronger the respondent's local connection, the more effective the visualisation

Local connection	Opinion		Willingness to take action	
	changed	not changed	Will take action	Will not take action
No local connection	15	17	13	19
Some local connection	17	7	10	14
Strong local connection	52	8	33	27

Analysis of the design process

Data visualisation designers could save time and effort by applying a similar process of finding, exploring and transforming equivalent weather data for their area to uncover locally significant information that shows a clear and direct impact on individuals, although finding other information of local significance would need to be more bespoke.

- 1) Access accurate weather data for the local area from an authoritative source.
- 2) Explore broad climate trends and extreme weather events to identify which would be most salient for the public.
- 3) Pair the selected weather data with impacts and accompany with visceral stories/images to enhance emotional engagement from the audience.

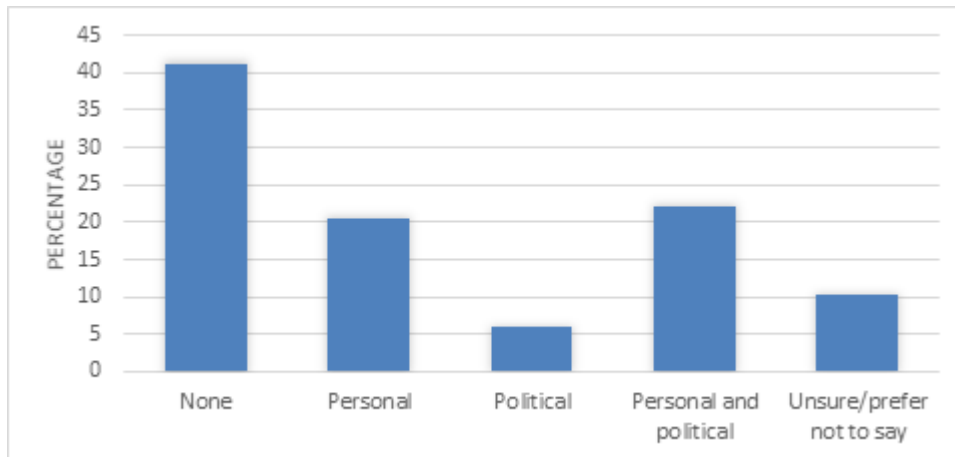
Sketch prototyping is suitable for exploring which data is most suitable because sketch prototypes can be produced quickly and easily. For Sheffield, the data suitable for showing a clear, direct impact on people was days, weeks and months of highest precipitation paired with flooding impacts, and the health impacts of air pollution.

Heuristics helped to support the design process by making sure all the important aspects of what makes a visualisation effective were considered. Consideration of the eventual media dissemination was important during the design process. The visualisation had to be effective when viewed on a PC, on a phone and in print. Elements were therefore static and presented vertically rather than horizontally. Casual feedback was useful for picking up on potential improvements that the designer had missed.

How effective were the visualisations for persuading people to take action?

Figure 1 shows what kind of additional action respondents intended to take, if any, after seeing the visualisation. Exposure to the visualisations was somewhat effective for persuading people to take both personal and political action, so these or similar visualisations would be suitable for use by a wide range of environmental campaign groups.

Figure 1: The visualisations were somewhat effective for persuading people to take personal and political action



Impact on people with lower levels of education and ethnic minorities

XR hoped to be able to influence working class people and ethnic minorities in particular. Level of education was used as a proxy demographic measure for class (those under 25 were not included because typically many people in this group have not finished their formal education). 77% of people who were over 24 and educated to less than undergraduate level said their opinion changed and 62% said they would take additional action around environmental issues. 68% of non-white respondents said they had changed their minds and 95% said they would take additional action. This is greater than the percentages for respondents from all demographic groups. This may mean that the visualisations were particularly effective for these demographics. See Table 2 for absolute figures.

Table 2: The visualisations were more effective for those who have not completed higher education and non-white respondents

Demographic	Opinion		Willingness to take action	
	changed	not changed	Will take action	Will not take action
Have not completed higher education	8	3	8	20
Have completed higher education	77	29	49	28
White	66	30	43	43
Non-white	18	2	13	5

Examination of qualitative data

Table 3 lists the themes for what makes people change their minds and what stops people from changing their minds. This information can be used to work out how to improve the visualisations. Based on these responses, there are a number of ways the visualisations could be improved. The most fruitful potential area of improvement is to communicate explicitly about what people can do about the issues portrayed in the visualisations. It would be beneficial to show that the personal and political actions an individual can take can make a significant difference, particularly in terms of making people believe they can

influence the government. The actions people can take should be made explicit, and as lack of time was often given as a reason for not being able to do more about the environment, suggested actions should take little time.

Table 3: Themes for why people changed their minds and barriers to attitude change

What makes people change their mind?	What stops people from changing their minds?
Seeing it as a serious issue Connection to Sheffield Being exposed to new information Being reminded of what they already know	No connection to Sheffield Not sure what to do Already doing lots Lack of time Already aware Don't live in Sheffield Personal action will make little difference Government could do more Don't care Other issues are more serious

A paragraph titled “What can we do about this?” followed each visualisation shown in the survey. This signposted people to XR’s website, but this was insufficient for making people feel like they knew what to do and for convincing them they could have a significant impact.

This fits with the findings of Nicholson-Cole (2005). Their interviews suggested that middle-class young professionals, who made up a large proportion of the respondents for the survey, generally did not see how one person could make a difference. The research recommends communicating what individuals can do to make a difference. These actions must come across as being easy to do, positive and feasible given other life commitments. However, it is unclear how best to achieve this, and this would be beneficial to explore in future research.

Some people indicated they didn’t change their mind because they don’t have a connection to Sheffield. This suggests it would be beneficial for campaign organisations to visualise data for a range of local areas.

Some people didn’t see the issues portrayed as being serious, although they didn’t say which issues they thought were more serious. Nicholson-Cole (2005) found that weather changes are the most salient impact of climate change. An Ipsos survey found that the top 3 issues people considered to be most important were global warming/climate change, air pollution and dealing with waste (IPSOS, 2019). An MIT poll found global warming was deemed most important in the US, followed by destruction of ecosystems and water pollution (Herzog, 2012). People’s answers to this kind of poll may vary across time and location. It is therefore somewhat difficult to predict what people will view as the most important issues, and the ones they deem most important may not lend themselves to demonstrating a simple and direct local impact. More research could be done to find out what is most effective in each local area, or for particular groups of people. Many respondents to the survey for the present study did see either the air pollution or the flooding information they saw as important, so these may still have been the best choices for Sheffield.

Limitations

There was a minor issue with the final survey: The additional questions assumed that the visualisations wouldn't lead to a negative change in opinion e.g. no one would want to take less action about environmental issues after having seen one of the visualisations. To gauge the likely impact of this methodological error, the comments were examined and the pre and post treatment attitude scales were analysed. None of the comments indicated that people had changed their opinion negatively, although many were neutral, as expected. 5 participants indicated that they intended to take less personal or political action around environmental issues in the attitude determination question following the visualisation compared to prior. This may have been because the visualisations changed their minds to the negative, or it may be that they were on the boundary between two categories and answered differently the second time around. This methodological error may therefore have a small impact on the validity of the results of the survey.

One issue with the dependent variables is that people often do not do what they say they will do, and there can be a gap between attitude and action (Anable et al., 2006). In the future a longitudinal study could be carried out to find out whether there was any difference in the amount of action taken around environmental issues between people who were exposed to relevant visualisations and a control group.

There was a minor error in the flooding visualisation. The caption for February 2020 said shoppers were stranded at Meadowhall; this event actually occurred in November 2019, although transport to Meadowhall was disrupted in February 2020. Had people been exposed to the correct information, it is possible some people may have given different responses, but the overall message of the visualisation is the same so any differences are likely to have been negligible.

Conclusion

This finding can be applied to environmental campaigns, as well as any campaign situations that require local public awareness; any groups can apply this by similarly focusing visualisations on locally relevant data. Human centred design approaches were successful for producing visualisations that had the desired impact, so the requirements engineering process used for this project could be adapted for future projects. Heuristics were effective for supporting the design process for an inexperienced designer. The process used in this study for analysing and transforming weather data could be replicated using data from other areas to uncover information that is likely to be compelling for the general public.

Qualitative data from the survey revealed that the visualisations could be made more effective by pairing them with specific actions that don't take much time, and clear evidence that actions an individual takes can make a meaningful contribution. More research needs to be done to confirm this and work out how best to convince people they are able to make a meaningful contribution. Other potential areas for future research could involve evaluating the effectiveness of alternative design approaches and refining the heuristics used to support the design.

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