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Tailoring the visual communication of climate projections for local adaptation practitioners in Germany and the UK

Susanne Lorenz, Suraje Dessai, Piers Forster and Jouni Paavola

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Sustainability Research Institute
SCHOOL OF EARTH AND ENVIRONMENT

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Its five inter-linked research themes are:
Theme 1: Understanding green growth and climate-compatible development
Theme 2: Advancing climate finance and investment
Theme 3: Evaluating the performance of climate policies
Theme 4: Managing climate risks and uncertainties and strengthening climate services
Theme 5: Enabling rapid transitions in mitigation and adaptation

More information about the Centre for Climate Change Economics and Policy can be found at: http://www.cccep.ac.uk/

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1. Understanding climate information needs across society and
2. The social status of techno-scientific knowledge in adaptation to climate change.

The whole programme will be applied to the UK context given the sophistication of existing knowledge systems (such as probabilistic climate scenarios) and the progressive climate policy landscape (that requires public authorities to regularly report on adaptation activities).

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Abstract

Visualisations are widely used in the communication of climate projections. However their effectiveness has rarely been assessed amongst their target audience. Given recent calls to increase the usability of climate information through the tailoring of climate projections, it is imperative to assess the effectiveness of different visualisations.

This paper explores the complexities of tailoring through an online survey conducted with 162 local adaptation practitioners in Germany and the UK. The survey examined respondents' assessed and perceived comprehension of visual representations of climate projections as well as preferences for using different visualisations in communicating and planning for a changing climate.

We show that even within a fairly homogenous user group, such as local adaptation practitioners, there are clear differences in respondents' comprehension of and preference for visualisations. We found that a sizeable proportion of the respondents (UK: 27.3%, DEU: 39.7%) have the highest assessed comprehension score for a graph format other than the one they perceive to be the easiest to understand. Respondents use what they think they understand the best, rather than what they actually understand the best. These findings highlight that audience-specific targeted communication may be more complex and challenging than previously thought.

Keywords: *Climate change adaptation, climate projections, visualisation, communication, decision-making, local government*

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1. Introduction

Adaptation to climate change is inevitable (1). Climate projections - 'simulated response[s] of the climate system to a scenario of future emission or concentration of greenhouse gases and aerosols'(2) - are often used in scientific analysis and risk assessments to help decision-makers understand the risks posed by climate change and plan accordingly. But if maladaptation is to be avoided and decision-making made effective, then climate projections and information need to be usable by and accessible to those people in the private and public sphere that have to practically prepare and plan for the impacts of a changing climate. These decision-makers and planners will hereafter be referred to as adaptation practitioners.

Climate projections are often communicated visually and it is important to examine the usability and accessibility of visualisations closely. Some research has already been conducted on the role of climate visualisations in the fields of climate change (3), impacts (4), modelling and projections (5), and adaptation and decision-making (6, 7). Moreover, lessons can also be learnt from research on visualisation of risk and other information in the health and cognitive sciences (8-10), environmental hazards and geosciences (11-13), risk (14, 15), design (16), computing (17, 18), and hydrology (19, 20).

The existing literature suggests that visualisations and communication ought to be tailored to the target audience (21, 22) and support user needs (12). There are calls in the literature for making visualisations more effective and for better evaluation of their effectiveness (13, 23, 24). The lack of empirical work on visual communication is acknowledged and more research on visualisation has been called for (11, 12, 21). There is a widely held belief in the literature that successful tailoring of climate information will ultimately increase its usability as well (25, 26). Better understanding of user preferences and comprehension is needed to ensure greater usability of climate information (11, 19, 21). However, assessing user comprehension and preferences is a complex undertaking due to discrepancies between assessed and perceived comprehension (27) as well as the potential inconsistencies between preferences and comprehension (8-10).

Considering these complexities, is it really feasible to produce tailored visual climate information in practice? This paper examines this question by conducting an empirical experiment with local adaptation practitioners in Germany and the UK on the usability of visualisations of climate projections. Local adaptation practitioners are an under-researched group of users of climate information (28, 29), despite being recognised as playing an important role in addressing the challenges posed by climate change (30, 31). We explored local adaptation practitioners' understanding of and preferences for different visualisations of climate projections. Our aim is not to find one 'ideal' visualisation, but rather to highlight the complexities involved in tailoring and improving the usability of climate information.

In the next section we explain the methods we employed to assess user comprehension and preferences for the visualisation of climate projections in Germany and the UK. Section three outlines the results from the two surveys and in section four we discuss how our experimental findings can substantiate the complexities in the visual communication of climate information as well as highlight some of the challenges of tailoring. Section five provides concluding remarks.

2. Methodology

An online survey was developed to explore how local adaptation practitioners in Germany and the UK interpret visual representations (hereafter referred to as graph formats) of climate projections. The survey set up, despite asking hypothetical questions, allowed us to collect empirical data that will nevertheless be reflective of decision and communication scenarios for adaptation practitioners. Both countries are considered to be amongst the leaders of climate change adaptation in Europe (32, 33), but exhibit differences in terms of the extent to which adaptation has become a discrete policy field (34) and in terms of how scientific uncertainty is communicated in national adaptation strategies (35). Tailoring and perceived usability of climate information for decision-making will have to be examined at a more local scale because of their very nature. Keeping in mind the national differences between the two countries, we explore differences and similarities in the comprehension of and preference for information provision at the local level that can help to inform the tailoring of climate information and its visualisations.

The aim of the survey was to better understand both participants' comprehension of and their preferences for different graph formats in planning, decision-making and communication on adaptation in their organisations. We purposefully sampled employees of Local Authorities that work on environmental policy, climate change, sustainability or adaptation. Participants were recruited through direct email, advertisements in newsletters and web portals, and through networks of relevant organisations such as the UK Climate Impacts Programme, the Local Government Association Climate Local Online Forum and the Klimaplattform. All participants completed the same questions and were not randomised. The survey was administered in German and English, and was translated by the lead researcher, to ensure consistency of the questions. Responses were collected between March – July 2013 in the UK (n = 99) and between October 2013 – February 2014 in Germany (n = 63). Individuals entering the survey were not offered any incentives or monetary rewards in return for their participation.

2.1. Development of different visualisations (graph formats)

Four graph formats were developed to visualise the output of 14 Global Climate Models (GCMs) from the fifth phase of the Climate Model Intercomparison

Project (CMIP5). The graph formats used in the two countries were based on output values for the grid cell around Newcastle, UK in order to expose the participants from both countries to the same climate information. The choice of the grid cell is irrelevant for the experiment, only enabling to extract data from the climate models for a given location. Of the four graph formats used two can be considered 'traditional' (linear scatter plot and histogram) and the other two 'alternative' (pictograph and bubble plot).

- The scatter plot and the pictograph show the change in mean summer temperature for the 2050s (2040 - 2069) under RCP 6.0, a medium greenhouse gas concentration trajectory, relative to a historical baseline period (1975 – 2004). The plots thus show 30 year seasonal mean changes for each of the 14 GCMs.
- The histogram and the bubble plot show the frequency for ranges of change in summer temperature for the 2050s (2040 - 2069) under RCP 6.0, a medium greenhouse gas concentration trajectory, relative to a historical baseline period (1975 – 2004). The plots are based on annual summer changes for each of the 30 years for each of the 14 GCMs.

2.2. Experimental procedure

The survey participants were given at the start a brief introduction to the survey and the aims of the research project, including information on confidentiality and informed consent. The climate data visualised in the survey was briefly explained and although exactly the same data and graph formats were shown in both surveys, the English survey stated that the values were for a location in North East England, whereas the German participants were informed that it was for a location in North East Germany. This was done to ensure that the participants from both countries felt that the data shown would be relevant to their national contexts.

2.3. Criterion assessment

The aim of this analysis was to assess four key criteria: assessed and perceived comprehension; and use by self and use for showing to others, further explained below.

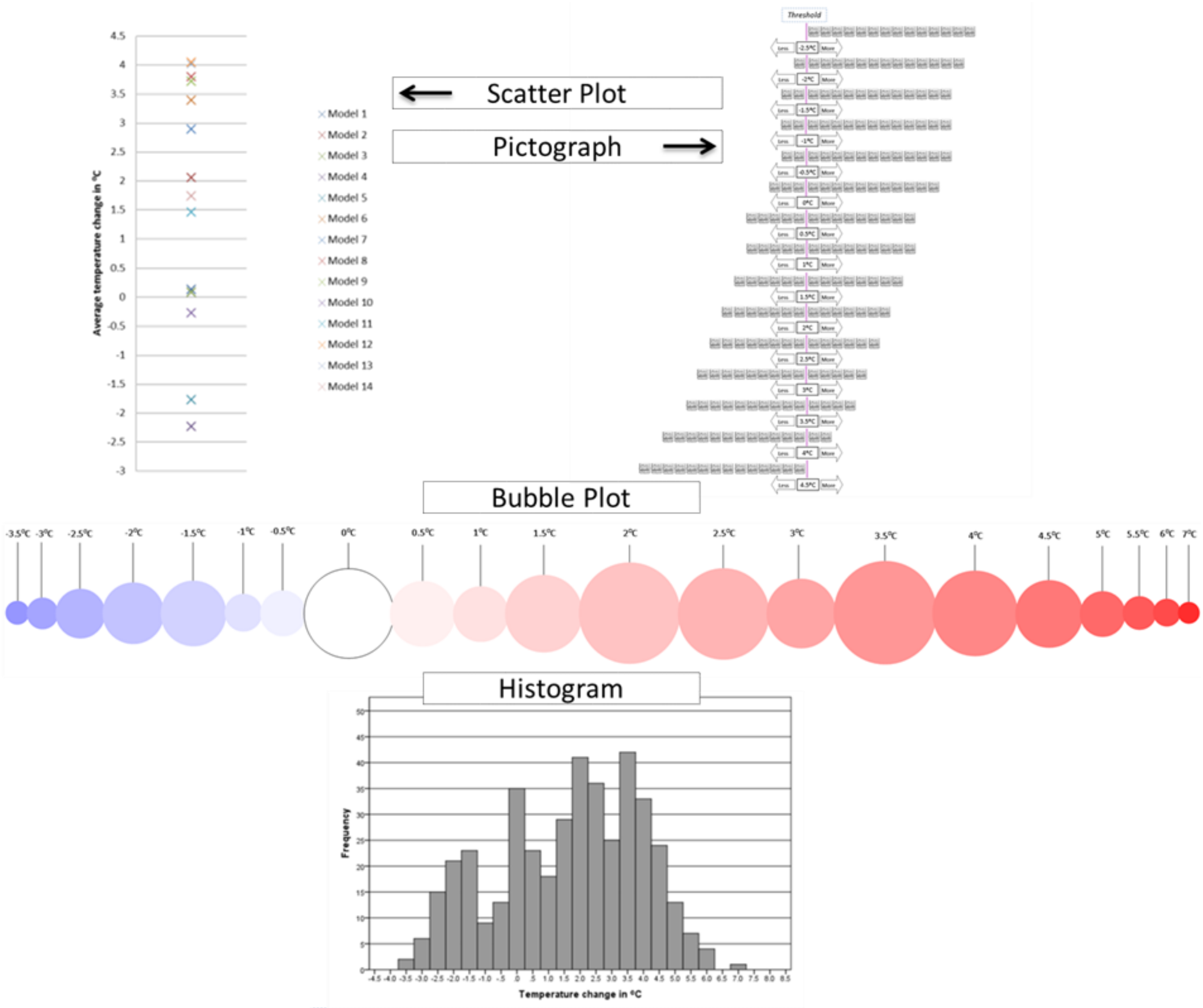

Figure 1 This shows the four graph formats that were used in the survey. Each one of them also contained a figure caption explaining the data and the concept of the figure.

2.3.1. Assessed and perceived comprehension

Respondents were shown the four graphs in the following order: 1) scatter plot, 2) histogram, 3) pictograph, and 4) bubble plot. Respondents were asked to answer the following multiple choice questions about the graph formats.

Scatter plot and pictograph:

- How many models project a decrease in summer temperature?
- How many models project an increase in summer temperature by more than 3.0°C?
- None of the models project a temperature change above which temperature value (to the nearest half of a degree)?

Histogram and bubble plot:

- Which is the most likely temperature change projected by the models?
- What is the range of projected temperature change in the figure?
- Which value is more likely, -2.5°C or 5.0°C?
- Are you more likely to get a temperature change below -2.5°C or above 5.0°C?

Every response was coded ‘0’ for incorrect and ‘1’ for correct answers. An assessed comprehension score (ACS) was created by calculating the mean of the coded answers for each respondent for each figure, and for all four graph formats together. To assess perceived comprehension (PC), respondents were asked ‘Which figure did you find the easiest to understand?’ with the option of choosing any one of the four formats.

2.3.2. Use by self and use for showing to others

Local adaptation practitioners not only consume climate information for their own use and planning, but also communicate it further to colleagues, managers or elected representatives as part of their roles. Therefore, we assessed the preferences for the use of graph formats that is both inward-facing (use by self) and outward-facing (use for showing to others). Use by self relates to individual decision-making. Preferences and perceived usability of graph formats for use by self was assessed by asking ‘If you had to make a planning decision, which of these figures would you find most helpful for your decision-making process?’. Respondents could choose one of the four graph formats or ‘Depends on the decision’ or ‘None of the above’. Preferences for use for showing to others were assessed by the question ‘If you had to persuade someone in your organisation (e.g. your colleagues or your boss) of the necessity to start planning for changes in future summer temperatures, which one of these figures would you choose?’ Respondents could choose one of the four graph formats or ‘I wouldn’t use a figure at all’.

The survey also collected qualitative data, as respondents had the opportunity to leave further explanations of their choices in comments boxes for the questions on perceived comprehension, use by self and use for showing to others.

2.4. Other sample characteristics and sample description

Table 1 gives an overview of the other sample characteristics for the two samples. The UK sample is somewhat younger and has thus a higher percentage of respondents with less years of relevant work experience, but in the main the two samples are comparable.

Table 1 Sample description

		UK sample	Germany sample
Number of respondents		99	63
Gender	**% female**	40.4%	42.9%
	% male	59.6%	57.1%
Age groups	**20-29 years**	13.1%	3.2%,
	30-39 years	36.4%	22.2%,
	40-49 years	30.3%	27%
	50-59 years	16.2%	39.7%
	60 and over	4.0%	7.9%
Education	**degree or higher academic qualification**	92.9%	100%
	no degree or higher academic qualification	7.1%	
Work experience in a related job	**0-5 years**	17.2%	15.9%
	6 – 10 years	32.3%	17.5%
	11 – 15 years	20.2%	14.3%
	16 – 20 years	9.1%	3.2%
	21 – 25 years	7.1%	25.4%
	26 – 30 years	5.1%	15.9%
	31 – 35 years	4.0%	4.8%
	36-40 years	5.1%	3.2%
% colour blind		2%	0%

Three measures around self-assessed knowledge and experience were included: 1) level of engagement with climate projections (‘How much do you engage with climate projections in your day-to-day job?), 2) involvement in adaptation in work within the organisation (‘Have you been actively involved in the climate change adaptation process in your organisation?’) and 3) climate change knowledge (‘How good is your knowledge of the topic of climate change?’). These three measures were assessed on a 6 point Likert scale with 1 being the least favourable and 6 being the most favourable option. Following the data collection responses were categorized into ‘low’ (1-3 on the Likert scale) and ‘high’ (4-6 on the Likert scale). As the survey also collected data (not reported here) using the subjective numeracy scale developed by Fagerlin et al. (36), which measures individual scale items on a 6 point Likert scale, it was decided to use the same scale for all of the measures in the survey to ensure consistency.

2.5. Analysis

Following the production of descriptive statistics for the four key criteria and the other sample characteristics, it was decided to use non-parametric statistical analysis as the assessed comprehension scores (ACSs) for the graph formats were not normally distributed (37). We first compared the ACS for each graph format (a continuous variable) within country with the Wilcoxon signed rank test and between countries with the Mann Whitney U test. We used the Chi-square test for independence to investigate the relationships between the other three criteria (PC, use by self and use for showing to others – categorical variables) within country and to compare the same criteria between countries. The differences between the ACSs across the three categorical variables was explored using the Kruskal Wallis test, followed by the Post-hoc Mann Whitney U test and MANOVA (with bootstrapping employed). The differences of the ACSs across the dichotomous sample characteristics were explored using the Mann Whitney U test, whereas the differences of the ACSs across the other categorical sample characteristics were examined using the Kruskal Wallis test. All other relationships were explored using the Chi-Square test.

3. Results

3.1. Outcome description

We hypothesised at the outset that the four key criteria would be associated with each other. Figure 2 illustrates these hypothesised associations between assessed (A) and perceived comprehension (B) and use by self (C) and use for showing to others (D). Below we assess each criterion separately, followed by the differences and relationships between them. Lastly we will test whether the other sample characteristics have any influence on them.

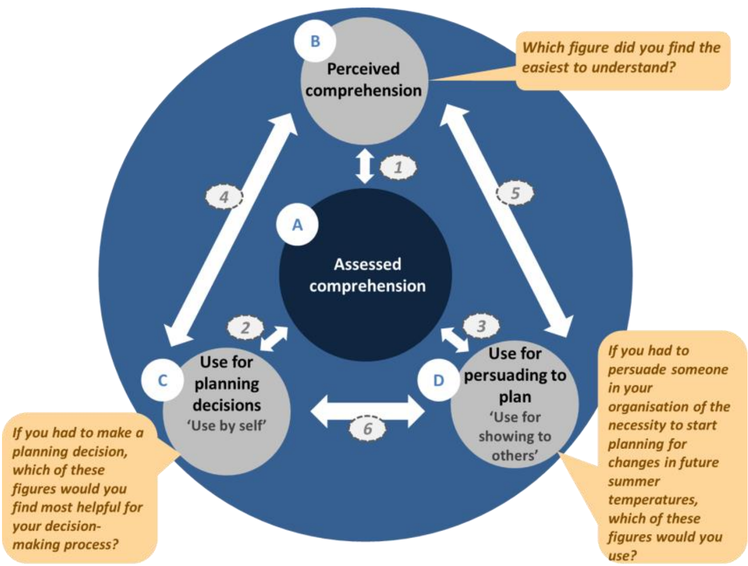

Figure 2 The four key criteria are denoted by capital letters: assessed comprehension (A); perceived comprehension (B), use of planning for decisions – use by self (C), and use for persuading to plan – use for showing to others (D). The associations are represented with the numbered arrows (1-6).

3.1.1. Assessed comprehension (A)

Table 2 summarises the mean ACS and standard deviation for each graph format in the two countries, as well as comparisons of the two samples. Whilst the UK respondents achieved statistically significantly higher ACSs on the scatter plot, the bubble plot and the overall ACS than German respondents, they achieve a lower ACS on the pictograph.

Table 2 Assessed comprehension scores for all graph formats

	UK			DEU			ACS compared across both countries		
	$\bar{x}$	*s*	*Med*	$\bar{x}$	*s*	*Med*	*U*	*z*	*r*
Scatter Plot	.8822	.17375	1	.6984	.22965	.67	***1761	-5.232	.41
Histogram	.9015	.16295	1	.7897	.23847	.75	**2298	-3.209	.25
Pictograph	.4949	.28715	.33	.6190	.31598	.67	**2391	-2.628	.21
Bubble Plot	.8838	.15284	1	.7976	.22386	.75	**2494.5	-2.393	.19
Overall ACS	.7906	.11501	.77	.7262	.16883	.75	*2450	-2.305	.18

* p < .05   ** p < .01   *** p < .001

The comparison of the ACSs of UK respondents for different graph formats reveals that there is a statistically significant difference between the scatter plot and the pictograph (z=-7.364, p <0.000 with a large effect size r =.52); the histogram and the pictograph (z= -7.972, p < 0.000 with a large effect size r =.57) and the bubble plot and the pictograph (z=-7.940, p < 0.000 with a large effect size r =.56). For German respondents we find that there is a statistically significant difference in ACSs between the scatter plot and the histogram (z=-2.309 , p < 0.021 with a small effect size r =.21), the scatter plot and the bubble plot (z=-2.748 , p < 0.006 with a small effect size r =.24), the histogram and the pictograph (z=-3.402 , p < 0.001 with a medium effect size r =.30) and the pictograph and the bubble plot (z=-3.497 , p < 0.000 with a medium effect size r =.31). The results indicate that the pictograph is the least understood graph format, although this is less pronounced among the German respondents. This could be due to 'bad design', but could suggest that respondents, particularly in the UK, might have been less willing to engage with something new or different. The findings suggest that showing respondents different graph formats might not make much of a difference, unless the graph formats widely differ from what respondents are used to. In that case, assessed comprehension seems to be lower.

3.1.2. Perceived comprehension (B)

In both surveys the histogram is perceived as the easiest graph format to understand (UK: 54.5%, DEU: 47.6%), followed by the scatter plot (UK: 21.2%, DEU: 34.9%), the bubble plot (UK: 18.2%, DEU: 14.3%) and the pictograph (UK: 6.1%, DEU: 3.2%). There is no significant difference in PC between the UK and German respondents ($\chi 2$ (3, n= 162) = 4.082, p = .253, Cramer's V = .159). The qualitative explanations given by the respondents suggest that the three key reasons for the popularity of the histogram, in order of popularity, are: familiarity with the graph format, perceived clarity of display and perceived ease of readability of frequencies. This can also help to explain the higher ACSs on the histogram across both samples.

3.1.3. Use by self (C)

The histogram is the most strongly preferred graph format for use by self (UK: 52.5%, DEU: 42.9%). Respondents considering their choice dependent on the planning decision at stake formed the second largest group (UK: 18.2%, DEU: 19.0%) followed by those choosing the scatter plot (UK: 13.1%, DEU: 17.5%). The bubble plot (UK: 3.0%, DEU: 11.1%), the pictograph (UK: 5.1%, DEU: 0%) and not using any graph formats (UK: 8.1%, DEU: 9.5%) were less favoured options. There is no difference in preferences expressed for use by self between the two samples ($\chi 2$ (5, n= 162) = 8.588, p = .127, Cramer's V = .230).

3.1.4. Use for showing to others (D)

The two most popular graph formats for use for showing to others were the histogram (UK: 48.5%, DEU: 52.4%) and the bubble plot (UK: 24.2%, DEU: 25.4%). Not using any graph format (UK: 16.2%, DEU: 7.9%), the scatter plot (UK: 9.1%, DEU: 11.1%) and the pictograph (UK: 2.0%, DEU: 3.2%) were less popular options. There is no difference in preference patterns between the two samples ($\chi 2$ (4, n= 162) = 2.514, p = .642, Cramer's V = .125).

The histogram is the most preferred graph format for both use by self and use for showing to others. For use for showing to others the bubble plot is the second most popular format. Its higher ranking for use for showing to others compared to use by self could be explained by the view of local adaptation practitioners that they have to do some persuading and convincing to increase buy in for adaptation actions. Qualitative survey responses suggest that the bubble plot is considered to be more visually persuasive and a good 'initial hook' for discussions.

3.2. Differences in assessed comprehension across perceived comprehension (1)

The results reported in Table 3 indicate only one significant difference in ACS across respondents' different choices on the PC – this was on the pictograph. After Bonferoni adjustment, the post-hoc Mann Whitney U test revealed that in the UK sample, those that pick the pictograph (n =6) as the easiest to understand get a higher median score (Md = .67) compared to those that pick the bubble plot (n = 18, Md = .33), U = 15, z = -2.88, p = .004, r = .29). The link between PC and ACS seems tenuous, especially considering that the pictograph seems to be an outlier in terms of ACS. Using the results from the MANOVA, we find that the ACS difference between those that chose the scatter plot, histogram, bubble plot or pictograph was statistically significant on the combined dependent variables , F (4, 99) = 2.009, p = .023; Pillai's Trace = .236; partial eta squared = .079. The dependent variables are the ACS scores for the four graph formats. The MANOVA test creates a summary variable which linearly combines the individual dependent variables (37). When the results for the four dependent variables were considered separately, using a Bonferoni adjusted alpha level of .0125, none of the differences were statistically significant. In the German sample the MANOVA did not reveal any statistically significant difference between those that chose the scatter plot, histogram, bubble plot or pictograph on the combined dependent variables, F (4, 63) = .846, p = .603: Pillai's Trace = .165; partial eta squared = .055. In summary, there is no systematic difference of ACS across PC in our samples. The key finding is that there is a clear mismatch between actual understanding and perceived ease of understanding. Compared to those who show a match between the graph format with the maximum ACS and the one chosen as the easiest to understand (UK: 66.7%, DEU: 36.5%), a sizeable proportion of the respondents (UK: 27.3%, DEU: 39.7%) achieve the maximum ACS for a graph format other than the one they perceive to be the easiest to understand.

Table 3 Differences in assessed comprehension for each graph type across perceived comprehension, use by self and use for showing to others based on Kruskal-Wallis tests

		Scatter plot		Histogram		Pictograph		Bubble plot	
		UK	DEU	UK	DEU	UK	DEU	UK	DEU
Perceived comprehension	χ^2	4.335	3.058	5.799	.855	***9.242**	.969	2.511	1.312
Use by self	χ^2	3.965	9.373	4.757	8.341	7.487	.845	5.151	2.098
Use for showing to others	χ^2	4.276	3.525	6.169	.415	2.697	3.793	4.053	2.470

* p < .05 ** p < .01 *** p < .001

3.3. Differences in assessed comprehension across use by self and use for showing to others (2 & 3)

We do not find any differences of ACSs for the four graph formats across use by self or use for showing to others (see Table 3). The MANOVA test does not reveal any differences in ACSs amongst those that choose different graphs to help them make a planning decision (use by self) in the UK sample ($F(4, 99) = 1.127$, $p = .319$; Pillai's Trace = .228; partial eta squared = .057) or in the German sample ($F(4, 63) = 1.249$, $p = .232$; Pillai's Trace = .317; partial eta squared = .079). There are no differences in ACS regarding graph choice for use for showing to others either in the UK sample ($F(4, 99) = .901$, $p = .568$; Pillai's Trace = .148; partial eta squared = .037) or the German sample ($F(4, 63) = .710$, $p = .782$; Pillai's Trace = .187; partial eta squared = .047).

3.4. Relationship between perceived comprehension and use by self and use for showing to others (4 & 5)

Our investigation into the relationship between PC and use by self found a strong link in both the UK sample ($\chi2$ (15) = 94.312, $p = .000$, Cramer's V = .564) and the German sample ($\chi2$ (12) = 46.741, $p = .000$, Cramer's V = .497). In the German sample we note that for the scatter plot, the histogram and the bubble plot the majority of the respective respondents pick the same figures both as easiest to understand and as appropriate for use by self. In the UK sample, we observe the same for the histogram and the pictograph. However, the majority of those that pick the scatter plot as easiest to understand would still pick the histogram for planning. We find a strong relationship between use for showing to others and PC in both samples (UK: $\chi2$ (12) = 51.732, $p = .000$, Cramer's V = .417, DEU: $\chi2$ (12) = 37.370, $p = .000$, Cramer's V = .445). We find a clear link between PC and use for showing to others for the histogram and the bubble plot, with the majority of respondents choosing the same graph format as the easiest to understand as well as most persuasive. Many of those that chose the scatter plot as the easiest to understand still picked the histogram for persuasion. Those that picked the pictograph were split between the histogram and 'not using a figure at all'.

We find that while use was related to perceived comprehension, it was not significantly associated with assessed comprehension. This indicates that respondents tend to use what they think they understand best, rather than what they actually understand best.

3.5. Relationship between use by self and use for showing to others (6)

The Chi Square test reveals a strong relationship between use by self and use for showing to others in both the UK sample ($\chi 2$ (20) = 68.885, p = .000, Cramer's V = .417) and the German sample ($\chi 2$ (16) = 39.646, p = .001, Cramer's V = .397). The crosstabs indicates the clearest link for the histogram and the bubble plot in both samples, with respondents choosing the same figure for use by self and use for showing to others. These results suggest that respondents' choice of graph formats for use by self and use for showing to others are internally consistent.

3.6. Effects of other sample characteristics on comprehension and use

Table 4 and 5 summarise the associations between the other sample characteristics and the four criteria (A, B, C and D), the ACSs broken down for each graph type. With education being a constant in the German sample due to all participants having at least a Bachelor degree, no statistical tests could be undertaken for this variable. Two significant findings can be seen in the UK sample. First, males (Md = .67, n = 59) have a higher ACS on the pictograph than females (Md = .33, n = 40), U = 889.500, z = -2.204, p = .027, r = .16. Secondly, a significant link between PC and the level of individual involvement in adaptation can be seen ($\chi 2$ (3, n= 99) = 9.763, p = .021, Cramer's V = .314), with the histogram followed by the scatter plot being perceived as the easiest to understand by both those with high (histogram: 49.3%, scatter plot: 18.3%) and low (histogram: 67.9%, scatter plot: 28.6%) levels of engagement. Interestingly, the 18.2% that picked the bubble plot all had high levels of engagement. As these findings were not consistent across the two samples, they will not be explored further at this stage. Overall, the results indicate that demographic variables and variables measuring the level of engagement with climate projections, knowledge of climate change and the involvement in adaptation do not have any effect on comprehension or use.

Table 4 Effects of other sample characteristics on assessed comprehension.

				Mann-Whitney U test results					Kruskal-Wallis test results		
				Gender	Education	Project-ions engage-ment	CC Knowledge	Adaptation involve-ment		Age	Work exper-ience
A	ACS - Scatter plot	**UK**	**U**	1150.5	292.0	1044.0	686.5	920.0	χ^2	2.812	7.084
			z	-.256	-.499	-.092	-.119	-.701			
		DEU	**U**	4.645	N/A	456.5	237.0	267.5	χ^2	4.007	4.040
			z	-.336	N/A	-.183	-.997	-.377			
	ACS - Histogram	**UK**	**U**	1060.5	308.5	961.5	629.0	965.0	χ^2	6.187	5.736
			z	-1.034	-.224	-.847	-.766	-.274			
		DEU	**U**	.463	N/A	353.5	250.0	243.0	χ^2	6.325	6.103
			z	-.343	N/A	-1.739	-.699	-.835			
	ACS - Pictograph	**UK**	**U**	***889.5**	308.5	958.5	621.0	897.0	χ^2	.233	5.048
			z	-2.204	-.196	-.767	-.750	-.802			
		DEU	**U**	4.275	N/A	373.5	215.5	245.5	χ^2	3.237	3.760
			z	-.853	N/A	-1.404	-1.340	-.770			
	ACS – Bubble Plot	**UK**	**U**	1149.5	209.5	943.0	552.0	992.0	χ^2	2.703	13.473
			z	-.252	-1.776	-.969	-1.556	-.018			
		DEU	**U**	.462	N/A	406.5	268.5	263.0	χ^2	2.967	9.481
			z	-.359	N/A	-.936	-.341	-.448			
	ACS – overall	**UK**	**U**	1079.5	262.0	926.0	547.0	879.5	χ^2	4.617	4.838
			z	-.721	-.825	-.972	-1.401	-.896			
		DEU	**U**	4.695	N/A	460.0	275.0	226.5	χ^2	4.545	7.294
			z	-.230	N/A	-.113	-.200	-1.080			

* p < .05 ** p < .01 *** p < .001

Table 5 Effects of other sample characteristics on perceived comprehension, use for self and use for showing to others.

				Chi-square test for independence test results						
				Age	Gender	Education	Work experience	Projections engagement	CC Knowledge	Adaptation involvement
B	PC	**UK**	χ^2	14.639	1.878	1.285	13.770	3.699	7.283	***9.763**
		DEU	χ^2	19.672	2.389	N/A	19.214	2.191	3.053	1.616
C	Use by self	**UK**	χ^2	16.824	3.864	1.800	39.504	6.413	3.077	3.423
		DEU	χ^2	17.001	4.243	N/A	31.172	2.337	2.751	8.185
D	Use for showing to others	**UK**	χ^2	19.094	2.703	1.979	36.707	1.685	3.107	1.460
		DEU	χ^2	25.929	4.228	N/A	33.307	8.618	5.130	3.253

* p < .05 ** p < .01 *** p < .001

4. Discussion

The aim of this paper was to explore empirically the differences and similarities in the comprehension of and preference for different forms of visualisation amongst adaptation practitioners in the UK and Germany. Our findings suggest that in both countries there is a disconnect between users' assessed comprehension, perceived comprehension and use by self and use for showing to others. However, there is a strong link between people's perceived comprehension and their preferences for graph formats they use themselves and for communicating with colleagues and superiors about the necessity to take action on adaptation (see Fig 3.).

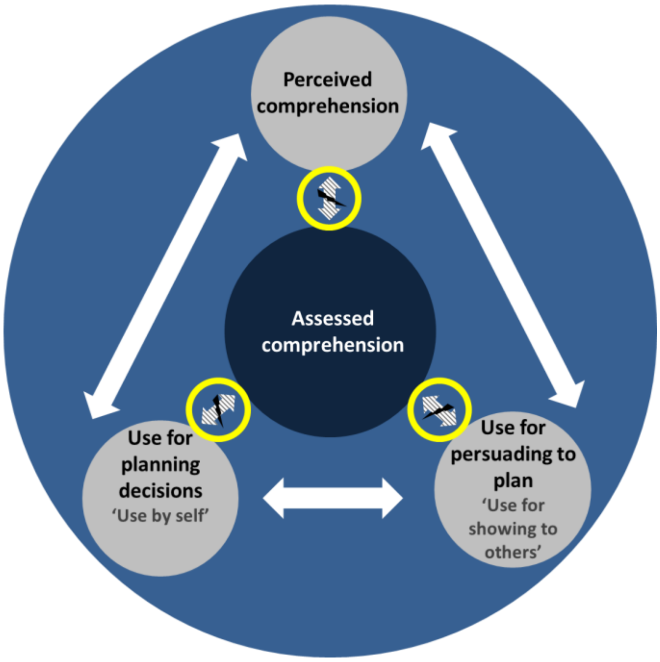

Figure 3 Associations between the four key criteria showing on the one hand the disconnect between users' assessed comprehension and the other three key criteria, and on the other hand the strong relationship between perceived comprehension and use by self and use for showing to others.

Our findings regarding the gap between comprehension and preference resonate with the results reported in the health sciences literature. Parrott et al. (9) found that people's reading of familiar graph formats is affected by learned heuristics: respondents' familiarity plays a bigger role in the process of reading and sense-making of graphs than the actual comprehension of the information shown. They argue that this could not only lead to a disconnect between the encoded and decoded meaning of the graph but also in respondents stating preferences for graphs that they do not understand as well as other graphs (9). Our results also resonate with findings of a study of physicians' assessment of visually displayed information, in which respondents' preferences for graph formats and displays appeared to be based on familiarity with the graph formats rather than on their comprehension (10). Qualitative explanations in our surveys suggested this as well.

The disconnect supports Ancker et al.'s (8) argument that although it is important to focus on the preferences of information recipients, this may result in poor quantitative judgements. There is a complex interplay between respondents' comprehension and preferences for use of visualisations in practice and cognitive biases are involved in it. We need to be aware of them and consider how they could be dealt with or overcome if we are to make visual communication of climate projections more effective.

The biases in information provision and use are consistent across the two samples. This is interesting considering the differences in relation to adaptation at the national level between the two countries (34, 35). This is not to say that local adaptation practitioners are a homogenous group and that advice for tailoring is generalizable. On the contrary, the findings highlight that comprehension and preferences, and thus usability, are specific to the individual and in many cases likely to be connected to the stage of adaptation planning in a given local authority. Respondents highlighted that certain graph formats are better for initial persuasion needed to ensure buy-in into adaptation, whereas other formats communicate better the exact figures needed for more specific adaptive measures. The consistent cognitive biases and the within group differences demonstrate that the demands for more 'audience specific communication' may be more complex and challenging than has been recognised to date.

We acknowledge that there are potential limitations to our findings, such as self-selection bias: our sample may have more respondents with an inherent interest in visualisation and under-represent the less interested. Due to different computer display sizes and resolutions, some respondents reported not being able to see the entire visualisation without scrolling, which may have affected their responses. However, self-selection bias is an issue that social science surveys will always have to be mindful of and seeing the visualisations did not appear to have been systematically problematic. Therefore we do not think that these issues significantly impact our findings. Furthermore, it could also be that those who are less motivated to utilise climate projections may be less motivated to utilise formats that they perceive to be less easy to use (even if they are better at using them), which could impact on the relationship between assessed and perceived comprehension. Lastly, our statistical tests may have lower statistical power than ideally desirable due to the small sample size. Nevertheless, we have uncovered interesting patterns that are consistent across both samples, increasing our confidence in our findings. Further experimental data collection with larger samples and in more countries would allow for more rigorous statistical testing.

The inconsistencies and disconnects between respondents' comprehension and preferences leave us to wonder how our results could inform the communication of climate projections as well as information tailoring more broadly. Lemos and Rood's (38) argument that producers and users of knowledge have different assumptions as to what is useful and what is actually usable information should be applied also to the visual aspects of information provision. Whilst research strives to find new and more effective ways of communication and visualisation of information and impacts, we acknowledge that what is effective cannot necessarily be judged a priori by the information producers (4) without empirical testing. Even if individual mismatches between comprehension and preferences could be overcome or addressed, past research highlights that there are further cognitive challenges, such as confirmation bias, anchoring or belief persistence (39), and institutional complexities, such as different approaches to risk governance (40) that need to be considered in tailoring efforts. What is designed as the best-fit for comprehension and preferences may not fit with the local institutional contexts and guidelines.

We ought to be mindful of questions such as who is doing the tailoring and for whom? Should we tailor communication to respondents' comprehension or should we tailor it to their preferences? More to the point, should we tailor information if this results in something that users do not want? We cannot entertain simplistic ideas of finding a silver bullet for tailored visual information provision. We should consider co-design (41) alongside co-production. We cannot lose sight of the ulterior motive of climate science communication to foster action on adaptation and improve adaptive capacity. Strengthening adaptive capacity will often occur through social and organisational learning (42, 43). Vulturius & Swartling (43) found that learning and engagement with adaptation improved when information users could relate communicated scientific knowledge better to their contexts and needs, highlighting a need for more tailored information. If co-production and co-design of information were thus to take place alongside each other, it can be anticipated that learning is further increased with an ultimate positive impact on adaptive capacity as well.

5. Conclusion

In the introduction we highlighted that visualisation of information faces the demands for more audience-specific tailoring, greater evaluation of its effectiveness and more empirical evidence. Yet, requests for the communication and visualisation of climate change adaptation information to be more effective and understandable (25) and suggestions for the tailoring of climate information (26) have remained mostly within the theoretical realm. We report empirical evidence about the complexities involved in visualisation of information and tailoring of communication in practice. Our results highlight that ideal solutions for tailored communication of climate data for decision making on adaptation may not be found and that their search may be problematic and futile because of a lack of within-group homogeneity and the disconnect between assessed and perceived comprehension and preferences for the use of graph formats. This does not mean that further advances in this field are not needed - our results just highlight that claims regarding effective visualisations need to be tested and verified with more veracity, as much within groups as between them.

We recognise that visual information provision to decision-makers is only a small part of the much more extensive process of co-production of knowledge and the facilitation of user-producer interaction. Yet visual information is a crucial issue if we are to consider the information provision and knowledge production process holistically. Our paper responded to the request for more empirical evidence, researching both adaptation practitioners' comprehension and their preference for different visual formats for the communication of climate projections. We did not set out to find an 'ideal' visualisation, but instead our results demonstrate that we need to invest more thought into how tailoring can be facilitated at the same time as realising that even though there may be no such thing as a solution to the tailoring question, co-design and increased empirical testing may take us some way towards more rather than most effective visualisations. Being aware of the potential difficulty in bridging the 'gap' between assessed comprehension and perceived comprehension and use, future research in this field ought to seek to better understand how it can be incorporated and better understood in the tailoring process.

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