

Institution: University of East Anglia		
Unit of Assessment: 4 - Psychology, Psychiatry and Neuroscience		
Title of case study: Improving the effectiveness of visualisation and communication of climate science to a diverse worldwide audience		
Period when the underpinning research was undertaken: 2005 - 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
K. Coventry	Professor	2012 – to present
I. Lorenzoni	Senior Lecturer	2006 – to present
J. Harold	Lecturer	2017 – to present
D. Griffiths	Lecturer	2014 – to present
H. Gudde	Post-doctoral Researcher	2017 – to present
A. Minns	Tyndall Centre Executive Director	2003 – to present
Period when the claimed impact occurred: 2016 – 2020		
Is this case study continued from a case study submitted in 2014? No		
1. Summary of the impact An interdisciplinary team of psychological and social scientists at UEA produced a set of guidelines to improve the effectiveness of visualisations of climate change data based on UEA-led research on human communication and perception. These guidelines have been adopted by the Intergovernmental Panel on Climate Change (IPCC) and other organisations (e.g. Future Climate for Africa) as a gold standard to communicate climate science findings. The UEA team worked directly with the IPCC using these guidelines to enhance high-profile IPCC reports with significant dissemination, including the <i>Special Report on 1.5°C of Global Warming</i> and the <i>Special Report on Climate Change and Land</i>. These reports have been instrumental in informing governments' recent climate change mitigation policies. The widespread adoption of the UEA guidelines by the climate science community has improved how climate science data are communicated to policy makers and other stakeholders worldwide.		
2. Underpinning research Non-specialists often have difficulty processing and understanding complex scientific findings, whether presented visually or in written form. Climate change data are regarded as a paradigmatic case where difficulties in comprehension can lead to disengagement and misunderstanding. Such negative outcomes are particularly costly given the international governmental and societal effort required to meet the climate change challenge. The IPCC – the United Nations body providing scientific assessments of climate change to 195-member countries/governments – identified improvements in the presentation of scientific information as a key strategic priority (IPCC Expert Meeting on Communication, 2016). Interdisciplinary research at UEA has helped to address this priority. Work led by Coventry has explored how people comprehend, describe and remember visual information (e.g., Outputs 1, 2). Output 1 shows how language affects how people process visual information, and Output 2 presents a model combining expectations from long term memory with perceived visual information to account for (mis)memories for spatial information. This work unpacks the mechanisms involved in processing and remembering visual information critical for the design and communication of complex visual information. This research on perception and communication has been integrated with research by UEA social scientists in the School of Environmental Sciences and the Tyndall Centre on how people understand and engage with climate change. For example, Output 3 identifies the barriers to engagement with climate change in the UK public. Output 4 demonstrates that images associated with climate change vary visually across a range of dimensions, and that some images can trigger affective associations, indicating individuals are distant from immediate		

consideration of climate change.

Coventry, Lorenzoni and Harold formed an interdisciplinary team and collaborated with the NSF-funded Spatial Intelligence and Learning Center (USA) to develop a set of guidelines to enhance the production of climate science figures and graphs (Output 5). This research synthesised the cognitive and psychological science literature using current evidence about bottom-up and top-down constraints in the representation and comprehension of data visualizations.

Output 6 shows that non-specialists associate greater visual complexity, as measured by subband entropy, with comparatively greater perceived comprehension difficulty. In addition, the research found that IPCC authors are aware of problematic complexity of figures (e.g., those in Summary for Policy Makers (SPM) reports). However, the IPCC authors identified constraints that prevented them from making the figures more accessible, such as maintaining scientific rigour, page space constraints, and catering to the needs of experts. Although the set of SPM figures support the narrative of the reports, their visual complexity is a barrier to effective communication.

3. References to the research

(Outputs; UEA authors highlighted in **bold**)

1. **Coventry, K. R.**, Christophel, T., Fehr, T., Valdés-Conroy, B., Herrmann, M. (2013). Multiple routes to mental animation: Language and functional relations drive motion processing for static images. *Psychological Science*, 24(8), 1379-1388. DOI:10.1177/0956797612469209
2. **Coventry, K. R.**, **Griffiths, D.**, Hamilton, C. (2014). Spatial demonstratives and perceptual space: Describing and remembering object location. *Cognitive Psychology*, 69, 46-70. DOI:10.1016/j.cogpsych.2013.12.001.
This work was awarded the British Psychological Society Cognitive prize in 2015.
3. **Lorenzoni, I.**, **Nicholson-Cole, S.**, **Whitmarsh, L.** (2007). Barriers perceived to engaging with climate change among the UK public and their policy implications. *Global Environmental Change*, 17, 445-459. DOI:10.1016/j.gloenvcha.2007.01.004
4. **Lorenzoni, I.**, Leiserowitz, A., **Doria, M. D.**, Poortinga, W., Pidgeon, N. F. (2006). Cross-national comparisons of image associations with “global warming” and “climate change” among laypeople in the United States of America and Great Britain. *Journal of Risk Research*, 9, 265-281. DOI:10.1080/13669870600613658
5. **Harold, J.**, **Lorenzoni, I.**, Shipley, T. F., **Coventry, K. R.** (2016). Cognitive and psychological science insights to improve climate change data visualisation. *Nature Climate Change*, 6, 1080-1089. DOI:10.1038/nclimate3162
6. **Harold, J.**, **Lorenzoni, I.**, Shipley, T. F., **Coventry, K. R.** (2020). Communication of IPCC visuals: IPCC authors' views and assessments of visual complexity. *Climatic Change*, 158, 255–270. DOI: 10.1007/s10584-019-02537-z

Examples of Grant Support

Project: Deictic Communication – A Multidisciplinary Training (DCOMM).

PIs: Coventry, K. R., and co-PIs from other European countries.

Funder: Marie Skłodowska-Curie European Training Network. **Dates:** 2016-2020.

Grant value: EUR3,460,823 (GBP597,873 to UEA).

Project: Improving methods of communicating climatic uncertainties to aid decision-making.

PIs: Lorenzoni I., Harold, J., Coventry, K. R..

Funder: PricewaterhouseCoopers. Future Climate For Africa - Applied Research Fund.

Dates: 2017-2018. **Grant value:** GBP84,372 (UEA GBP44,568).

Project: The production of a more user-focused set of the Nature Climate Change guidelines (Output 5) for IPCC authors, design agencies, and other scientists interested in communicating climate change effectively.

PIs: Minns, A., Harold, J., Coventry, K. R., Lorenzoni, I..

Funder: Norwegian Environment Agency Funding and Helix. **Dates:** 2017.
Grant value: GBP15,000.

Project: Language and Perception (LanPercept).

PIs: Coventry, K. R., and co-PIs from other European countries.

Funder: Marie Curie Initial Training Network. **Dates:** 2012-2016. **Grant value:** EUR4,120,000 (GBP397,864 to UEA).

4. Details of the impact

In the face of substantial evidence that climate science communications are often too complex to understand by non-specialists, decision-makers have demanded more accessible and relevant climate information from experts. In response, the interdisciplinary UEA team has used their underpinning psychological research to i) develop new scientifically-grounded guidelines for the production of more accessible data visualisations of climate science, and ii) apply these guidelines to support the creation of data visualisations with world-wide dissemination and reach. The guidelines and associated testing and production of data visualizations have influenced scientists, policy makers, governmental bodies, environmental organisations, and ultimately members of the general public concerned about anthropogenic climate change.

(i) Creation and broad adoption of guidelines for dissemination of complex visuals

The UEA team synthesized the cognitive and psychological science literature (including their own findings) on how people comprehend visual information into a set of guidelines for use by climate scientists to improve visualizations used to communicate climate science data (Output 5). The team then engaged with the IPCC and advised them to consider the role of cognitive and psychological science to enhance future IPCC communications. This culminated in the organization of a major workshop in London on *Communicating Climate Change* (10th-11th November 2016) bringing climate scientists, policy makers and experts on communication together for the first time.

The UEA team then developed a condensed version of the guidelines (the 'MADE' principles – Message, Audience, Design, Evaluation) to support the IPCC, funded by the Norwegian Environment Agency, the EU (HELIX project) and the Tyndall Centre. **Source 1** presents the principles and 12 associated guidelines and shows how the principles and guidelines apply, with examples of 'before' and 'after' IPCC SPM figures. Figure 1 (below) shows an example of an IPCC Figure that on the surface appears well designed (it is visually appealing), but is in fact very hard to comprehend. The application of the MADE principles (e.g., strategic use of text to structure visual processing; see Output 1) improved comprehension by doubling the number of policy makers who actually understood it when tested. The resulting report documenting the MADE principles was presented to the climate science community at the 2nd World Symposium on Climate Change Communication (**Source 2**). The report was featured in the IPCC Communications Handbook by Climate Outreach (**Source 3**; MADE principles discussed and cited, e.g., p. 23) and in an e-learning course supporting African experts and governments in the review of IPCC reports (**Source 4**).

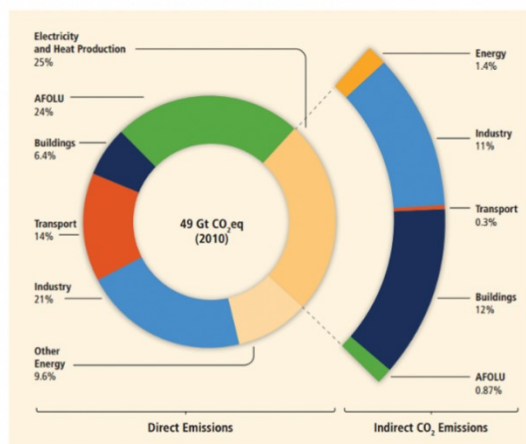
The guidelines have been adopted in the IPCC Visual Style Guide (**Source 5**). The IPCC distributes this guide to all IPCC authors assessing climate change research and communicating the research via IPCC reports. For example, for the Special Report on Global Warming of 1.5°C, the IPCC distributed the style guide to 829 main authors from over 80 countries. The UEA team presented the 'MADE' report directly to the IPCC at three IPCC events with lead authors in Sweden (2017), Ireland (2018) and France (2019).

The guidelines have also garnered interest from British Telecom and the Met Office, with invitations to present at their headquarters. Short articles have been written on request for CarbonBrief and ENDSReport (**Source 6**). Furthermore, the *Nature Climate Change* article and MADE principles resulted in collaboration on a *Future Climate for Africa* grant with two large interdisciplinary teams of researchers (AMMA-2050, FRACTAL) working with a wide range of stakeholders (politicians, government officials, farmers) in several African nations (South Africa, Botswana, Senegal, Namibia, Malawi). These activities have further extended the reach of MADE to the communication of climate uncertainty and understanding of uncertainty models

across Western and Southern Africa. The final report from the Future Climate for Africa grant (2018) including the MADE principles and applications of them, has been circulated across 35 countries to scientists, policy makers and governmental delegates (**Source 7**).

Before

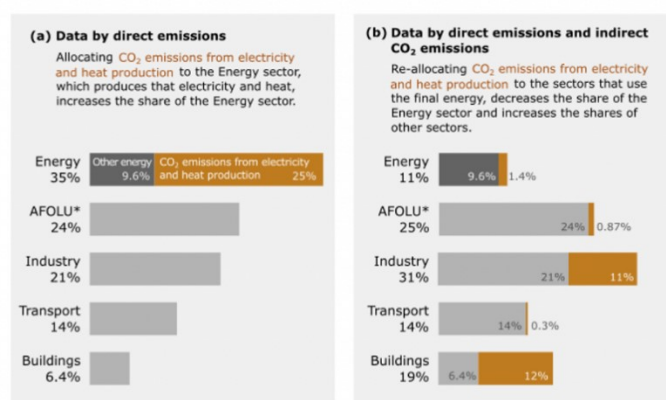
Greenhouse Gas Emissions by Economic Sectors



Total anthropogenic GHG emissions (GtCO₂eq/yr) by economic sectors. Inner circle shows direct GHG emission shares (in % of total anthropogenic GHG emissions) of five economic sectors in 2010. Pull-out shows how indirect CO₂ emission shares (in % of total anthropogenic GHG emissions) from electricity and heat production are attributed to sectors of final energy use. 'Other Energy' refers to all GHG emission sources in the energy sector as defined in Annex II other than electricity and heat production [A.II.9.1]. The emissions data from Agriculture, Forestry and Other Land Use (AFOLU) includes land-based CO₂ emissions from forest fires, peat fires and peat decay that approximate to net CO₂ flux from the Forestry and Other Land Use (FOLU) sub-sector as described in Chapter 11 of this report. Emissions are converted into CO₂-equivalents based on GWP₁₀₀ from the IPCC Second Assessment Report. Sector definitions are provided in Annex II.9.

After MADE

Greenhouse gas emissions in 2010 from human activity, by economic sectors



*AFOLU = Agriculture, forestry and other land use

Total greenhouse gas emissions from human activity in 2010: 49 gigatonnes CO₂-equivalent

Technical notes:
'Other Energy' refers to all GHG emission sources in the energy sector as defined in Annex II other than electricity and heat production [A.II.9.1]. The emissions data from Agriculture, Forestry and Other Land Use (AFOLU) includes land-based CO₂ emissions from forest fires, peat fires and peat decay that approximate to net CO₂ flux from the Forestry and Other Land Use (FOLU) sub-sector as described in Chapter 11 of this report. Emissions are converted into CO₂-equivalents based on GWP₁₀₀ from the IPCC Second Assessment Report.

Figure 1: An example of MADE principles in action, applied to an IPCC Figure. While the 'before' version (left panel) appears visually appealing, it is in fact very hard to understand. Multiple design principles from MADE applied to the Figure significantly improved comprehension in both policymakers ($N = 54$, $p < .001$) and researchers ($N = 179$, $p < .001$). For policy makers, 44% correctly answered a comprehension question after viewing the original version (left), but 93% did so after viewing the revised version (right).

(ii) Implementation of the guidelines in IPCC reports

The collaboration with the IPCC developed further in 2017 with workshops at IPCC meetings (with >200 lead authors plus other non-lead contributors) on figure presentation, and iterative design and testing. This was achieved by working closely with IPCC Working Group I, and their information design agency in Norway (InfoDesignLab), culminating in new versions of all of the figures for use in the IPCC Special Report on Global Warming of 1.5°C Summary for Policy Makers (drafting author Harold, p. 3; Coventry, Lorenzoni and Gudde are acknowledged "with special thanks", p. 5; **Source 8**). As Dr. Anna Pirani, Head of Technical Support Unit for IPCC Working Group I, notes, "***This collaboration and the integration of the MADE principles and cognitive psychological expertise have transformed how [the IPCC] develop figures, particularly those of the Summary for Policymakers.***" Subband entropy (a computational measure of visual complexity) is directly related to ease of comprehension of figures (Output 6); applying the MADE principles to early drafts of the SPM figures with iterative testing led to a significant reduction in complexity across the set of final figures ($p = .01$), enabling the figures to be more easily comprehended. In the month following its publication, over 20,800 online and print articles published in 168 countries featured the report, with many of these articles reproducing the figures directly. Moreover, there were over 5,800 TV/media broadcasts in English alone. The figures have appeared in major media outlets in over 250 countries informing national governments' policies on climate change and "***[the figures are] very widely reproduced in government reports.***" (IPCC TSU WGI Head Dr. Anna Pirani, **Source 9**).

The success of the collaboration with the IPCC on the 1.5°C Reports led directly to further work as consultants (**Harold, Coventry, Lorenzoni**), again working with authors on all of the SPM Figures applying the MADE principles for the IPCC Special Report on Climate Change and Land (2019, **Source 10**; Harold is drafting author, p. 3, of the SPM and the UEA team worked as consultants on figure testing and production, **Source 9**) and the IPCC Working Group I contribution to the Sixth Assessment Report (expected 2021). The Climate Change and Land

report within its first week of publication featured in 7,520 print and online articles across 118 countries in 30 languages, again with reproduction of IPCC figures in much of the coverage.

The figures in IPCC reports are influential in the field of climate science and form the basis for world-wide political discussion to inform action on climate change. As IPCC Working Group III Head of Technical Support Unit (Science) Dr. Raphael Slade states, “...***the SPM is the key document used by the world’s governments in forming climate science policy. In particular, the figures are key to influencing policy and as such have been reproduced in government reports.***” (Source 9). The figures from the Special Report on Global Warming of 1.5°C alone have been accessed by millions of people across the world.

In addition to the publication of key figures in IPCC reports co-produced with the IPCC authors and InfoDesignLab, the MADE principles have had a deep effect on the way in which climate change scientists approach the development and production of scientific figures, with guidelines for IPCC authors embracing the need to factor in audience and iteratively test figures before publication. The dissemination and implementation of the MADE principles are now an integral part of visual figure development for the IPCC. As Head of IPCC WGIII TSU (Science) Dr. Raphael Slade states: “***The UEA team has had a profound impact upon the presentation of climate science data in IPCC reports, improving the reach of communication of complex climate change data for use by world governments and other key stakeholder groups.***” (Source 9).

5. Sources to corroborate the impact

1. MADE principle and guidelines

Harold, J., Lorenzoni, I., Coventry, K. R., Minns, A. (2017). *Enhancing the accessibility of climate change data visuals*. Report and associated website. Tyndall Centre for Climate Change Research, UK.

2. Plenary Presentation of MADE principles by Espen Larsen (Norwegian Environment Agency)

Larsen, E. (February, 2018). Making climate data visuals easier to understand. *2nd World Symposium on Climate Change Communication*, Graz, Austria.

3. IPCC handbook by Climate Outreach (MADE principles featured and cited)

Corner, A., Shaw, C., & Clarke, J. (2018). *Principles for effective communication and public engagement on climate change: A Handbook for IPCC authors*. Oxford: Climate Outreach.

4. e-Learning course on Expert and Government Review of IPCC reports: Digital source

downloaded from YouTube (9th February 2021) and held on file at UEA.

5. IPCC Visual Style Guide for Authors (based on UEA work; Harold is a contributor)

Gomis, M.I. & Pidcock, R. (2018). *IPCC Visual Style Guide for Authors*, IPCC Working Group I Technical Support Unit.

6. Key reports to external bodies to widen reach

CarbonBrief article. Harold, J. (October, 2017). How IPCC graphics could be made more accessible. Carbon Brief. *ENDs Report article*. Coventry, K. R. (March, 2017). Changing perceptions: Belief and climate science.

7. Future Climate for Africa Final Report

Coventry, K. R., Harold, J., Lorenzoni, I., Kavonic, J., Diop, I. S., & Visman, E. (2018). Improving methods of communicating climatic uncertainties to aid decision making. Project report and guidelines prepared for *Future Climate for Africa*.

8. IPCC Special Report on Global Warming of 1.5°C. Summary for Policy Makers and Main Report.

9. Letters from Heads of Technical Support Units for IPCC Working Groups I and III respectively

These letters identify the reach and impact of the IPCC reports and figures in particular, with specific reference to the major input from the UEA team.

10. IPCC Special Report on Climate Change and Land Summary for Policy Makers

Harold is named as a drafting author (p. 3) of the Summary for Policy Makers. The UEA team worked as consultants on figure testing and production (see Source 9).