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Linguistic analysis IPCC summaries for policymakers and associated coverage

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The Intergovernmental Panel on Climate Change (IPCC) Summary for Policymakers (SPM) is the most widely read section of IPCC reports and the main springboard for the communication of its assessment reports. Previous studies have showed that communicating IPCC findings to a variety of scientific and non-scientific audiences presents significant challenges to both the IPCC and the mass media. Here, we employ widely-established sentiment analysis tools and readability metrics to explore the extent to which information published by the IPCC differs from the presentation of respective findings in the popular and scientific media between 1990 and 2014. IPCC SPMs clearly stand out in terms of low readability, which has remained relatively constant despite the IPCC's efforts to consolidate and readjust its communications policy. In contrast, scientific and quality newspaper coverage has become increasingly readable and emotive. Our findings reveal easy gains that could be achieved in making SPMs more accessible for non-scientific audiences.

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Given the magnitude of the problem as well as the diverse set of audiences the IPCC reports to, the way in which findings have been communicated to – and received by – the media has sparked considerable controversy[1,2], epitomizing the sharp divide between communicating within the scientific community and conveying findings to the media[3]. Crucially, IPCC SPMs can be seen as reporting from experts in one field (scientists) to experts in different fields (scientists from other fields and policymakers), with all the disciplines and sub-disciplines each of these fields contain. The IPCC's efforts to consolidate and readjust its communications policy illustrate the challenges this creates. The IPCC's remit is to synthesize and communicate the current state of climate research to governments and policy-makers at all levels[4]. Its findings should be communicated in a way that can be understood by a non-scientific audience[5]. One of its key principles is to be policy-relevant but not policy-prescriptive[6]. We would therefore expect SPMs to reflect these principles by adopting a clear and neutral language that can be understood by a non-specialist audience. At the same time, it is of crucial importance how the print media interpret the results presented by the IPCC, as pivotal agents in science communication[7] to the general public. Previous research has focused on the way in which IPCC probabilistic statements are interpreted[8,9], and on the discursive construction of the IPCC in national newspapers[10] and social media coverage[11,12], including the influence of grammatical and word choices[13].

The purpose of this study is to analyse the language that has been used in IPCC SPMs as well as a sample of popular science journals and UK and US national (quality and tabloid) newspapers on the launch of the IPCC assessment reports (N = 1,010; see **Supplementary Table 1**) between 1990 and 2014. We focus on two dimensions of this communication process. The Flesch Reading Ease algorithm[14,15] enables us to assess the comprehension of

IPCC SPMs and related print media coverage. The algorithm is based on the assumption that text containing longer sentences and more complex words is more difficult to comprehend. The content analysis software DICTION[16] allows us to assess the degree of optimism and therefore the tone of different bodies of text. Both are widely established metrics that have been used in a variety of contexts ranging from paediatrics[17] to accounting research[18,19].

Flesch Reading Ease scores by publication type for the period 1990-2014 are presented in **Figure 1**. Average scores reflect that all four publication types target different audiences, employ a different language and transmit different messages. Mean scores across tabloid newspapers (*Daily News, The Mirror, The Sun*) and quality newspapers (*New York Times, Washington Post, The Independent, The Times*) are relatively low compared to the way in which these publications cover other issues[14]. This is unsurprising given that the launch of an IPCC report is a very specific event referring to a complex phenomenon. For scientific publications only editorials and news articles of *Nature* and *Science* were considered. They occupy a middle-ground between IPCC SPMs and quality newspaper coverage. IPCC SPMs and tabloid coverage on the launch of the reports clearly stand out with mean Flesch Reading Ease scores of 20 and 50, respectively (**Figure 1**).

However, changes can be observed over time in some publication types (**Figure 2**; see also **Supplementary Figure 1**). Readability of quality newspapers and scientific publications peaks in 2007, possibly as a result of a relatively high share of opinion pieces linked to increased public concern triggered by major media events around the time such as the Stern Review[20] and the Nobel Peace Prize awarded to Al Gore and the IPCC[21]. The fourth assessment report in 2007 is also the first IPCC Report to receive significant coverage by tabloid newspapers included in our sample.

In contrast, readability of IPCC SPMs does not follow this trend. Whilst no significant differences in readability scores can be identified in mean scores between the five different assessment periods, descriptive statistics show that mean readability scores for the First Assessment Report (AR1) SPMs are notably higher than for those of later assessment periods. This decrease might reflect the increasing complexity of the underlying science over time. At the same time, later SPMs might assume a higher degree of prior knowledge on behalf of the reader. For example, the initial sections of the AR1 Working Group 1 SPM (*'Introduction: what is the issue?'*, FRE 44.1; *'What are the greenhouse gases and why are they increasing?'*, FRE 37.4) provide a more general introduction to the subject area and are clearly aimed at a non-expert audience. As such, readability scores of these sections are notably higher than the remainder of this SPM. No such passages, introducing the basic underlying science in layman's terms, can be found in later SPMs. However, this decrease in readability over time is not a uniform trend across the different Working Groups (WGs). WG2 and WG3 show clear downward trends, whereas readability of WG1 SPMs remains relatively stable over time. In line with previous studies[22], these differences between working groups show that natural sciences are not necessarily the most difficult ones to communicate to general audiences.

In addition to the link between scientific fields and writing styles, another more pragmatic reason could be that WG2 and WG3 are much more diverse in terms of the scientific fields they draw from than the relatively homogeneous WG1[23]. Likewise, findings from WG2 and WG3 might be exposed more directly to pressures arising from the remit to be policy-relevant but policy-neutral[6]. This diversity of scientific fields and policy implications might result in a greater need to compromise, in turn resulting in longer and more complex

sentences. The AR5 WG3 SPM is the least readable document across the entire sample with a Flesch Reading Ease score of 6.7.

A different pattern can be identified in the readability of synthesis reports (SYR) over time. Again, the AR1 synthesis report shows the highest readability score. However, readability drops sharply in AR2 and subsequently recovers in AR3 and in particular AR4, albeit remaining at a level that is lower than in AR1. There is another sharp drop in readability from AR4 to AR5 which is not surprising given AR5's WG3 and WG2 low readability scores. The average readability score across the three Working Groups for each assessment report is very close to the readability score of the Synthesis SPM for each assessment report. This observation is consistent with the fact that the Synthesis report draws most of its text from the other WGs SPMs.

The readability of Technical Summaries (TSs), pre-plenary and post-plenary SPMs for each WG in AR4 and AR5 were compared (**Figure 3**). TSs are intended to capture the most important scientific aspects of the full Working Group Assessment Report; they are longer than SPMs and include pointers to the chapters and sections where the full assessment can be found[24]. The pre-plenary SPM is a confidential draft that is sent to governments for a final review a few months before the WG and IPCC session that approves and accepts the SPM (thus making it post-plenary after copyediting) and the Assessment Report respectively. The plenary process is important to the SPM because its "approval" means that the material has been subjected to detailed line by line discussion and agreement between government delegates and authors. Being more scientific, one would expect TSs to be less readable than SPMs and given the line by line approval one would expect pre-plenary SPMs to be less readable than post-plenary SPMs. This logical pattern is only observed twice (AR4

WG3 and SYR) and its reverse once (AR5 WG2) with one more occasion when TS readability is higher than SPMs (AR4 WG1). In all other instances (five out of eight cases), TS readability is lower than SPMs readability, except for AR5 WG3 post-plenary SPM (which is exceptionally low). When comparing pre- and post-plenary SPMs, in five out of eight cases, the readability is lowered by the plenary process. We compared each change in AR4 and AR5 SPM readability (from pre- to post-plenary) with IPCC plenary discussions as reported by the Earth Negotiation Bulletin[25] (see **Supplementary Table 2**). We found a strong relationship between political mood and SPM readability. When political tensions and disagreements are high (AR4 WG1, WG2 and AR5 WG1, WG3, SYR) readability is lowered. When plenary sessions are characterised by efficient organisation, constructive and straight-forward exchange and a good spirit of cooperation (AR4 WG3, SYR and AR5 WG2) readability is increased. It is worth highlighting AR5 WG3 as the largest decrease in readability after plenary in our sample (ΔFRE = -5.3); Earth Negotiation Bulletin reporting of this plenary session show the political nature of discussions characterising line by line approval as "arduous" and 'concerns of countries often expressed in the UNFCCC [United Nations Framework Convention on Climate Change] context leaking into the IPCC' plenary'.

Clear differences can also be identified between the different publication types as well as over time in terms of DICTION optimism scores (**Figure 4**). Starting with the assumption that IPCC SPMs adopt a language that is neutral in tone, we have used the mean optimism score across all IPCC SPMs as a benchmark for our assessment. For all other documents, raw DICTION scores were converted into Z-scores, expressing the deviation of the score of each individual document from the mean score of IPCC SPMs, divided by the standard deviation. We can therefore identify how the tone of related media coverage differs from the original

SPMs. **Box 1** provides illustrative examples of coverage with corresponding readability and optimism scores.

On average, the tone of scientific publications, quality and in particular tabloid coverage is clearly more pessimistic than the tone found in the IPCC SPMs. In line with previous research[26], the clearest deviations can be found among tabloid newspapers. Newspapers need to turn a piece of scientific information into a piece of news, which among other aspects requires bringing future climate change consequences into the sphere of immediate interest of the reader. Using emotive language is one of the journalistic strategies for bringing the future into the immediate[27].

Linguistic differences in coverage between publication types are also reflected by the frequency of terms indicating a positive or negative outlook in the DICTION dictionary. **Table 1** presents a comparison of terms according to their relative frequency in each of the four publication types. Unsurprisingly, *risk* emerges as a central term in SPM texts: across all 20 SPMs, the term is mentioned 462 times and thus accounts for 10% of all cases in which any of the 784 DICTION terms indicating either positive or negative outlook are mentioned. In stark contrast, the mean frequency of the term *risk* across all four publication types is half of that. The terms with the highest differential in frequencies for SPMs compared to other publication types indicate a very measured use of language; for example, *positive*, *negative*, *important*, *qualified* or *knowledge* all reflect a comparatively neutral tone even though they indicate a positive or negative outlook.

Tabloid coverage reflects a clearly different use of language. Extreme weather events (*flood*, *disaster*, *storm*) and their catastrophic consequences (*poverty*, *crises*, *death*) emerge as

common themes. Overall, negative terms predominate in contrast to the three other publication types that reflect a more balanced distribution of positive and negative terms.

Beyond the differences in mean optimism scores, interesting changes over time can be identified (**Figure 5**; see also **Supplementary Figure 2**). Scientific publications show relatively moderate deviations from SPM optimism scores, with only little visible differences over time. In stark contrast, a downward trajectory can be identified in quality and tabloid newspapers, with the tone of coverage becoming increasingly pessimistic over time. It should be noted that the extreme score for tabloid coverage around AR3 is based on only five tabloid articles published in this period. Again, increasing levels of public awareness of climate change might have resulted in a profound change in newspaper coverage of the launch of IPCC assessment reports: related coverage can be expected to have moved from the science section towards headline news over time, in turn resulting in a less neutral and thus more emotive tone of this coverage. This is further supported by the fact that over time, more extreme values and thus an increasing polarization can be identified in both quality and tabloid newspaper coverage. In 1990, deviations of more than one unit from mean IPCC SPM optimism scores could be found in 50% of all coverage in that year. However, this share steadily increases to 68% in 2013/14. It is interesting to note that across the sample, Flesch Reading Ease scores are significantly negatively correlated with DICTION optimism scores (Spearman's ρ; $r = -0.17$; $p < 0.001$). In other words, more readable text tends to have a more pessimistic tone.

Our findings have important implications for the IPCC and communication of science more generally. The IPCC needs to find ways to improve the readability of its SPMs, particularly those of WG3, but also WG2 more recently. Engaging professional science communicators

as part of the negotiation of SPM texts could improve the readability of these documents, in particular given that we found that this negotiation between countries and scientists at the IPCC AR5 WG3 plenary had a further detrimental impact on the readability of their SPM. At the same time, plenaries are time-constrained events where yet another actor could potentially hinder rather than help, and add to already existing concerns that the original voice of the scientific panel could be distorted and politicized[28]. An alternative could be science communication training for parts of the panel, e.g. lead authors involved in producing the pre-plenary SPM.

To a certain extent, the way in which the IPCC has addressed uncertainties could serve as a blueprint for this process. Here, a series of guidelines were put together to assist lead authors with this topic in more recent reports[29,30], which helped to use a more comprehensible and less ambiguous language. This practice could be extended to science communication more generally.

The need for more effective communication to non-scientific audiences has long been identified as a crucial challenge for the IPCC[31]. However, it has becomes particularly urgent given the observed trends in newspaper coverage on the topic. Our findings are in line with existing studies observing a distortion of scientific knowledge in the popular media based on various journalistic norms[32,33], in turn shaping the social construction of climate change[34]. Our findings also provide further evidence that the mainstreaming of climate change is likely to exacerbate this mismatch between scientific and wider societal understandings of climate-related knowledge: the more climate change-related news have moved beyond the science niche towards headline news in recent years, the more likely we have been to see increasingly emotive, opinionated coverage in the popular media. Thus, there is an even

greater need for the IPCC to communicate its findings in a way that non-scientific audiences (including the news media as transmitters) can comprehend their findings. Despite the various obstacles to effective science communication[35,36], the readability scores of scientific publications in our sample indicate that clear improvements are possible in this regard.

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AUTHOR CONTRIBUTIONS

R.B. and B.M.S. conceived the study. R.B., S.D. and G.N. designed the study. All co-authors contributed to analysis and writing.

IPCC SPM	
Term	*Δ Frequency*
RISK	+ 5.19%
GROWTH	+ 1.84%
IMPORTANT	+ 1.56%
VULNERABLE	+ 1.53%
NEGATIVE	+ 1.52%
ENHANCE	+ 1.46%
ADVERSE	+ 1.46%
LOSE	+ 1.40%
HEALTH	+ 1.30%
PRODUCTIVE	+ 1.26%
STRESS	+ 1.16%
QUALIFIED	+ 0.93%
POSITIVE	+ 0.81%
KNOWLEDGE	+ 0.63%
SECURE	+ 0.61%

Scientific Publications	
Term	*Δ Frequency*
PROBLEM	+ 1.29%
NEEDED	+ 0.96%
SUPPORT	+ 0.87%
IMPORTANT	+ 0.69%
GOOD	+ 0.65%
REASON	+ 0.52%
KNOWLEDGE	+ 0.52%
STRONG	+ 0.49%
SUCCESS	+ 0.49%
HARD	+ 0.42%
ERRONEOUS	+ 0.39%
GROSS	+ 0.37%
SENSE	+ 0.37%
CAREFUL	+ 0.36%
CLEAR	+ 0.35%

Quality Newspapers	
Term	*Δ Frequency*
POWER	+ 0.84%
WORSE	+ 0.77%
PROBLEM	+ 0.52%
CLEAR	+ 0.52%
GOOD	+ 0.41%
KIND	+ 0.37%
TORNADO	+ 0.35%
PRIME	+ 0.33%
HOPE	+ 0.32%
REASON	+ 0.31%
FAIL	+ 0.28%
LOVE	+ 0.27%
POVERTY	+ 0.23%
REVOLUTION	+ 0.23%
SACRIFICE	+ 0.23%

Tabloid Newspapers	
Term	*Δ Frequency*
FLOOD	+ 3.15%
POVERTY	+ 1.57%
THREAT	+ 1.46%
BLAME	+ 1.42%
WORSE	+ 1.31%
STOP	+ 1.10%
SUFFER	+ 1.04%
TRUTH	+ 0.97%
PRETTIER	+ 0.94%
CRISES	+ 0.84%
DISASTER	+ 0.78%
DANGER	+ 0.76%
STORM	+ 0.74%
DEATH	+ 0.72%
AUTHORITATIVE	+ 0.54%

Table 1: Most popular terms underlying DICTION positive/negative dictionary by publication type. 'Δ Frequency' denotes the relative frequency of a term for a specific publication type compared to the overall sample on average. For example, across the sample of tabloid coverage, 'flood' accounts for 6.65% of all mentions of terms indicating either a positive or negative outlook in the DICTION dictionary. By comparison, the relative frequency across all four publication types is 3.15% lower. DICTION terms indicating a positive (negative) outlook are shown in light grey (dark grey).

Box 1: Illustrative examples of coverage with corresponding Flesch Reading Ease and DICTION optimism scores.

Global Warming 'Will Kill Billions' *(The Sun, 07 April 2007; FRE 55.6, DICTION -4.05)*

BILLIONS face death from hunger, drought, disease and natural disasters, the world's climate change experts warned yesterday. Years of rising sea levels will also destroy coastal cities like New York and Tokyo. And a third of the planet's animals and plants could be wiped out. The doomsday scenario is the bleakest yet from scientists, who blamed man-made greenhouse gases.

The shock report from the influential United Nations' Intergovernmental Panel on Climate Change -the leading world authority on the subject -said up to 3.2billion people will face water shortages within 80 years. A further 600million could be left starving. Millions more will die in heat waves, wildfires, droughts and storms triggered by global warming. […]

Climate Panel Reaffirms Major Warming Threat *(New York Times, 23 January 2001; FRE 41.5, DICTION -1.57)*

In the most emphatic warning yet about the danger of global warming, scientists from 99 nations meeting here issued a report today that sharply increased projected climate change blamed on air pollution and warned of drought and other disasters. The report, which could spur stalled world negotiations on curbing greenhouse gas emissions, said global temperatures could rise by as much as 10.5 degrees over the next century. By comparison, the earth's temperature rose about 9 degrees since the last ice age. […]

Act Now to Save Planet *(The Mirror, 05 May 2007; FRE 59.6, DICTION +7.1)*

WE still have time to save the planet from global warming, but we must change the way we live NOW, climate scientists warned yesterday. Renewable energy such as wind and solar power, green homes and hybrid electric cars are all available and can be used worldwide to slow climate change. […]

Climate change offers bleak future *(Nature, 22 February 2001; FRE 34.3, DICTION -6.20)*

Global warming is damaging natural systems across the whole planet, according to a report from the international group of scientists charged with studying climate change. All continents will suffer economically, the report says, but Africa, Asia, South America and the small island states will be most affected. The report is the second in a series of three from the Intergovernmental Panel on Climate Change (IPCC). Some natural systems, including glaciers and coral reefs, "may undergo significant and irreversible damage", the panel says […]

America and China take giant step in responding to climate change *(The Times, 20 November 2014; FRE 42.9; DICTION +2.35)*

Historic is a word that most of us use too freely, but the announcement of an agreement on climate change between the United States and China looks deserving of the term. The fact that these countries, the world's largest emitters of carbon dioxide, reached a bilateral agreement last week on curbing those emissions isn't merely a cause for optimism, it's a timely development that, I believe, could reinvigorate efforts to tackle a critical and urgent challenge.

Why should we care? Well, if anyone were still complacent about the scale of the problem that climate change poses, then the recent report by the Intergovernmental Panel on Climate Change will have come as a stark wake-up call. As the report points out: "Warming of the climate system is unequivocal and unprecedented, with emissions rising faster than ever before." […]

IPCC Summary for Policymakers *(AR5 WG3, 14 April 2014; FRE 3.7; DICTION +0.26)*

[…] Without additional efforts to reduce GHG emissions beyond those in place today, emissions growth is expected to persist driven by growth in global population and economic activities. Baseline scenarios, those without additional mitigation, result in global mean surface temperature increases in 2100 from 3.7 °C to 4.8 °C compared to pre-industrial levels (median values; the range is 2.5 °C to 7.8 °C when including climate uncertainty, see Table SPM.1) (high confidence). The emission scenarios collected for this assessment represent full radiative forcing including GHGs, tropospheric ozone, aerosols and albedo change. Baseline scenarios (scenarios without explicit additional efforts to constrain emissions) exceed 450 parts per million (ppm) CO2eq by 2030 and reach CO2eq concentration levels between 750 and more than 1300 ppm CO2eq by 2100. This is similar to the range in

atmospheric concentration levels between the RCP 6.0 and RCP 8.5 pathways in 2100. For comparison, the CO2eq concentration in 2011 is estimated to be 430 ppm (uncertainty range 340 - 520 ppm). […]

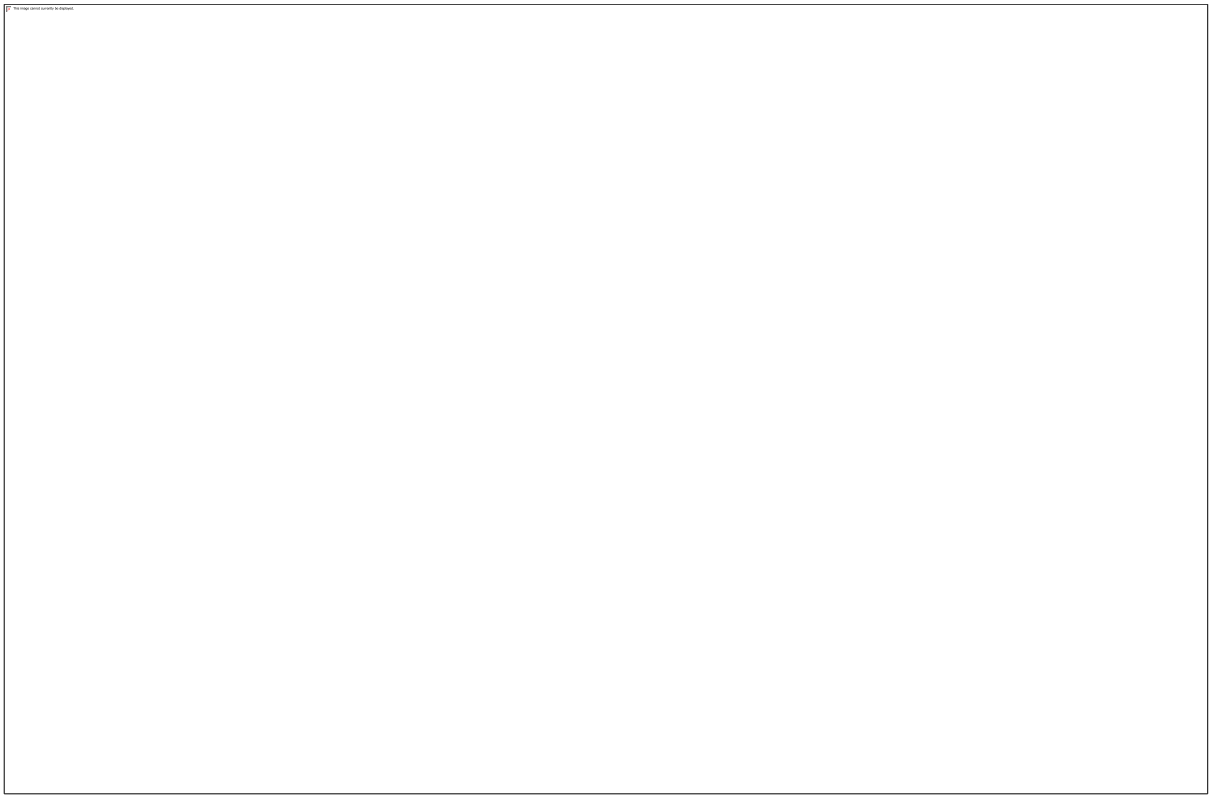

Figure 1: Box-and-whisker plots displaying Flesch Reading Ease (FRE) scores for IPCC SPMs and scientific publications (*Nature* and *Science*) as well as quality (*The Independent*, *The Times*, *New York Times*, *Washington Post*) and tabloid newspapers (*The Mirror*, *The Sun*, *Daily News*) related to the launch of IPCC assessment reports from 1990-2014. On the right-hand side are typical FRE ranges for different types of publications.

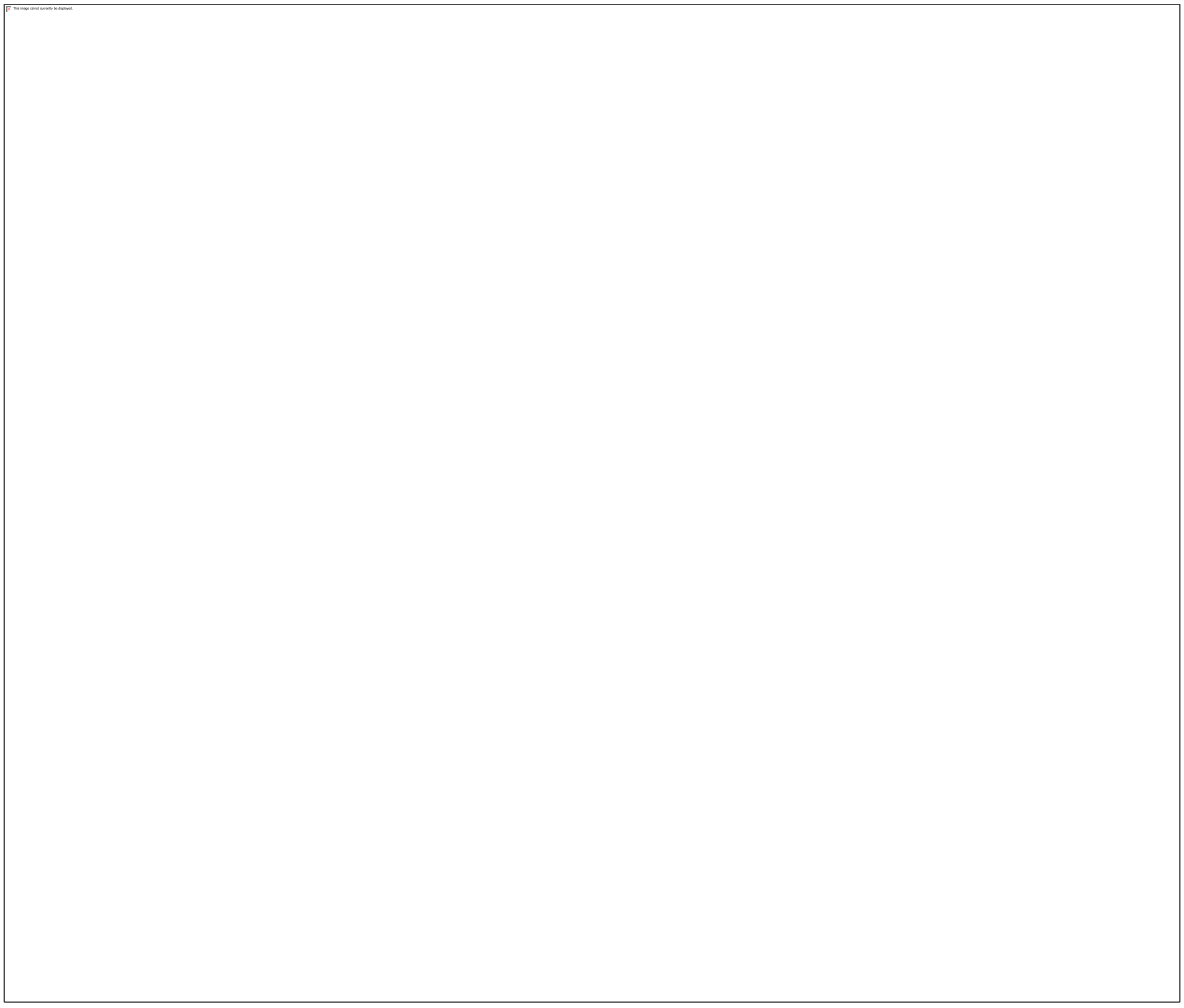

Figure 2: Mean Flesch Reading Ease scores over time for IPCC SPMs and scientific publications, as well as quality and tabloid newspapers related to the launch of IPCC assessment reports from 1990-2014. a, Overall mean FRE scores for the four publication types (with standard errors). **b**, FRE scores for the individual IPCC SPMs for each Working Group and Synthesis Report (or equivalent).

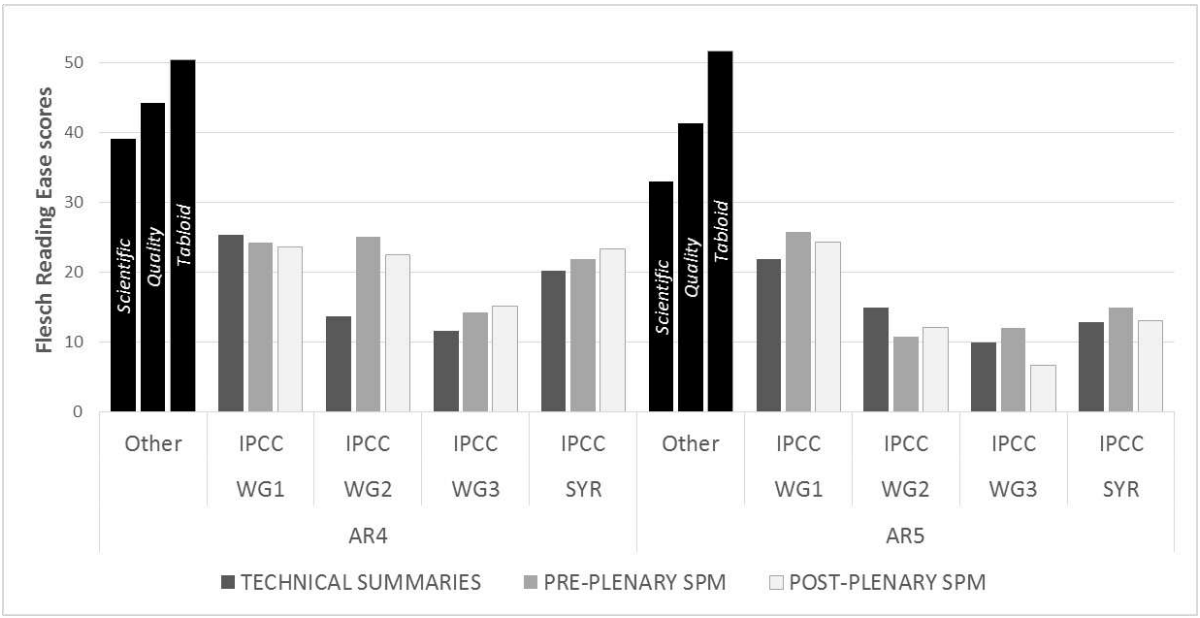

Figure 3: Comparison of Flesch Reading Ease scores for pre- and post-plenary AR4 and AR5 IPCC SPMs as well as Technical Summaries. We found no significant differences in mean scores between pre- and post-plenary versions as well as Technical Summaries. For illustration, mean scores for AR4 and AR5 are also included for the other three publication types (black bars).

Figure 4: Box-and-whisker plots displaying DICTION optimism scores for IPCC SPMs, scientific publications, quality and tabloid newspapers related to the launch of IPCC assessment reports from 1990-2014.

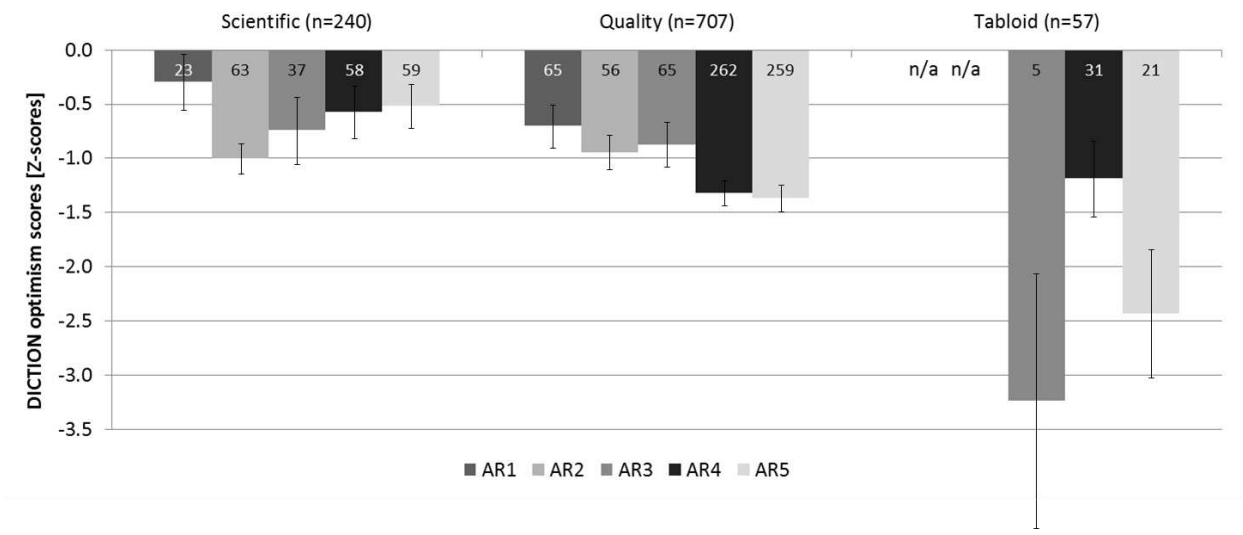

Figure 5: Mean DICTION optimism Z-scores (with standard errors) of different types of media compared to the IPCC SPMs mean over time. Numbers on bars indicate size of individual subsamples. Before 2001, no coverage on the IPCC could be found in any of the three tabloid newspapers included in the sample (*The Mirror*, *The Sun*, *Daily News*).

METHODS

We conducted a linguistic analysis of IPCC SPMs and related print media coverage for each of the five assessment reports. The analysis focused on SPMs as well as well as leading scientific journals (*Nature*, *Science*) and UK and US-based quality (*The Independent*, *The Times*, *New York Times*, *Washington Post*) and tabloid newspapers (*The Mirror*, *The Sun*, *Daily News*). Newspapers were selected based on type, circulation and political alignment. In an initial step, other UK-based quality newspapers such as *The Guardian* and *The Daily Telegraph* were also included in the sample for a preliminary analysis. Based on the fact that there was hardly any coverage on the IPCC linked to the first three Assessment Reports in *The Daily Telegraph* (no coverage at all for AR1 and AR2), we decided to select *The Times* as the quality newspaper with the highest circulation among UK centre-right publications. Resulting from this choice, we then decided to select *The Independent* – which we consider as a centre-left leaning quality newspaper – in order to arrive at a balanced sample. *The Independent* and *The Times* have repeatedly been used in analyses of UK-based quality newspapers in the context of climate change[34,37,38]. There would not have been a US-based quality newspaper equivalent of *The Guardian* available, and *The Independent* is the centre-left leaning quality newspaper with the second-highest circulation in the UK (after *The Guardian*). However, the inclusion of *The Guardian* would not have produced significantly different findings. Our preliminary analysis showed that whilst IPCC-related coverage was significantly higher in *The Guardian* when compared to the four newspapers included in the sample, overall mean readability scores for the set of Guardian articles was 40.1 and therefore very much in line with our sample of quality newspapers; likewise, DICTION optimism scores reflect the pattern identified for our sample.

For each of the assessment reports, media coverage was collected starting two months prior to the launch of the first working group report and ending two months subsequent to the launch of the synthesis report. Full-text articles were obtained from various databases such as *LexisNexis* and *Faktiva* and stored as simple text files for cleaning and subsequent processing. The search terms "Intergovernmental Panel on Climate Change" and "IPCC" were used to identify relevant articles. These were subsequently screened to exclude unrelated news articles. In particular, this included UK-based coverage on the Independent Police Complaint Commission which is also abbreviated as IPCC. For *Nature* and *Science* coverage, research articles and review articles were excluded from the sample given the time-lag between submission and publication as well as clear differences in writing style. All relevant articles published between two months before the launch of the first assessment report and two months after the launch of the last assessment report were included in the sample (N=1024; **Supplementary Table 1**). In a separate analysis, the readability of AR4 and AR5 SPMs was compared with their pre-plenary versions as well as AR4 and AR5 Technical Summaries.

Cleaning consisted of the removal of special characters not recognized by the tools employed, as well as spurious space characters introduced in the middle of words by the copy-and-paste operation. The former was achieved automatically by a routine run over all documents, the latter by automatically tabulating orthographic mistakes for each document and manually opening and fixing those showing broken words errors. Finally, a third routine automatically replaced British English with American English spelling, as the latter is used by the DICTION software package.

Flesch Reading Ease[14] scores were calculated using a Visual Basic routine processing all files in Microsoft Word 2010. MS Word 2010 implements the original Flesch Reading Ease algorithm

which is based on the assumption that text containing longer sentences and more complex words is more difficult to comprehend. It provides a score between 0 and 100 with easy-to-read texts scoring higher than more complex ones.

The computer-based psycho-social dictionary DICTION[39] analyses semantic features of text based on 31 disjoint dictionaries containing around 10,000 words. Optimism is one of the five main constructs calculated by DICTION, and is in turn based on six of the disjoint dictionaries ([Praise + Inspiration + Satisfaction] – [Blame + Hardship + Denial]).

For each document, raw totals (number of words per category), document frequencies and standardized scores are calculated. In order to make raw scores comparable across publication types, all numeric results have been converted into Z-scores, using mean scores for IPCC SPMs as a benchmark. Namely, for the entire sample, the difference between the mean score of IPCC SPMs and the score of each individual document, divided by the standard deviation, has been used as the final measure for each document. Polysemy, i.e. the occurrence of words or phrases with different but related meanings, is treated via simple statistical weighting: polysemic words produce multiple score types, proportional to the average use of the senses in texts, which are all taken into account.

For the comparison of relative frequencies of DICTION terms (**Table 1**), we initially calculated raw frequencies of all terms included in the DICTION optimism/ pessimism dictionaries for all four publication types. These raw frequencies were subsequently expressed as a percentage of the sum of all occurrences of any of the terms listed in the dictionaries. The relative frequencies referred to in **Table 1** then denote the difference between the frequency of a term (expressed as percentage) in a given publication type compared to its frequency across all four publication types. In order to calculate average frequencies across the entire sample,

frequencies for the four publication types were weighted equally in order to avoid bias towards quality newspapers as by far the largest individual subsample (n=707): $\Delta f_{SPM} = f_{SPM} - (f_{SPM} + f_{Science} + f_{Quality} + f_{Tabloid} / 4)$.

All boxplots in the figures show median scores, upper and lower quartiles as well as minimum and maximum scores for each publication type. Kruskal-Wallis tests were conducted to assess the significance of the differences in mean scores; follow-up pairwise tests, applying Bonferroni corrections to control for Type I errors, were employed to identify significant differences between subsamples.

For the Flesch Reading Ease (FRE) score (**Figure 1**) we identified clear significant differences in mean scores between publication types (χ^2 (3, N = 1,024) = 175.2, $p < 0.001$). Significant differences were found between each of the subsamples ($p < 0.001$) but not within any of the four subsamples. Over time (**Figure 2**) we identified significant differences between means of FRE score for the entire sample between the five assessment periods (χ^2 (4, N = 1,024) = 68.1, $p < 0.001$). We also found significant differences between AR4 and all other assessment reports ($p < 0.001$ for all pairwise tests involving AR4) as well as AR5 and all other assessment reports except AR3 ($p < 0.05$ for pairwise tests with AR1 and AR2). Of the four publication types, scientific publications as well as quality newspapers showed significant differences in mean FRE scores (scientific publications: χ^2 (4, N = 240) = 25.1, $p < 0.001$; quality newspapers: χ^2 (4, N = 707) = 27.7, $p < 0.001$). In both cases, follow-up pairwise comparisons showed significant differences ($p < 0.05$ or lower) for AR4 with other assessment reports (scientific publications: AR3 and AR5; quality newspapers: AR1, AR2 and AR5).

For the DICTION optimism score (**Figure 4**) we identified clear significant differences between publication types (χ^2 (3, N = 1,024) = 31.1, $p < 0.001$). Follow-up tests showed significant

differences between all publication types except between tabloid and quality newspapers as well as between SPMs and scientific publications. No significant differences in mean optimism scores could be identified within any of the four subsamples. Over time (**Figure 5**), significant differences between means of different types of media and the IPCC SPMs mean were identified between the five assessment periods (χ^2 (4, N = 1,024) = 14.8, $p < 0.01$). We also found significant differences ($p < 0.01$) between AR1 and AR4 as well as AR1 and AR5. Of the four publication types, only quality newspapers showed significant differences in mean optimism scores (χ^2 (4, N = 707) = 13.2, $p < 0.05$) between the five assessment periods. Significant differences ($p < 0.05$) between AR1 and AR4 as well as AR1 and AR5 were also found.

The research design is subject to a number of limitations. As a consequence of the text mining approach used to identify relevant articles, the sample includes not only articles exclusively focusing on the IPCC but also coverage of other issues whereby the IPCC is only mentioned in passing. Furthermore, newspaper syndication and the influence of news wires might have biased readability and optimism scores for quality and tabloid newspaper coverage. In addition, there are two limitations linked to the use of DICTION. First, results might be distorted based on the existence of homographs[40]. For this reason, other DICTION constructs such as its certainty score could not be considered for this analysis. Second, DICTION has been developed in a US context and can be considered as most suitable for US-based publications. Whilst British English spelling was converted into American English spelling as part of pre-processing of files, construct validity might still be slightly lower for UK-based coverage.

In addition, the analysis focused on plain text versions of the documents and as such did not consider the potential impacts of illustrations or different types of formatting. Finally, the

linguistic analysis was only performed on English language content given that DICTION is limited to English language text and readability scores for other languages would not be comparable. Nevertheless, it should be kept in mind that whilst IPCC SPMs are published in various different languages, the English language version is the one agreed at the Plenary before it is subsequently translated into other languages.

ADDITIONAL REFERENCES (METHOD SECTION)

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