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Running title: CAN AND THE EXTREMITY EFFECT

It can become 5 °C warmer: The extremity effect in climate forecasts

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Abstract (148 words)

Climate projections and other predictions are often described as outcomes that *can* happen, indicating possibilities that are imaginable, but uncertain. Whereas the meanings of other uncertainty terms have been extensively studied, the uses of modal verbs like *can* and *will* have rarely been examined. Participants in five experiments were shown graphs and verbal statements showing projections of future global warming, sea level rise, and other climate-related issues. All studies gave support for the *extremity hypothesis*, which states that people use can-statements to describe the topmost values in a distribution of outcomes, regardless of their actual probabilities. Despite their extremity, outcomes that *can* happen are believed to have a substantial likelihood of occurrence. The extremity effect was replicated in two languages (Norwegian and English), and with several related terms (*can*, *possible*, *could*, *may*). The combination of extremity and exaggerated likelihood conveyed by such statements could lead to serious miscommunications.

Keywords

Climate forecasts; Communication; Verbal probabilities; Extremity; Probability judgments

Public significance statement :

When people are asked to predict future outcomes that ‘can’ (could, may) occur, they typically select the highest possible values. Despite their extremity, such outcomes will often appear quite likely. The combination of extremity and exaggerated likelihood conveyed by such statements could lead to serious miscommunications.

It can become 5 °C warmer: The extremity effect in climate forecasts

Forecasts of global warming and other projections of climate changes are fraught with considerable uncertainty. Experts and research institutes often suggest a gamut of future scenarios that differ dependent upon which data they are based on, which prediction models are chosen, and on which assumptions they rest (e.g., future levels of CO₂ emissions, new technologies, and population growth; see Freedman, 2013; IPCC, 2013; Rohde, n.d.). How will such divergent projections be summarized, for instance by a science journalist who wants to condense a variety of predictions into a simple statement that should ideally be comprehensible and accurate at the same time?

One frequently chosen formulation that often appears in headlines includes the seemingly innocent and noncommittal term *can* (Adams et al., 2017). This term is common in reports on substances, activities or procedures that have been found to expose consumers to various risks. “Hair conditioner can cause hair loss.” “Red meat can cause stomach cancer.” “Cigarette smoking can seriously damage your health.” One might claim that phrases with *can* are particularly suitable for hazards where the extent of damage has not been scientifically established, or which affect an indeterminate number, perhaps only a few. For instance, Norwegian authorities had to change health warnings on snuff boxes from snuff “damages health” to snuff “can damage health” in response to EU directive 2001/EG/37, which claimed that the pathogenic effects of snuff were not conclusively established.¹ In a recent study about causal expressions in news headlines, Adams et al. (2017) found that headlines with “can cause” (e.g., “Being breast fed can make children behave better”) were rated less causal than statements without *can* (“Being breast fed makes children behave better”).

¹ The directive was revised in 2014, after new studies had given compelling evidence for the link between snuff usage and various ailments (European Union law, 2014). In consequence, the warning message was strengthened by removing the modal verb “can”.

Phrases with *can* are widely used in people's conversations about probabilistic events. In these contexts, it comes in handy when speakers do not know, or do not want to report exact probabilities. Teigen, Brun, and Frydenlund (1999) asked participants to imagine that they were engaged in a discussion with a conversation partner who underestimated the risks associated with several potentially dangerous activities (like skiing and mountain climbing) and substances (like alcohol and tobacco). Which arguments would they use if they disagreed? Would they explain the riskiness of an activity in terms of probabilities and frequencies (e.g., claiming that downhill skiing is risky because accidents often occur)? Such arguments were surprisingly rare and were used by less than 15% of participants for activities, and by even fewer for substances. Instead, they said that mountain climbing is risky because fatal accidents *can* occur. Or, tobacco is dangerous because it *can* cause lung cancer.

The role played by *can* in these contexts is to draw attention to one of several potential effects of the activity in focus, and in addition claim that this outcome is *possible*. In other words, *can* belongs to the group of uncertainty expressions that can be identified as having an affirmative, "upward" direction, by indicating the speaker's expectation of a target outcome to occur. Such positive (affirmative) phrases, like *a chance*, *possibly*, or *likely* can be contrasted with negative phrases, like *uncertain* or *doubtful*, which point "downwards" towards a target outcome's non-occurrence (Honda & Yamagishi, 2006; Teigen, 1988). This directionality is related to, but not identical with degree of probability (Budescu, Karelitz, & Wallsten, 2003; Piercey, 2009), as for instance low probabilities can be described both in a positive and a negative way (*a chance* vs. *very uncertain*). Yet, when low-probability events are described with a positive phrase (like *possible* and *can*) they may appear more likely and give more reasons for concern than when described with a negative phrase. In other words, phrases with different directionality can give rise to judgmental framing effects (Keren, 2011; Teigen & Brun, 2001).

As a verbal probability term, *can* is slippery because it does not seem to designate a specific frequency or probability level. However, when we turn the question around, and instead of probabilities ask people about which one of several outcomes that *can* happen, a notable regularity appears. Teigen and Filkuková (2013) presented outcome distributions to participants and asked them to complete such statements with an appropriate outcome value. For instance, they were shown an approximately normal distribution of battery durations, ranging from 1.5 h for the worst to 3.5 h for the best computer battery. The statement: “A battery in these computers can last for hours” was in most cases completed with 3.5 h, namely the highest number in the distribution, even if this had a very low ($< 10\%$) occurrence frequency. This response pattern applied to positive and negative outcomes in several domains. Subsequent research has shown extreme interpretations of several other verbal probability phrases when investigated by the same approach, including *a chance*, *possible*, *not certain*, and *improbable* (Jenkins, Harris, & Lark, 2016; Teigen, Juanchich, & Filkuková, 2014; Teigen, Juanchich, & Riege, 2013). These results form the basis for an *extremity hypothesis* for *can* and several other expressions about potential future outcomes. In its weaker form, the hypothesis claims that high outcomes are chosen more often than low outcomes in *can*-statements of future events. In a stronger version, communications about top outcomes are preferred to middle ones, even when the latter are more likely.

But while speakers use *can* to describe extreme, and hence not very likely outcomes, this need not be equally obvious to listeners, who in some cases think that *can*-statements refer to more representative values. A similar inconsistency has been found for the term *possible*. This term is used primarily to describe outcomes in the upper end of the distribution, and is yet believed to indicate a rather likely value (Løhre & Teigen, 2014).

A reason for this apparent paradox might be sought in the contrast between two communication settings, or emphasis frames (Druckman, 2011), that differ with respect to

what is being said (what is in focus), and about which topic (Gundel & Fretheim, 2001). We might in this area distinguish between two such settings, one that focuses on choice of term, the other focusing on values.

(1) A statement of what *can* happen (or is *possible*) might come in response to an already targeted value that forms the topic of the conversation. “Can climate changes make the world X degrees warmer?” “Yes, X is possible / X can occur”. The question is, in this case, why the second speaker chooses to say *can* rather than *cannot*, or speaks of this increase as a *possibility* rather than, for instance, a certainty or an impossible event.

(2) Alternatively, we may imagine that the speaker has adopted a specific verbal term (like *possibly*, or *can*), and is now freely choosing an appropriate number of degrees. In this case, the question is why X is chosen out of all potential values, rather than a value higher or lower.

Listeners who are ignorant about the setting may have problems of achieving the proper alignment with the speaker, disrupting the normal communication interchange between conversation partners (Garrod & Pickering, 2004). A listener may, for instance think that the statement “It can be 5 degrees warmer” is issued in a setting where the modal verb is freely chosen (Setting 1), when in fact it may have been produced in Setting 2, with a focus on degrees.

Can in the IPCC reports

In the introduction to the fifth assessment report from the Intergovernmental Panel on Climate Change (IPCC), readers are given a list of verbal probability terms, with corresponding numerical translations. In this way, readers will know that *very likely* (“extreme precipitation will very likely be more intense and more frequent in a warmer world”; Stocker et al., 2013, p. 112) is used to indicate a 90–100% likelihood, while *likely*

corresponds to a probability between 66 and 100%.² But what about *can*? Despite its frequent use throughout the reports, *can* is not on the list of likelihood terms, and is not assigned a numerical probability translation. So what should readers think about the uncertainty associated with statements like these from the IPCC report (italics ours):

“Drought *can* increase suicide rates by 8%” (Field et al., 2014, p. 841).

“Anthropogenic heat fluxes across large cities *can* average within a range of approximately 10 to 150 W m² but over small areas of the city *can* be three to four times these values or even more” (Field et al., 2014, p. 551).

The use of *can* in place of a predefined verbal probability term, could have several reasons. One is that the chances are not known. Another is the inherent ambiguity of the term itself, with *ability* and *possibility* as two overlapping interpretations. Consider this statement: “Urban green space and green roofs can moderate temperature and decrease surface rainwater runoff” (Barros et al., 2014, p. 1297). Here *can* clearly suggests the *ability* of vegetation to counteract some effects of urban warming. In other cases, where *can* is used to qualify specific numerical predictions, the *possibilities* appear to be in focus. In the first of the above statements, one might surmise that 8% is an extreme estimate of increase in suicide rates.³ In the second, *can* allows for some high values (“three to four times these values or even more”).

The present research

The present studies were designed to examine the usage of *can* and related terms in the domain of climate predictions, where uncertainty is often illustrated graphically as a family of projections, surrounded by confidence intervals. It extends previous research (Teigen & Filkuková, 2013) by focusing on forecasts, rather than on frequency distributions. The studies

² A large scale study by Budescu, Por, Broomell & Smithson (2014), based on 27 samples from 25 different countries, revealed that readers typically disregard the numerical translations, even when they are made available, in preference of more regressive interpretations (probabilities closer to 50%).

³ This number appears to be based on a single study from New South Wales (Nicholls, Butler & Hanigan, 2006), where 8% is the *expected* (rather than topmost) increase, given a rather *extreme* decline (300 mm) in annual precipitation.

were conducted with the following main research questions in view: (Q1) To test and replicate the *extremity hypothesis* (i.e., the tendency to focus on high, or maximum values in a distribution of potential outcomes); (Q2) to investigate how well the extremity effect is understood by recipients of the communication; (Q3) to assess the perceived likelihood of such outcomes, by speakers as well as recipients; (Q4) to explore the effects of describing extreme values in different ways (e.g., as *possible* vs. *maximal* outcomes); (Q5) to extend the investigation to statements containing the related English auxiliary verbs *could* and *may*. These modal verbs are, like *can*, widely used in texts and discussions describing potential, but uncertain effects of climate change, perhaps with less causal force (Adams et al., 2017) and hence conveying weaker expectations.

The primary aim of this research was to establish regularities in the usage and interpretations of *can* and its cognate terms in a prediction context, rather than to analyze and explain the reasons behind these regularities, which would require a separate program of research.

Five studies were performed to test the extremity hypothesis (Q1) for various climate-related future events and to investigate the perceived likelihood of corresponding outcomes (Q3). The two first studies examined potential speaker/listener asymmetries (Q2) and the last three compared *can*-statements to other statements that also suggest extreme values (Q4 and Q5). An overview of themes and research questions in the individual studies is given in Table 1.

<Insert Table 1 about here>

In Study 1 we asked participants to place themselves in the shoes of a science journalist who is trying to summarize a set of temperature projections with a *can*-statement. If the purpose is to convey the essence of these projections to the readers, would the journalist focus on an extreme forecast, or a more representative one? Participants in a different

condition were asked how they, as readers, would perceive a can-headline without seeing the projections on which it was based, the question being whether readers are able to “unpack” the headline in a way that captures the gist of the original projections, or whether the use of *can* has a potential for leading readers astray. In Study 2 statements of what *will* happen and what *can* happen were compared, for positive as well as negative events, both from the perspective of a speaker and of a recipient of the communication. Participants also produced probabilistic interpretations of such statements. Extreme events are in most contexts (e.g., in a normal distribution of outcomes) rare, and accordingly much less likely than outcomes closer to the midpoint of a distribution. But what *can* happen is generally believed to have an intermediate rather than a small chance of occurring. This might create a conflict in the interpretation of can-statements, which on one hand are believed to describe an extreme event, and on the other hand to indicate a substantial probability. This potential paradox was further explored in Studies 3 and 4, where participants were instructed to assess both the extremeness and the probability of the same outcome. Forecasts were in Study 3 illustrated with future temperature projections from different research institutes, whereas Study 4 described future projections of sea levels, accompanied by uncertainty ranges. We predicted that extreme values would be selected in both cases, in line with the extremity hypothesis, and that they would be believed to be more likely when described as *possible* outcomes, or outcomes that *can* happen (both terms with positive directionality) than when they simply were characterized as *maximum* values. In Study 5 predictions of what *can* happen were compared with what *could* or *may* be the case, by English-speaking participants for whom these alternative terms might sound more natural for predictions surrounded by uncertainty. We expected that could- and may-statements would resemble can-statements by suggesting extreme outcomes, but perhaps with less certainty.

Study 1: From graphs to headlines

In news reports, especially in the headlines, announcements about what *can* happen are usually presented without information about the likelihood of this outcome, or the existence of other, rivalling forecasts. Study 1 was designed to test the extremity hypothesis (Q1) by asking participants in one condition to summarize a graph showing eight projections of global warming by one single headline containing the word *can*. Participants in another condition received the *can*-headline without the projections on which it was based, and were asked to suggest a plausible range of projections. This design allowed us examine the degree of correspondence between communicators' use of *can* and recipients' understanding of this usage (Q2). Observe that the communicators in the Graph condition had access to range information, whereas recipients only saw the headlines and had to generate their own context.

<Insert Figure 1 about here>

Method

Participants were recruited on campus at the University of Oslo, $N = 147$ (90 women and 44 men, 13 did not report gender; median age = 23 years). They were randomly assigned to two different conditions by receiving different questionnaires.

Participants in the Graph condition (Condition 1) were presented with a graph showing global warming projections from year 2000 to 2100, based on models issued by eight different research institutes (Figure 1). They were asked to imagine a journalist writing a newspaper article about these forecasts. What would he/she choose as a headline for the article? Insert one number in the following statement:

“It can be degrees warmer by the year 2100”⁴

Participants in the Headline condition (Condition 2) did not see the graph, but were instead told that the journalist had chosen the following headline for the newspaper article, based on projections from eight research institutes:

⁴ In this and later vignettes concerning temperature change “degrees” refer consistently to the Celsius scale, which is the only temperature scale in use in Norway. In the graph the temperature unit was explicitly labelled °C, as used in IPCC reports.

“It can be 5 degrees warmer by the year 2100”

(The choice of 5 degrees for this condition was based on an expectation that this increase would be the modal answer in the graph condition.)

As a rough indication of the perceived likelihoods involved (Q3), participants in both conditions were further asked whether the journalist would describe this rise in temperatures as *quite likely*, or *not so likely* ⁵.

They were then asked to suggest the *most likely* temperature rise, by inserting a number in the following statement:

“Based on extant models it will most likely be degrees warmer by the year 2100”.

To capture their perceptions of the can-statement, participants in the Headline condition, who had not seen the graph, were subsequently asked to state what they thought were the lowest and highest forecasts from the eight institutes. This would indicate whether they read “can be 5 degrees warmer” as the top forecast or as a more average projection.

At the end of the questionnaire, all participants rated their agreement with two statements about their climate change beliefs: “I am sure climate changes occur,” and “Claims of human activity changing the climate are exaggerated”, on seven point (1–7) Likert scales.

Results

Figure 1 shows that the eight models predict temperatures for the year 2100 that are 2–5 degrees higher than the baseline year 2000. Most participants (58.5%) in the *Graph condition* suggested “It can be 5 degrees warmer” as their preferred headline. Some even suggested temperatures above 5 degrees (15.4%), whereas temperature changes of less than 5 degrees were suggested by only 26.2%. Despite its extremity, the 5 degrees’ forecast was not considered unlikely. All but one participant (98.5%) in the Graph condition described the outcome chosen for the headline as a “quite likely” (rather than “not so likely”) outcome.

⁵ The Norwegian terms were “ganske sannsynlig” and “lite sannsynlig”

However, most participants (55%) in this condition admitted that the most likely temperature increase would be less than 5 degrees (median = 4.0 degrees).

Readers in the *Headline condition*, who were simply told that “It can be 5 degrees warmer”, agreed that a 5 degree rise in temperatures was *quite likely* rather than *not so likely* (95.8%). Without access to the graph, they expected this to be the most likely temperature, as well (median = 5.0 degrees). A majority (83.9%) suggested that the rise would be 5 degrees or more. Thus the can-statement made participants in the Headline condition think of higher temperature than participants in the Graph condition, as shown in Figure 2. The difference between conditions is highly significant, $\chi^2(1, 116) = 19.004, p < .001$.

<Insert Figure 2 about here>

Range estimates in the Headline condition showed that most participants (57.6%) thought that the highest projections would be above 5 degrees, placing the target estimate inside the distribution of estimates rather than at the top. Thus, they failed to realize that a headline stating that global warming “can be” 5 degrees, is most likely referring to the most extreme projection.

Participants in both conditions strongly agreed that climate changes occur ($M = 6.46$, $SD = 0.75$), and did not think that the role of human activity had been exaggerated ($M = 2.74$, $SD = 1.51$). Their opinions on these issues were unrelated to their interpretations of *can*. A combined climate belief score (with the second scale reverse coded) correlated $r = -.02$ and $r = -.10$ with estimated temperatures in the headline and the graph conditions, respectively.

Discussion

The high values selected in the Graph condition supported the extremity hypothesis, which says that communicators tend to use the highest value in a distribution when describing what *can* happen. But this requires a setting where information about all values in the distribution is provided, as shown in the graph. Participants without the graph believed that

the headline described a representative rather than an extreme value. They may have thought that the topic of the assertion is a temperature rise of 5 degrees, the question being whether this rise *can* or *cannot* happen. Without access to the graph they lacked contextual range information and failed to reconstruct the proper setting in which the headline statement was asserted.

The study suffered from two obvious limitations. First, the forecasts concerned a single, undesirable event, namely global warming. For this much-debated event, extreme (worst case) outcomes would be particularly important to communicate and to consider. This might have contributed to the extremity effect observed among speakers. Second, the likelihood of the selected outcome was measured in a crude way by giving participants a forced choice between likely and not likely. Study 2 was set up to address these limitations.

Study 2: *Will* versus *can*

Study 2 was designed to include both desirable and undesirable outcomes that speakers say *will* or *can* happen.

What *will* happen is commonly regarded to be a highly probable, ideally a 100% certain outcome. For instance, in the Probability Mapping Standard of the Canadian Intelligence, *will* and *is certain* are synonymous expressions for a probability of 10/10 (Barnes, 2016). But in most multiple-outcome distributions, like the battery life and weight loss programs studied by Teigen and Filkuková (2013) there are no 10/10 options, as even the most probable outcome is far from certainty. In such situations, many participants solve the sentence completion task by letting *will* indicate the *lowest* value, implying that duration or weight loss of this magnitude (or more) is bound to happen. A battery will (at least) last for 1.5 hours and a dieter will (at least) lose 3 kg. Such “at least” readings of numbers have been discussed in pragmatic interpretations of numerals (Levinson, 2000; Musolino, 2004) and

have also been suggested as a part explanation of framing effects (Mandel, 2014; Teigen & Nikolaisen, 2009).

Extreme values are typically (in unimodal distributions) less common than values closer to the mean. They are accordingly not among the most probable ones. If *can* is used to describe one of the topmost values, the probability of this outcome should be judged as rather low. In the studies by Teigen and Filkuková (2013) outcome probabilities could be derived from frequency distributions accompanying each vignette. However, participants were not asked whether they perceived these frequencies as indicating the probabilities involved. In Study 1, participants indicated probabilities by forced choice between two verbal descriptions, one positive and one negative. Nearly all chose the positive formulation (quite likely), perhaps perceiving it as a better match for *can*, which also has a positive directionality. Moreover, they might assume even the most extreme projection appeared quite likely for the research team that produced it. We provided in the present study the research teams' own prediction ranges to ensure that the top values were perceived as extreme also by the forecasters.

Like Study 1, the study included one Speaker (communicator) condition, where the ranges of potential outcomes were stated and the question was what an expert says *will* or *can* happen, and one Recipient condition where the forecasters' will- and can-statements were presented and participants estimated the ranges that the forecasters might have in mind. Degree of correspondence (agreements and disagreements) between communicators and recipients of the communication would indicate how well such statements are understood. Observe that will- and can-statements described in this study concern the same events, and were evaluated by the same participants. This allowed for direct comparisons of statements with these two modal verbs, and made it easy to assume an underlying range of outcomes compatible with both statements.

Method

Participants were 88 students, 55 women and 28 men (5 did not report gender), median age 23 years, recruited on campus at a Norwegian university, and randomly allocated to two conditions by receiving different questionnaires.

All questionnaires contained two vignettes about climate prognoses concerning a fictitious island state, Sulasemi, which was allegedly threatened by a rise in ocean level (based on Harris & Corner, 2011). The vignettes were constructed to describe outcomes of different valence (negative with flooding, and positive with bird preservation).

Flooding. The first vignette described three flat Sulasemi islands. With a future sea level rise of 50 cm, Asawa would be flooded. A sea level rise of 75 cm would also overflow Barani, and with a rise of 100 cm Calano, the third island, would be flooded as well. The situation was illustrated by schematic profiles of the three islands with horizontal lines showing corresponding levels of ocean rise.

Participants in the *Speaker* condition were told that climate experts predicted a rise in sea level of minimum 50 cm and maximum 100 cm by the end of this century. One climate expert says: “The projections imply that will be flooded by the year 2100”. Another forecaster says: “The projections imply that can be flooded by the year of 2100”. The participants’ task was to insert appropriate island names in the blanks in each statement. The order of *can*- and *will*-statements was counterbalanced across participants. In both cases, participants were asked to indicate the experts’ presumed probabilities for these events to occur on 11-point scales from 0 to 100%. Finally, they rated the agreement between the two experts on a five-point scale from 1: *completely disagree* to 5: *completely agree*.

Participants in the *Recipient* condition were asked to indicate which ranges of sea level rise (minimum and maximum values) two forecasters have in mind when saying “Asawa will be flooded”, or “Calano can be flooded”. They also estimated the probabilities implied by these statements, and how well the experts agreed with each other. In contrast to Study 1, the

description of the three islands contains implicit range information, making the settings for speakers and listeners more similar.

<Insert Figure 3 about here>

Birds. The second vignette described the effects of a program developed to support and promote a rare species of birds, Danabo, on the Sulasemi islands, which were endangered by the rise in sea level. The accompanying graph (Figure 3) showed projections calculated by three teams of researchers. One team concluded that the program would ensure a stable bird population, the second a 50% increase, whereas the third suggested that the population would grow to twice its present size.

Participants in the Speaker condition were asked to complete one forecaster's statement about how large the population of birds *will* be at the end of the present century, and another forecaster's statement about what the population *can* be, by filling in appropriate numbers. They also indicated the probabilities associated with these forecasts.

Participants in the Recipient condition received two expert statements, one saying that the future population of Danabo *will* be as it is today (10,000 birds), whereas the other says it *can* grow to twice its present size (20,000 birds). Which ranges do these experts have in mind (minimum and maximum number of birds), and which probabilities do they attach to their estimates? The stated numbers provide a hint about ranges, placing speakers and recipients in settings that are better aligned than was the case in Study 1.

Results

Speaker condition. In this condition, the ranges of sea level and bird population were given, the question being how *will* and *can* are used. With a sea level rise of 50–100 cm, most participants (79.2%) chose Asawa as the island that *will* be flooded, with a mean probability of 82.3%. This island would in fact be flooded by any rise in sea level from 50 cm and upwards.

The graph showed that the third island, Calano, would only be flooded with a sea level rise of 100 cm or more. Nevertheless, this island was most often selected (by 58.3%) as the island that *can* be flooded. The mean probability of can-statements was 50.2%, regardless of which island was selected. Participants judged the can- and will-forecasters to be in good agreement with each other ($M = 4.04$). In the bird vignette participants were divided between those who felt that the population *will* be 10,000 ($n = 21$) or 15,000 ($n = 20$) (only six participants suggested a different number of birds). The mean probability of what *will* happen was 72.3%. Again, the most extreme forecast, 20,000 birds or more, was most often selected for the statement about what *can* be the situation in the year 2100 (by 58.4%), with a mean probability of 46.3%.

Recipient condition. Here, statements with *will* and *can* were given, the question being the range of outcomes speakers had in mind. When participants in this condition were told that “Asawa will be flooded”, they believed that this statement implied a minimum sea level of $M = 52.9$ cm and a maximum sea level of $M = 89.3$ cm ($Mdn = 50$ – 100 cm sea level rise), with a mean probability of 90.3%. They thought that “Calano can be flooded” indicated roughly the same range, $M_{min} = 64.5$ and $M_{max} = 102.6$ ($Mdn = 50$ – 100 cm), with a mean probability of 51.3%. Thus they agreed that *can* implied a value at the top of the range.

In the bird vignette participants were told that one scientist had said the bird population *will* be on the same level as today (10,000). This expert was believed to have a narrow range in mind, from $M_{min} = 9,838$ to $M_{max} = 12,872$ birds (both medians at 10,000 birds), with a mean probability of 62.6%. Another forecaster who said that the population *can* be twice as large as today (20,000) was believed to have in mind a range of 10,000 ($M_{min} = 11,250$) to 20,000 ($M_{max} = 20,380$). The maximum value was here perceived as having a mean probability of 50.0%.

Discussion

The results show that statements about what *will* happen refer either to the lowest or to the most probable outcome in a distribution. In the flooding vignette this is the same event (the flooding of Asawa), whereas in the bird vignette the probabilities of the lowest and the middle outcomes were not specified. One may here assume that the middle forecast is the most likely one, and might have been chosen for this reason, whereas the lowest forecast is chosen by language users who think that 10,000 birds saved could mean 10,000 birds *or more*. This interpretation is supported by the fact that participants who chose 10,000 birds were more certain than those who chose 15,000 ($M = 82.0\%$ vs. $M = 64.0\%$; $t(38) = 2.48$, $p = .018$).

Can was used by communicators to indicate the most extreme outcome in both vignettes, as predicted by the extremity hypothesis (Q1). In the flooding vignette, this is the worst outcome, whereas in the bird vignette it is the most optimistic scenario. In contrast to Study 1, recipients and communicators agreed (Q2). Evidently, the contrast between *will* and *can* in two parallel statements alerted participants to these terms' different pragmatic uses (Schwarz, 1996). Recipients in this study differed from participants in the headline condition in Study 1 who received the *can*-statement without context. Study 2 included context information also in the recipient condition suggestive of ranges (e.g., about sea levels that would cause flooding). Assuming in addition that both speakers had a common range in mind, it became easy for recipients to realize that *can* denoted top values, preventing speaker/recipient asymmetries.

Probabilities were in this study assessed on a percentage scale to allow more precise estimates of the perceived likelihoods involved (Q3). It is remarkable that outcomes that *can* happen were judged to have a probability of around 50%, despite being located at the top of the speaker's uncertainty interval. An elevated use of 50 will sometimes indicate "fifty-fifty" in the sense of "I don't know" (Fischhoff & Bruine de Bruin, 1999). However, such non-

numeric use of 50% is less likely when rated on an explicit numeric probability scale ranging from 0-100% (Bruine de Bruin, Fischbeck, Stiber, & Fischhoff, 2002). Moreover, 50% was in the present study the median in the participants' response distribution with one third above and one third below 50%, for both vignettes.

Study 3: Possible vs. maximal temperatures

The preceding studies demonstrated the extremity effect in *can*-statements of future climate change. A forecaster who is asked how warm it *can* be will typically suggest a top temperature. Surprisingly, this outcome was at the same time considered quite likely and given on the average a probability close to 50%, which seems exaggerated, as extreme outcomes are among the least likely in most outcome distributions. The present study was conducted to compare responses to *can*-statements with responses to statements about *possible* and *maximal* future values (Q4).

Possible is similar to *can*, both semantically and pragmatically. It has previously been found to elicit extreme values (Løhre & Teigen, 2014; Teigen, Juanchich, & Filkuková, 2014). As a verbal probability expression it is typically placed around the middle of the scale, close to 50% (Theil, 2002). It also has a positive directionality. When asked to explain why a target outcome is *possible*, most people produce exclusively pro-reasons rather than focusing on the uncertainty involved (Teigen & Brun, 1995).

Maximum refers, by definition, to the topmost values of a range or distribution. However, like other terms describing upper bounds (less than X, at most X) it has by the same test a negative directionality, because they tend to be explained with reasons for why the outcome is not higher (Hohle & Teigen, 2017).

Study 3 was conducted to compare the judgment of statements with positive directionality (*can* and *possible*) with a maximum value statement. We expected that all three terms would be used to describe extreme values at or near the top of a distribution, but not

necessarily associated with the same probabilities. When people consider high extremes as *possible*, or values that *can* occur, they may judge such outcomes as more probable than when they are described as *maximum* values.

Method

Participants were 197 students (median age 20 years) from the University of Tromsø, Norway, tested in a break between lectures, and randomly allocated to three different conditions, by receiving one of three different versions of the same questionnaire. Six questionnaires were discarded as incomplete or not completed with single numbers, as requested.

All participants received a questionnaire similar to the one used in Study 1, with a graph showing global warming projections from 2000 to 2100 from eight different research institutes (Figure 1). They were asked to imagine a journalist writing a newspaper article about these forecasts with one of these headlines (to be completed with an appropriate number):

Can condition: “It can be degrees warmer by the year 2100”.

Possible condition: “It is possible that it will be degrees warmer by the year 2100”.

Maximum condition: “It will be maximumdegrees warmer by the year 2100”.

In the article, the journalist discussed probabilities as well. What do you think he/she will write?

“Such an increase in temperature is about % probable”. (All conditions)

How do you perceive this journalist? To be rated on a 5-point scale from 1: *reassuring* to 5: *alarming*.

Results

Participants in all conditions filled in high temperatures in the headline statement, regardless of whether it was described as a maximal or simply a possible temperature ($M_{\text{can}} = 4.56$, $M_{\text{possible}} = 4.66$, and $M_{\text{maximum}} = 4.82$; $F(2, 190) = .353$, $p = .70$.) As expected, the modal

value was 5 degrees in all three conditions. This value was suggested by 55% of the participants in the *Can* condition, and by 66% and 65% of participants in the *Possible* and *Maximum* conditions, respectively. These percentages are not significantly different from each other, and are similar to the percentage of participants selecting 5 degrees (58.5%) in Study 1. To compare the effects of verbal phrase upon probability estimate and ratings of concern, participants who answered 5 degrees were selected for closer analysis.⁶

Mean judgments in the three conditions are given in Table 2. The table shows that probability estimates were generally high, especially in the *Can* and *Possible* conditions, as expected. Planned contrasts revealed that the two positive phrases (*can* and *possible*) led to higher probability estimates than the same temperature increase framed as a maximum value, $t(115) = 2.48, p = .015$, whereas the two positive phrases did not differ from each other, $t(115) = 0.53, p = .595$. Likewise, the two positive phrases gave more reason for alarm than the statement about the same temperature framed as a maximum, $t(115) = 2.39, p = .019$, but were not significantly different from each other $t(115) = 1.36, p = .178$.

<Insert Table 2 about here>

Discussion

The study replicated the findings from the previous studies, namely that what *can* happen is typically selected to be the upper extreme, and yet an outcome that is seen to be more likely than not. The study further showed that the two expressions with a positive directionality, *can* and *possible*, received similar ratings, and that both these phrases led to higher probability estimates than for participants who in a separate condition characterized 5 degrees as a *maximum* temperature increase. However, even this maximum was not considered unlikely, despite its extremity. Only a handful of participants seemed to think that the top value is only one of eight that are suggested by different research institutes, and should

⁶ Analyses where all participants were included, regardless of headline estimate, gave similar results; $t(188) = 2.34, p = .020$ and $t(188) = 2.18, p = .030$ for probabilities and concern ratings, respectively.

accordingly not be allotted more than 10–15% chance, unless the projections from this specific research institute should be regarded as much more reliable than the others. High probability estimates might also be justified if participant misread the question about “a such increase in temperature”, to mean something else than a 5 degree increase, for instance an increase “up to 5 degrees” or an increase of “maximum 5 degrees”. To control for these possibilities, Study 4 was conducted.

In this experiment, participants were presented with predictions of sea level rise based on different models that were surrounded by probability intervals indicating the degree of uncertainty associated with each of the model. So even if one model is preferred, extreme values in the uncertainty distribution around this model would have low probability of occurring. In addition, participants were explicitly asked to estimate the probability of the specific level of sea rise they had selected, preventing potential misunderstandings of which probability they were supposed to assess.

Study 4: Sea level rise with confidence intervals

In the previous studies, participants were presented with several different outcomes that were either derived from different models (Studies 1 and 3, bird scenario in Study 2) or simply defined as a range between upper and lower bounds (sea rise in Study 2). A recent study by Dieckman, Peters and Gregory (2015) indicates that such descriptions can make people think that all outcomes within the range are equally likely. This might contribute to overestimated probabilities for extreme outcomes, as indicated by the exaggerated values produced by participants in the present studies (although it cannot fully explain the degree of this exaggeration). Dieckman and colleagues further showed that ranges with an explicit “most likely” value in the middle, surrounded by a confidence interval, were more easily identified as being similar to a normal distribution, with middle values more likely than those at the extremes. These are features that also characterize many IPCC climate change graphs,

where prediction lines from different models are surrounded by a shaded area designed to capture confidence intervals (also called uncertainty ranges), as illustrated by Figure 4.

<Insert Figure 4 about here>

In Study 4, we used such graphs to test the extremity hypothesis for *can* in a context of projected rise in global sea level. The presence of a “best guess” (solid line) surrounded by a confidence interval might serve to reduce the perceived chances of extreme outcomes, especially when framed as “maximal” values. A statement of what *can* happen was again expected to imply a stronger concern than statements of what *maximally* is going to happen, due to the pragmatic directionalities of these phrases (upward vs. downward).

Method

Participants. Participants were undergraduate psychology students attending a lecture at a Norwegian university. Responses from 10 participants (five in each condition) were discarded for not complying with instructions (e.g., writing ranges rather than single numbers). Valid questionnaires were obtained from 138 participants, 99 women and 39 men, median age 20 years. They were self-allocated to two conditions by birthdates.⁷

Questionnaires. All participants were shown a diagram in colors displaying projection of sea level rise from IPCC based on four different models, along with “likely” ($p > .66$) intervals surrounding the “best” predictions, as displayed in Figure 4. It was explained that the figure was based on four models with solid lines showing mean values from the lowest and highest model, respectively, whereas the shaded color surrounding the lines indicated uncertainty ranges. The probabilities covered by these intervals were not disclosed. Participants were told about a journalist trying to summarize forecasts for the year 2100. The

⁷ Condition A: participants with birthdays from April-September; Condition B: birthdays from October-March.

journalist in the *Can condition* wrote: “The ocean can rise bycm”, whereas the journalist in the *Maximum condition* wrote: “The ocean will rise by maximum cm”.⁸

Next, all participants suggested what they thought the journalist would write about the probability value for this rise (namely for the indicated value). Finally, they indicated whether the journalist appeared to them as *not concerned*, *a little concerned*, *quite concerned*, or *very concerned* (coded as 1–4).⁹

Results

Estimates of *maximum* ocean rise and estimates of what *can* happen both led to very high estimates, with 1 m (100 cm) as the modal response in both conditions. Means were slightly (but not significantly) higher in the maximum condition than in the Can condition, $M_{\text{maximum}} = 86.0$ cm vs. $M_{\text{can}} = 79.6$ cm, $t(1, 136) = 1.70$, $p = .091$. Probabilities for this increase were perceived as higher in the Can condition, as shown in Table 3. Moreover, the journalist in the Can condition appeared to be on the average *quite concerned*, whereas the journalist who described the maximum increase was somewhat less concerned (modal response: *a little concerned*).

To contrast the effects of *can* vs. *maximum*, a separate analysis was performed on participants who thought the journalist would suggest a sea level increase of 80 cm and higher (57.4% of participants in the Can condition and 70% in the Maximum condition did so). It is apparent from the graph in Figure 4 that this is a quite extreme response, situated well above the “best” estimate of the most extreme scenario. Yet this sea level rise was considered quite likely, just below 50% by participants in the Can condition, but much less likely by participants who used these values to characterize the *maximum* sea rise, as seen in the lower panel of Table 3. A journalist reporting *maximum* values, even this high, appears to be only a

⁸ Some participants produced their responses as 1 m or decimal numbers because of the 0–1 m (er det riktig?) scale on the vertical axis. These numbers were converted to centimeters in the analyses.

⁹ The corresponding Norwegian terms were: Ikke bekymret, litt bekymret, ganske bekymret, veldig bekymret.

little concerned, whereas a journalist reporting the same values as sea level increases that *can* happen is assumed to be *quite concerned*.

To control for excessive use of 50%, which are often considered as default responses (Bruine de Bruin & Carman, 2012), an additional analysis was performed with such estimates removed. The results are added to the lower panel in Table 3, showing that the mean probability estimate for *can* was essentially unaffected (48.4%) and remained significantly higher than mean estimate for a *maximum* increase (30.5%).

<Insert Table 3 about here>

Discussion

Most participants selected *can* values that were as high as judged maximum values providing yet another confirmation of the extremity hypothesis for *can*. This study used an authentic IPCC graph that also showed uncertainty ranges. Thus the selected top outcomes were explicit outliers in the forecasters' uncertainty distributions. Despite this, participants who selected outcomes based on what *can* happen, estimated probabilities for these outcomes to be medium, rather than low. The same outcomes were judged less likely when considered as *maximum* values. Interestingly, this cannot be regarded as a simple labelling effect (Pohl, 2017), as the verbal labels were not arbitrarily affixed to values by the experimenter, but used by the participants themselves to generate representative values. The *can*-forecasts were also perceived as more alarming, indicating that the inflated probability estimates reflected their true opinions and were not just an "I don't know"-response.

Study 5: Can, could and may

All previous studies were conducted in Norway with Norwegian-speaking participants. Although the extremity hypothesis has previously been confirmed with English-speaking participants for *possible* and some other verbal probability phrases (Teigen, Juanchich, & Filkuková, 2014), the English modals *can*, *could* and *may* have not been investigated. These

modals might serve similar functions in predicting uncertain climatic projections, perhaps with a stronger emphasis on hypotheticality (in the case of *could*) and uncertainty (in the case of *may*). In their study of causality in headlines, Adams et al. (2017) found that “conditional cause” statements (involving *may*, *might*, and *could*) indicated a weaker degree of causality statements than *can*. Discussions of proper usage of *can/could* (e.g., Merriam-Webster, 2008) and *may/might* (The Economist Style Guide, n.d.) in English suggest that these verbs have different shades of meaning, which are not always easily rendered in other languages. For instance, in Norwegian *can* (*kan*) is used more broadly, including contexts where native English speakers would prefer *may* or *could*.¹⁰ In the IPCC reports, these modal verbs are used about equally frequently to describe potential future climate effects, as illustrated by the statement below (*italics ours*).

“Under a +3.7 °C scenario by 2100, the worldwide reduction in heating energy demand due to climate change *may* reach 34% in 2100, while cooling demand *may* increase by ≥ 70 %; net energy demand *could* reach – 6 % by 2050 and + 5% by 2100” (Edenhofer et al., 2014, pp. 697–698).

Study 5 was designed to compare climate forecasts containing the three modals *can*, *could*, and *may*, as judged by English-speaking respondents. We expected to replicate the extremity effect for all three terms, but not necessarily associated with the same degree of certainty.

Method

Participants were 200 American respondents recruited through Mechanical Turk, 44% female, mean age 36.6 years ($SD = 11.4$). Most respondents (89%) had at least some college education. They received two vignettes, one about rise of sea level, illustrated by the graph

¹⁰ An anonymous reviewer suggested that most (perhaps all) of the translated sentences in Studies 1-4 were better written with the word 'could' than 'can'. We have, however, decided to retain *can* to stay closer to the original, more general term.

presented in Figure 4 (with the error bars on the right removed), and the other about the reduction in energy demand (based on the IPCC quote above).

In the sea level vignette, participants in three separate conditions were asked to fill in the level of sea rise that a journalist would say *can*, *could*, or *may* occur at the end of the century. Next, they estimated the journalist's probability of this rise to occur (as a number between 0 and 100%), and finally what he/she would write about the most likely level of sea level rise, based on the graph.

In the heating energy vignette, participants read the following forecast of a range of more positive side effects of global warming.

“By year 2100, the worldwide reduction in heating energy demand due to climate change will be between 23% and 45%, with a reduction of 34% as the most likely value. A journalist, reporting on these forecasts writes: ‘By 2100, there can [could] [may] be a ... % reduction in heating energy demand (fill in the missing value)’.

Participants were then asked to indicate the journalist's estimate of the probability of this reduction.

Subsequently, participants in all conditions asked to compare three statements with different modals: “In the future, the world can / could / may become 3 degrees warmer”, and were asked (a) which statement sounds more apt in a forecast of global warming, and (b) which statement expresses the most uncertainty.

Finally, they reported their beliefs in climate change on two scales from Broomell, Budescu, and Por (2015), adapted from Heath and Gifford (2006): General existence-belief in global warming (sample item: “Global warming is occurring now”), and belief that global warming is caused by humans (sample item: “The main causes of global warming are human activities”). The eight statements were rated on Likert scales ranging from 1: *strongly*

disagree to 5: *strongly agree*. Four items indicating climate skepticism were reverse scored, and the combined scale had a satisfactory reliability ($\alpha = .95$).

Results

Sea level vignette. Ten answers to this vignette had to be discarded because of missing responses or unrealistically high sea levels (above 200 cm).¹¹ The modal response was 100 cm in all conditions (reported by 61.2%, 67.8%, and 44.6% of participants for *can*, *could*, and *may*, respectively). Mean sea levels are displayed in Table 4, indicating support for the extremity hypothesis in all conditions. The table also shows that these rather extreme values were regarded as quite probable, also in the *could* and *may* conditions, with most probability estimates from 50% and upwards. A separate analysis of those who suggested a 100 cm sea rise in response to the first question gave about the same probability estimate regardless of condition, $M_{\text{can}} = 46.0\%$, $M_{\text{could}} = 51.6\%$ and $M_{\text{may}} = 51.9\%$. Yet participants in all conditions agreed that the most likely level of sea rise was much lower, close to the middle value of the graph. There were positive correlations between the sea level indicated by modal verb, and the *most likely* sea level rise: *Can*: $r = .56$ ($p < .01$), *Could*: $r = .47$ ($p < .01$), *May*: $r = .31$ ($p < .05$). Thus, the higher the journalist said that the sea level *can/could/may* rise, the higher he/she also thought the most likely increase would be.

<Insert Table 4 about here>

Energy reduction vignette. In this vignette, participants had been provided with numbers defining the range as well as the most likely (middle) value. This led to bimodal distributions, with 42% of the participants suggesting the middle, “most likely” value and 37% selecting the topmost value for being the level of energy reduction that *can*, *could*, or *may* occur. Mean levels did not differ between conditions (bottom row of Table 4), but the

¹¹ In the questionnaires, participants had been informed that 100 cm was equal to 34.6 inches. As a consequence, a few answers appear to have been given in inches. They were retained in the subsequent analyses, because of a lack of unambiguous exclusion criteria, and might have served to *lower* the means for sea level presented in Table 4.

middle value was considered more likely ($M = 65.5\%$) than the topmost value ($M = 35.5\%$), regardless of condition; $F(1,146) = 54.99, p < .001$.

In the final question given to all respondents, statements with all three modals were directly compared. *May* and *could* were equally often chosen as appropriate in climate forecasts, as shown in Table 5, with *may* conveying more uncertainty. Thus, English-speaking respondents appear to prefer these modals to *can* when all three terms are presented jointly. Yet when they were judged one by one (Table 4), all three terms were used to express equally extreme estimates, which were at the same time considered more likely than unlikely.

<Insert Table 5 about here>

Discussion

The extremity hypothesis was replicated with English-speaking participants for three different modals: *can*, *could* and *may*. Even if *can* appeared less appropriate and was judged to convey less certainty than the two other modals, all three terms were similar in suggesting top values and were also estimated to convey probabilities of 50% or higher. The sample as a whole contained more climate believers than climate sceptics ($M_{\text{belief}} = 4.03, SD = 1.04$), but the strength of their beliefs appeared unrelated to their judgments of levels and probabilities of sea rise (no significant correlations).

The presence of an explicitly stated most likely value in the Energy reduction vignette made this value a potential target for what *can* occur, rivalling the topmost value. This suggests that the extremity effect can be modified by presentation of other, relevant reference point values. Yet top values were selected ten times more often than the bottom values in the range of outcomes, supporting the weaker version of the extremity hypothesis in a distribution where three values (middle value and upper and lower range endpoints) are specified.

General Discussion

We identified in the introduction five main research questions. The present research gave strong support to the extremity hypothesis for climate related predictions (Q1): Speakers in five studies used the modal verb *can* consistently to describe high (top) future outcomes. This use was not always understood by listeners when such statements were taken out of context (Q2). The probabilities assigned to *can* seemed higher than warranted by outcome extremity (Q3). People selected high values also when asked about *possible* or *maximum* outcomes, but the perceived probability for *maximum* outcomes was lower than for *possible* and *can* (Q4). A final study showed that the extremity effect and problem with inflated probabilities could be extended to the related English modals *could* and *may* (Q5). Below, findings pertaining to these research questions are discussed in more detail, with an emphasis on Q1 (the extremity of *can*) and Q3 (its associated probability estimates).

The modal auxiliary *can* is a verb with multiple related meanings, including ability, possibility, knowledge, requests, and permissions (Longman Dictionary of Contemporary English, 2009; Merriam-Webster Online Dictionary, 2010). In a forecasting context, as in the present studies, this term is taken to characterize outcomes that are seen to be realistic and obtainable, i.e., that have a non-zero probability of occurring. Most people who are shown the set of projections in Figure 1 will presumably admit that all individual temperatures between 2 and 5 degrees are possible, and hence instances of global warming, which *can*, to the best of our knowledge, become a reality before the end of the century. Similarly, the shaded intervals in Figure 4 indicate that any sea level projection between 30 and 100 cm is imaginable, although not equally likely. Yet when asked to pick an outcome to be included in a *can*-statement, speakers select a value near or at the top of the distributions. This cannot be explained as a selective preoccupation with the most threatening scenario, as the extremity effect also applies to positive events (the bird vignette in Study 2) and to events with a more ambiguous valence (the energy saving vignette in Study 5). Nor did it appear to be related to

intensity of climate change beliefs, as measured in Studies 1 and 5. The preference for high values was replicated for related terms, like *possible* in Study 4 and *could* and *may* in Study 5, indicating that the effect is not limited to one specific interpretation of *can* in one specific language. All studies confirmed the “weak” version of the extremity hypothesis (a preference for high rather than low values), and in most cases top values were preferred to middle ones, confirming the “strong” version of the hypothesis, as well.

A limitation of the present set of studies is their reliance on just two languages (Norwegian and English) and participant samples with no claim of representativeness (Paolacci & Chandler, 2014). However, if biased interpretations of climate forecasts are common in samples of educated lay participants, there is little reason to believe that more representative samples of the general population would be more balanced and consistent.

A second limitation is that only a subset of potential verbal descriptors is used. We compare in Study 3 and 4 interpretations of outcomes that *can* happen with those that could *maximally* occur, but might also have included other negative phrases (like *uncertain*), and control conditions without a verbal descriptor, to assess more exactly the effects of *can* on subsequent probability estimates.

Further, we do not claim to have explained the extremity effect. Our primary aim was to establish the robustness of this effect in a context of climate forecasts, as presented to people who are potential consumers of such information, rather than to identify its linguistic or psychological roots. Some factors that could play a role in accounting for the effect are briefly discussed below.

First, the effect may be related to a general fascination of maximal achievements as being more impressive and consequential than minimal or average outcomes. For instance, when skills and abilities are assessed, it is the topmost achievement that counts. A person who is asked about her proficiency in swimming is not supposed to answer: “I can swim 100 m”

(although this may also be true) when in fact she can swim as much as 200 m. In line with this, the scalar modifier “up to” is frequently preceding numbers in statements of *can* (Teigen & Filkuková, 2013). Tests of abilities are traditionally classified as tests of maximal rather than typical performance (Cronbach, 1949). Thus, the idea of a maximal outcome associated with *can* in a context of abilities may be carried over to or related to *can*-statements also in a context of forecasts. However, this speculation is not equally applicable to extremity effects in statements of what is *possible*, or what *may* happen.

We may further speculate that speakers select top values to make *can*-statements as informative as possible. This is achieved by placing *can* values adjacent to what *cannot* happen, thus if temperatures can increase by 5 °C, speakers imply that higher values are unlikely. From a Gricean perspective, communicative informativity is enhanced by contrasting what is said to other relevant statements that are *not* chosen (Grice, 1975; Levinson, 2000). The informativity of top values becomes especially evident in contexts describing developments or upwards trends. For instance, if forecasters think of potential sea level rises in the 30–100 cm range, but choose to say that a 50 cm rise is *possible*, they may be blamed for under-communicating the full extent of the potential increase. Following this interpretation, we may predict that the extremity effect will be most dominant in areas where increasing numbers reflect a real or imagined trend of increasing numbers. During periods of growth we look for future upward maxima, and in times of decline we are concerned about how large the drop will be, whereas more inconsistent changes may bring other values in focus. We would accordingly expect, after a period of fluctuating exchange rates, or variable oil prices, that statements about future possibilities might not consistently refer to the topmost values.

It follows from a pragmatic analysis that statements about possibilities will focus on different outcomes dependent on frame, or conversational context. In the preceding studies

the verbal phrases (the modals) were fixed, the question being which numerical value the speaker would select from a range of outcomes. This way of studying verbal probabilities has been dubbed the “which outcome approach” (Teigen, Juanchich, & Filkuková, 2014). Alternatively, the experimenters might have pre-selected a specific outcome value, for instance, a temperature increase of 2 °C, and asked participants to fill in which of several verbal terms would be appropriate. In this case, a range of terms (e.g., likely, possible, can and could) might be deemed appropriate. From the perspective of the receiver of the communication, it is accordingly crucial to know under which frame a *can*-statement is issued. When an outcome value is freely chosen by the speaker, it will (at least for *can* and its cognates) belong to the topmost values of the distribution, as dictated by the extremity hypothesis. But if an outcome value has been singled out for another, specific reason, for instance as a benchmark (like the two degrees target of the Paris agreement), a wider usage of *can* and its cognates becomes admissible. Recipients in Study 1 who were asked to estimate the likelihood of *can*-statements did not seem to be aware of the difference between these two settings, mistaking the journalist’s statement of a temperature that *can* occur for a statement about the most likely temperature increase.

To ensure appropriate understanding of an utterance, conversational partners must be communicatively aligned. This is best achieved when listeners are not just passive recipients of a message but can simulate the speaker and make predictions during the comprehension process (Pickering & Garrod, 2013). In Study 2, with two forecasters producing will- and *can*-statements about the same future events, listeners had the cues needed to identify the speakers’ setting, and could predict their usage of *can*-statements more accurately.

A surprising finding, conceptually distinct from the extremity effect, was the inflated probabilities attached to the selected outcomes of a *can*-statement. Extreme outcomes are in most outcome distributions infrequent, and should accordingly be associated with low rather

than medium and high probabilities. However, participants who read headlines with *can* (Study 1) thought that the values mentioned in these statements were “quite likely”, and readers of statements about islands that *can* be flooded, or birds that *can* be saved (Study 2) believed that the probabilities of these events were around 50%, even when they were aware of the extreme nature of these outcomes. This finding was replicated in Studies 3–5, which showed that participants placed in the role of communicators claimed that extreme outcomes they deliberately had selected, had a medium rather than low probability of occurring. Probability estimates of extreme outcomes were significantly below 50% only in two conditions: when the top values were labeled *maximum* outcomes (as in Study 3 and 4), or when a different outcome had been explicitly referred to as “most likely” (as in the energy reduction vignette of Study 5). The frequent occurrence of 50% in the other studies cannot simply represent a non-numerical “I don’t know” response (Fischhoff & Bruine de Bruin, 1999), as it did not emerge as an unmotivated ‘blip’ (Bruine de Bruin & Carman, 2012), but was the central value of the *can*-distributions in all studies. Reanalyses of probability estimates with all 50% responses removed (20-25% of all responses in Studies 3-5) introduced no essential changes in any of the analyses reported in Tables 2-4.

Previous studies have repeatedly shown that lay people (even students with a background in statistics) do not assign probabilities to multiple outcome events in a distributional fashion, but assess single outcomes one by one, leading to overestimated probabilities of focal events (e.g., Klar, 2002; Sanbonmatsu, Posavac, Kardes, & Mantel, 1998), and more generally to subadditive judgments of the exhaustive set (Riege & Teigen, 2013; Teigen, 1983; Tversky & Koehler, 1994). Thus a 50% probability estimate for one outcome does not necessarily mean that all other outcomes are held to be less likely. In fact, participants in Study 1 (graph condition) and Study 4 (sea rise vignette) believed that the most likely temperatures and sea rise estimates were to be found in the middle rather than in the

high end of the respective outcome distributions. Yet the top estimates were consistently judged as being 50% probable and sometimes even higher. A potential clue to these exaggerated probability estimates might be found in the fact that *can* along with *may*, *could*, and *possible* belong to the set of probability descriptors that have a positive, upward directionality. Phrases with positive directionality will be completed by pro-reasons, whereas negative phrases (like uncertain and doubtful) will be completed with counterarguments, indicating why a target outcome may not occur after all (Teigen & Brun, 1995, 1999). Thus, people who are asked to explain why a temperature increase can, could, or may reach 5 °C, would find it natural to refer to increased CO₂ emissions, overpopulation, failures to reach and keep international agreements, and so on. Such reasons imply a mechanism as well as a trend. Positive phrases are typically chosen when probabilities used to be lower (Juanchich, Teigen, & Villejoubert, 2010), so an outcome one is told *can* happen may have become more rather than less likely than before. Moreover, the possibility interpretation of *can* implies that enabling conditions are present, so nothing prevents it from happening in *principle* (given known constraints in the world), although we do not know its probability in *practice*, which will depend on all competing influences on the event (Fox, 2003). The conjecture that *can* and its cognates (possible, could, may) serve as mediators between the extremity of an outcome and an inflated probability assessment, was supported by results from Study 3, where an extreme increase in sea level was judged to be more likely when framed as a *possible* than as a *maximal* increase. However, a complete account of the effects of verbal label on probability assessment can only be achieved by additional studies, where outcomes from the same outcome distributions (as those presented in Figure 1 and 4) are characterized by a larger variety of labels, as for instance “it is uncertain [unlikely] [a chance] that sea level will arise by 100 cm”, as well as a control condition where participants are asked to estimate the probabilities of this outcome without any label.

Taken together, the extremity of *can* (and its cognates) and the inflated probabilities associated with these terms could lead to distorted interpretations of messages within several domains where risks and uncertainties are being verbally communicated. For positive events, best case scenarios may be taken for more likely than intended, for negative outcomes, worst cases may be perceived as imminent rather than hypothetical. An extended use of *can*-statements may lead to charges of overcommunicating the extent of climate change. Moreover, it is likely that the upper and lower bounds of a hypothetical outcome distribution will be more variable than its central value, leading to more variable messages about what *can* happen than what is most likely to happen. New assumptions and changed models have the potential to affect and extend the extremes of a hypothetical distribution more than its central values. It follows that there could be more variability and apparent disagreements about upper than middle values, perhaps feeding a notion of controversies among experts.

The present findings have implications for uncertainty communication in several domains, including medicine, law, military intelligence, consumer psychology, and project management. For instance, a new law about domestic abuse in the UK (with a maximum penalty of five years) received headlines like: “You can now get 5 years in prison for ‘psychological bullying’ in your relationship” (Lee, 2015). Patients, asking doctors and health advisors “how long can I live with aids” are typically answered with statements about life expectancies (medians) rather than what they can hope for. On the other hand, lottery ads make a point of announcing what you *can* win (top prizes) and not the most likely outcome (winning nothing). Illusions of communication will arise when the extreme outcomes, denoted by *can*, are mixed up with those that are expected or most likely. To prevent misunderstandings, honest communicators should supplement their *can*-statements with most likely estimates, or vice versa: enrich their expected values with statements about what *can* occur.

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Table 1. *Overview of main research questions and themes investigated in five vignette studies*

Main Research Questions	<i>Study 1</i> Temperatures	<i>Study 2</i> Sea level Birds	<i>Study 3</i> Temperatures	<i>Study 4</i> Sea level	<i>Study 5</i> Sea level Energy demand
Q1: Extremity of can (speakers)	X	X	X	X	X
Q2: Recipients' interpretations	X	X			
Q3: Likelihood estimates	(x)	X	X	X	X
Q4: Can vs. other terms (will, possible, maximum)		X	X	X	
Q5: English related modals (can, could, may)					X

Table 2. *Mean estimated probabilities and rated concern (1-5) for statements about a temperature increase of 5° C in three conditions, Study 3*

	It can be 5° C warmer	Possible with 5°C warmer	Maximum 5°C warmer	<i>F</i> (2, 116)	<i>p</i>
How probable (SD)	58.5% (26.0)	55.4% (23.7)	44.8% (25.7)	3.24	.043
How alarming (SD)	4.10 (0.81)	4.36 (0.63)	3.83 (1.05)	3.48	.027

Table 3. *Mean estimated probabilities (SD in parentheses) for rise in sea level and rated concern in two conditions, Study 4*

	Can	Maximum	t_{diff}	p
All participants	$n = 68$	$n = 70$		
Probability	50.6% (25.1)	40.1% (25.7)	2.40	.017
Concern (1-5)	3.00 (0.97)	2.46 (0.97)	3.59	.000
Participants with extreme sea level rise (> 80 cm)	$n = 39$	$n = 49$		
Probability	48.7% (25.9)	34.1% (25.3)	2.66	.009
50% responses removed	48.4% (28.7)	30.5% (26.5)	2.73	.008
Concern (1-5)	3.18 (0.76)	2.41 (1.00)	4.00	.000

Table 4. *Mean ratings (SD in parentheses) of climate forecasts with English modal verbs in three conditions, Study 5*

	Can	Could	May	Main effects	
Sea rise vignette				<i>F</i> (2, 187)	<i>p</i>
Level (cm increase)	85.5 cm (29.0)	85.2 cm (25.7)	79.2 cm (41.8)	0.76	.468
Probability	51.6% (28.8)	55.0% (30.7)	57.3% (27.0)	0.65	.522
Most likely level	55.3 cm (20.0)	63.9 cm (24.1)	56.4 cm (28.7)	2.22	.111
Energy vignette				<i>F</i> (2, 197)	<i>p</i>
Level (% reduction)	39.9 (10.9)	37.8 (6.8)	37.7 (8.4)	1.31	.273
Probability	49.8% (28.7)	54.4% (28.9)	53.4% (28.3)	0.49	.612

Table 5. *Number of participants (percentages) preferring can, could, or may as appropriate in climate forecasts and as expressions of uncertainty (all conditions, Study 5)*

Preference	Can	Could	May	χ^2 (2, $N = 200$)	p
In climate forecasts	35 (17.5%)	81 (40.5%)	84 (42.0%)	24.12	< .001
To predict uncertainty	27 (13.5%)	77 (38.5%)	96 (48.0%)	38.10	< .001

Figure Captions

Figure 1. Global warming projections from eight different models/sources, presented to participants in the Graph condition, Study 1, and to all participants in Study 3 (from Rohde, n.d.)

Figure 2. Most likely temperature increase suggested by participants in the graph and headline conditions (percentages of respondents), Study 1.

Figure 3. Three (fictional) projections of future bird populations presented to participants in Study 2.

Figure 4. Graph presented to participants in Study 4 and Study 5, showing global average sea level projections based on four scenarios of greenhouse gas concentrations. From Freedman (2013). Credit: IPCC 2013 Working Group I, Figure SPM9.

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