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"You know nothing, John Doe" – Judgmental overconfidence in lay climate knowledge☆

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ABSTRACT

The 1.5° target outlined in the Paris agreement requires immediate and fundamental climate action; the lack of climate knowledge, prevalent misconceptions and purported knowledge may be major barriers. Therefore, this study was carried out to analyze signs of judgmental overconfidence in lay climate knowledge using a quota sample of 499 Austrians. Results indicate that several misconceptions exist, e.g., regarding the role of the ozone hole or that water vapor is a greenhouse gas. Moreover, there is a clear indication of knowledge overconfidence: the respondents' confidence levels in their own answers are higher than the accuracy of the answers. This amount of *miscalibration* between confidence and accuracy increased as the difficulty of the question increased. Significant differences in the results can be found regarding sociodemographic aspects. In order to be effective, transformative policies need to take into account the potential confounding effects that knowledge overconfidence and misconceptions may have on the reception of these policies by the general public.

1. Introduction

There is widespread scientific consensus that the increasing levels of greenhouse gas emissions cause climate change and result in additional ecological consequences, such as the acidification of oceans, loss of biodiversity, destruction of ecosystems and the melting of glaciers (IPCC, 2018). These consequences extend beyond natural systems and have begun to backfire on humankind, e.g., in the forms of heat waves that lead to increased urban vulnerability (Reischl, Rauter, & Posch, 2018), an increase in the numbers of heat-related deaths, or new diseases due to shifts in climatic zones (Pachauri & Mayer, 2015). Current efforts to reduce greenhouse gas emissions seem insufficient, and it has been argued that immediate and fundamental behavior changes will be necessary to counteract these developments and meet the 1.5° target that was outlined in the Paris agreement (IPCC, 2018). This is especially true of the carbon-intense consumption patterns and lifestyles which are prevalent in developed countries, and being adopted with increasing frequency in emerging economies with growing middle class sectors and increasing living standards. Significant action is needed on both individual and collective levels to promote development within the political sphere; still, major societal changes do not seem to be in sight.

One psychological factor that potentially explains this lack of behavior change, among a variety of other influences, is the lack of factual knowledge: Despite the fact that a scientific consensus exists in the international academic communities, studies have revealed that the climate change literacy of laypersons (i.e., what people know about climate change) is limited and error-prone (Reynolds, Bostrom, Read, & Morgan, 2010; Sundblad, Biel, & Gärling, 2009; Tobler, Visschers, & Siegrist, 2012). This seems to hold true for different domains of factual climate change knowledge, for example, regarding underlying physical processes, causes, or consequences of climate change for samples in different geographical locations (Reynolds et al., 2010; Sundblad et al., 2009; Tobler et al., 2012). One cause of this problem could be the lack of or provision of only fragmentary climate change education in schools. Because the topic has only recently been placed on the political agenda, most adults were not taught about climate change during their school days, and components of climate change – especially the anthropogenic components – are still often not addressed in textbooks (Dalelo, 2011). A study conducted in Colorado furthermore showed that certain misconceptions related to climate science and climate change are widespread among public school science teachers, possibly due to the lobbying efforts of climate change deniers (Wise, 2010). Moreover, the mass media seems to represent the main source of information about climate change for the majority of the adult general public, which is strongly shaped by the respective belief systems and values of specific (political) interest groups (Clayton et al., 2015; Kellstedt, Zahran, & Vedlitz, 2008). Consequently, stories read in the newspaper or

☆ The first part of the title is a reference to popular culture: A famous line in the TV series *Game of Thrones* reads "You know nothing, Jon Snow".

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seen on television, although perhaps inaccurate or incomplete, form the baseline of mental models about climate change. In most cases, new information is filtered according to established views and identities (Clayton et al., 2015). The resulting misbeliefs and knowledge gaps, for example in the understanding of basic physical processes (Bostrom, Morgan, Fischhoff, & Read, 1994; Li, Johnson, & Zaval, 2011), may be a barrier to the acceptance of climate protection measures that intervene with established practices and behaviors of the general population. After all, the role of knowledge in influencing respective behavior has been underlined by several authors (Reser, Bradley, Glendon, Ellul, & Callaghan, 2012; Taddicken, Reif, & Hoppe, 2018; Tobler et al., 2012), although the literature includes distinctive findings regarding the power of knowledge to predict behavior if other factors are not also taken into account. As an example, smokers are often well aware of the negative health consequences of smoking, but still refuse to quit smoking. Still, knowledge has been found to act as an important, albeit indirect driver of behavior in that it influences the level of concern about climate change (Shi, Visschers, Siegrist, & Arvai, 2016). While lack of knowledge could be one barrier to more climate-friendly behaviors (Gifford, 2011), sciolism or purported knowledge could be another, even more relevant one. In this context, a range of literature has reported the phenomenon of knowledge overconfidence in general. Overconfidence refers to the observation that people frequently overrate the accuracy of their own knowledge (Yates, Lee, & Shinotsuka, 1996). This tendency is one of several so-called self-serving biases (Greenberg, Pyszczynski, & Solomon, 1982): Human decision-makers usually interpret facts in a way that serves the maintenance of a positive image of oneself, and thinking highly of one's own knowledge obviously contributes to a positive self-image. Overconfidence has been reported in analyses of general population samples (Lundeberg, Fox, Brown, & Elbedour, 2000; Yates, Lee, & Bush, 1997), as well as for specific subgroups such as entrepreneurs (Ilieva, Brudermann, & Drakulevski, 2018) or students (Schaefer, Williams, Goodie, & Campbell, 2004); overconfidence is moreover prevalent both with respect to general knowledge (Fischhoff, Slovic, & Lichtenstein, 1977; Forbes, 2005; Whitcomb, Önkal, Curley, & Benson, 1995) and specific knowledge, such as knowledge concerning genetically modified food (Fernbach, Light, Scott, Inbar, & Rozin, 2019), financial decisions (Porto et al., 2016), sexual health (Dunne, McCann, Millen, Wilson, & Macdonald, 2015), alcohol and drug use (Parker & Stone, 2014) or chemistry (Bell & Volckmann, 2011). Despite its possible relevance, to the best of the authors' knowledge the topic of overconfidence in the specific domain of climate change knowledge has not been addressed in a comprehensive way within the psychological literature. The aim of this study, therefore, was to (1) investigate the extent to which the climate change knowledge of laypeople is subject to overconfidence and (2) discuss counter-measures and implications for climate policies.

2. Theoretical background and framework

Johnson and Levin (2009) proposed a general framework for understanding environmental (in)action and claimed that knowledge, information and understanding form three important prerequisites for environmental and climate action. In studies in the context of psychology and climate change, knowledge and literacy are usually measured by distinguishing several categories, such as the causes, physical foundations and consequences of climate change (Tobler et al., 2012). These studies sometimes also involve questions on the perceived effectiveness of climate policies (Reynolds et al., 2010). Previous findings generally show that severe misconceptions as well as gaps exist in people's mental models concerning climate-related knowledge. Typical shortcomings in peoples' knowledge that have been noted involve misunderstandings about the greenhouse effect, misconceptions about the concepts of weather and climate (Bulkeley, 2000), or a tendency to attribute climate change to stratospheric ozone depletion (Guy, Kashima, Walker, & O'Neill, 2014; Read, Bostrom, Morgan, Fischhoff, & Smuts, 1994). Although a more recent U.S. study showed that the level of understanding in the current general population seems to have improved, a lack of understanding still exists regarding links between CO_2 emissions and fossil fuels as the main causes of climate change (Reynolds et al., 2010). Also, political identities and framing effects influence how climate change is being perceived (Benjamin, Por, & Budescu, 2017). A study by Tobler et al. (2012) on the climate knowledge of the Swiss public confirmed the existence of such misconceptions, although the sample showed a relatively good understanding of the role of carbon dioxide. The similar constructs of objective knowledge on and understanding of climate change have to be differentiated, however, as the latter is highly shaped through and differs per culture, therefore representing a social construct of the real problem (Reser et al., 2012). For example, populations in Western countries often perceive themselves as more distant from nature, leading to different decision-making processes, although the levels of factual knowledge are comparable to those of populations in other countries (Bang, Medin, & Atran, 2007; Johnson & Levin, 2009).

Clearly, not all knowledge is the same, and different forms of knowledge may vary with regards to their relevance for climate-friendly behaviors. As one example, Frick, Kaiser, and Wilson (2004) distinguish between system knowledge, effectiveness knowledge and action-related knowledge, and found that the latter two have a direct influence on actual performance, while better system knowledge had a positive influence on the other forms of knowledge. A similar classification is also used by Taddicken et al. (2018), who differentiate between causal knowledge (climate change and causes), basic knowledge (about the greenhouse gas effect and the role of CO_2), effects knowledge (on consequences of knowledge), action-related knowledge (related to decisions of individual consumers), and procedural knowledge, which refers to the level of understanding for the uncertainty prevalent in (climate) science. However, assuming that addressing the presumed knowledge deficit (Simis, Madden, Cacciatore, & Yeo, 2016) directly leads to more climate-friendly actions would be too simplistic. Even when information can be accessed accurately, knowledge levels are high and the understanding of advanced problems is clear, various additional factors play roles as well (Clayton et al., 2015; Milfont, 2012). Johnson and Levin (2009) introduced two different types of barriers that block the way to successful environmental or climate action: (i) the way in which the problem is communicated, and (ii) a variety of cognitive biases in human decision-making. In reference to the widely discussed *tragedy of the commons* (Hardin, 1968), Johnson & Levin labeled this observation as a *tragedy of cognition* (Fig. 1). The study reported in this paper relates to both types of barriers: It explores one cognitive bias (knowledge overconfidence), and this bias at least in part is related to climate change communication efforts and the challenges these efforts face.

The term *overconfidence* in general describes a miscalibration between subjective perception and actual performance (Fischhoff et al., 1977). The concept is closely related to that of metacognition, which refers to someone's knowledge of their knowledge (Kruger & Dunning, 1999). High metacognitive sensitivity, or *good calibration* is understood as the "ability to correctly judge the correctness of one's own decisions" (Sherman, Barrett, & Kanai, 2015). Overconfidence on the other hand

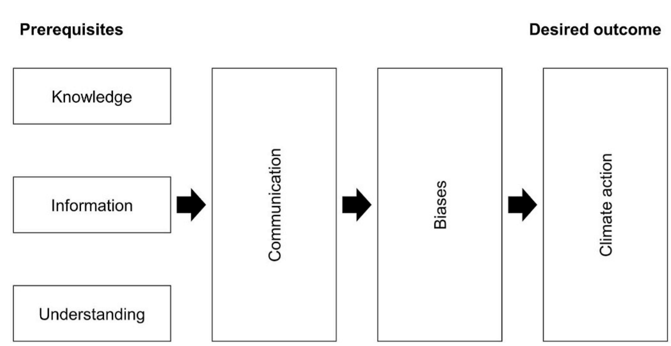

Fig. 1. The tragedy of cognition (modified from Johnson and Levin (2009)) [SINGLE COL].

represents a specific decision bias, in which confidence exceeds accuracy, i.e. the level of confidence in one's own performance is higher than the objectively measured level of that performance. Although the broader term *overconfidence* has been used in most studies, different types of this phenomenon can be observed and are known as *overestimation*, *overprecision* and *overplacement*. *Overplacement* defines a person's perception of their ability to perform better than others and is also known as the better-than-average effect, representing a relative construct. *Overestimation*, on the other hand, refers to the excessive belief in one's personal abilities compared to the actual performance in absolute terms. Finally, *overprecision* refers to a tendency to define overly narrow confidence intervals for stated answers; the relation between one's personal confidence in a particular answer and its actual accuracy is distorted (Merkle & Weber, 2011; Moore & Healy, 2008). Due to the nature of this study, and based on the findings of Moore and Healy (2008), no clear distinction between *overestimation* and *overprecision* can be made. Therefore, the more general term overconfidence is used in this paper.

The issue of potential (over)confidence in climate change knowledge is rarely addressed in the literature; four exceptions, however, are reported here. The first one is that of Sundblad et al. (2009), who examined climate change knowledge and confidence among Swedish experts, laypeople, politicians and journalists. They found, not very surprisingly, that experts as a group are the most knowledgeable about climate change, whereas journalists were found to be best-calibrated. Laypeople, who made up the largest group within the general population targeted in that study, had the lowest calibration levels. Sundblad et al. (2009) did not calculate an explicit overconfidence measure, but instead investigated the product moment correlations between the actual knowledge scores and the mean stated confidence ratings. As a second exception, Reser et al. (2012) investigated the state of climate change knowledge among members of the Australian population by using ten knowledge statements extracted from the original study of Sundblad et al. (2009). Although the certainty of the answers was measured using a six-point scale, again no explicit overconfidence score was computed. As a third exception, a study in the field of education conducted by Shephard et al. (2014) dealt with the environmental literacy of university students in New Zealand. Their study involved the concept of environmental literacy (including factual knowledge as well as calibration in terms of confidence) in a broader sense and did not place a particular focus on climate change knowledge; overconfidence/underconfidence levels were only implicitly considered in the environmental literacy score and were not explicitly computed. Finally, a recent German study (Fischer, Amelung, & Said, 2019) shall be added to this overview, which explicitly looked at accuracy of confidence in climate change knowledge of citizens and found confidence of citizens in their climate change knowledge not well calibrated. Interestingly, they found differences between the results for true and false knowledge statements: While respondents were quite well-calibrated for true statements, overconfidence was prevalent for false statements. This is related to the so-called *veracity effect*, which describes the general tendency of people to rather believe a statement to be true than false (Levine, Park, & McCornack, 1999).

In general, the presented studies differ in how they measure knowledge and confidence. However, all involve a concept of metacognition and do not only test the knowledge and literacy of respondents, but also their ability to reflect on what they believe to know. In line with the argumentation of Taddicken et al. (2018), the application of a metacognitive concept like *confidence in answers* also allows it to distinguish between informed respondents (who answer correctly with high confidence), uninformed respondents (who answer with low confidence, i.e. guess) and misinformed respondents (who answer incorrectly, but with high confidence). The study reported in this paper adds to the scarce body of literature on miscalibrated climate knowledge in the general population and indicates that overconfidence seems more prevalent than underconfidence in this specific domain.

3. Materials and methods

The data used for this study were generated by conducting a survey with a quota sample taken from the Austrian adult population ($n = 499$). The online survey was conducted in cooperation with a market research institute. Power analyses were used to determine the minimum sample size of $n = 333$ for testing differences in means ($alpha = 0.01$, $power = 0.9$, $|d| = 0.3$) and calculating correlations ($alpha = 0.01$, $power = 0.9$, $r = 0.3$). As the aim was to gather a representative sample of the Austrian population (also used for analyses beyond the scope of this study), a target sample size of $n = 500$ was chosen. Eventually 596 questionnaires were collected, of which 549 were complete. After excluding respondents who failed to answer the control question correctly, a set of 499 questionnaires could be used for further analysis. The sample is representative with regard to gender, places of residence and age (the youngest age group was slightly underrepresented). In terms of their educational backgrounds, people without a *Matura* (high school diploma) were underrepresented (50% in the sample vs. 67.5% in the population[1]). To measure the levels of explicit climate change knowledge (literacy) of the respondents, ten knowledge questions in a true/false format (see Fischer et al. (2019), Shi et al. (2016) and Reser et al. (2012) for similar approaches) were included. For each of these questions, participants could choose one answer and additionally had to state the subjective probability that the answers were correct. The options ranged from 50% (guessing) to 100% (fully confident) in decadal confidence steps, also described as a half-range task (Alba & Hutchinson, 2000). The answers to these questions regarding knowledge and the respective confidence levels were then examined to investigate the presence of potential overconfidence in climate-related knowledge.

$$\frac{1}{n}\sum_{i=1}^{T} n_t(r_{tm} - c_t) \tag{1}$$

Equation (1) (Jonsson & Allwood, 2003) describes the general measurement of overconfidence for an individual, where n represents the total amount of items, T is the number of used confidence classes, n_t is the number of times a particular confidence class was used, r_{tm} represents the mean confidence rating per confidence class[2] and c_t the share of correct answers (accuracy) per confidence class. In this study, we set $n = 10$ (number of climate change statements) and $T = 6$ (confidence levels subjects could choose from for each statement). The mean confidence level per person over all statements was then assigned to the classes 50–59, 60–69, 70–79, 80–89, 90–99 and 100, following Jonsson & Allwood (2003). If Equation (1) resulted in a positive value, the respondent was labeled as overconfident. If an accordance between the results was observed ($\leq \pm 1\%$ deviation), the respondent was labeled as well-calibrated; otherwise (in case of a negative result), the respondent was labeled as underconfident (Ilieva et al., 2018; Keren, 1991). Individual results were then summed up over all participants ($n = 499$) to calculate the mean overconfidence, accuracy and confidence levels. Based on the accuracy level measured as the share of correct answers per statement, the questions were then allocated to different difficulty levels depending on whether they were considered to be easy (70% and higher), medium (40–69.99%), or hard (0–39.99%). Furthermore, Pearson correlations for the accuracy and confidence levels, as well as in relation to the variable *age*, and two-sided t-tests between sociodemographic groups in terms of gender and

[1] https://www.statistik.at/web_de/statistiken/menschen_und_gesellschaft/bildung/bildungsstand_der_bevoelkerung/020912.html (12th January 2020); at the time of the survey period, numbers from 2016 were available.

[2] On an individual level, the stated confidence levels per step (50, 60, etc.) are equivalent to the respective mean confidence rating per confidence class (50–59, 60–69, etc.) as confidence was measured only incrementally. For example, if the confidence step 50 was chosen at least one time, r_{tm} for the confidence class 50–59 would also be 50 for an individual.

educational backgrounds, were conducted. The analyses were performed using R software (ver. 1.1.463).

4. Results

Before the results for overconfidence are presented, the general performance in terms of accuracy, namely, the amount of climate-related knowledge of participants, is illustrated. The results of this study fit into the overall picture that can be drawn from the existing literature addressed in sections 1 and 2, indicating low amounts of climate knowledge and overconfidence about the accuracy of this knowledge. Overall, out of ten statements that mainly address the physical foundations and causes of climate change, participants could only answer about half of the questions correctly ($M = 5.53$, $SD = 1.65$, $MIN = 1$, $MAX = 10$); therefore, their performance levels were only slightly above those that would have been expected if they had answered at random.

Table 1 illustrates the respective share of true and false positives and negatives. The hit rate (true positives), including all confidence levels, is 59.56%, indicating that about three of the five true statements were correctly identified as such. The false alarm rate (false positives) lies at 48.90%, indicating that only half of the false statements were identified as such, demonstrating a lower performance in detecting wrong statements compared to true ones. Table 2 gives an overview of the given climate statements as well as the proportions of correct answers (also described as accuracy), the mean confidence and resulting overconfidence levels. The easiest question (i.e., defined by the share of correct answers given) dealt with emissions related to the production of pork in comparison to wheat, while the most difficult one asked whether water vapor is a greenhouse gas. Note that correct answers with a confidence level of 50%, which can be interpreted as (correctly) guessed answers, were also counted and considered in these calculations for accuracy *(number-right scoring)*. If these guessed answers are excluded from the accuracy calculations *(1-0-0 scoring)*, participants performed worse ($M = 4.83$, $SD = 1.87$, $MIN = 0$, $MAX = 9$) and the accuracy levels of the answers per statement ranged between 14.8 and 72.7% (see Supplementary Material, Table A for shares of guessed answers per statement).

4.1. Overconfidence in knowledge

When comparing the levels of accuracy with the stated confidence levels ($M = 76.2$, $SD = 11.1$, $MIN = 50$, $MAX = 100$), the confidence in answers on average exceeded the accuracy by 20.9 percent points ($SD = 18.4$, $MIN = -30$, $MAX = 68$), providing support for the prevalence of overconfidence. Table 3 shows the overall confidence, accuracy and resulting overconfidence levels as well as the respective results per level of difficulty. As can be seen, participants seemed to be on average well-calibrated only for the easy questions (deviation between confidence and accuracy ≤ 1%), whereas overconfidence was prevalent for the medium and hard questions and increased as the level of question difficulty increased.

When examining the individual level, of the 499 subjects included in the study, 425 people were ranked as overconfident (85.2%), 55 as underconfident (11.0%) and 19 were labeled as well-calibrated (3.8%). In terms of the results per each statement, eight of ten statements (see Table 2) showed overconfidence in their answers. Only for statement 2 (emissions from pork production vs. emissions from wheat production) respondents were well-calibrated (+0.9%). This statement was also the easiest question with respect to the level of accuracy. Regarding statement 3 (continued warming despite stabilization of greenhouse gas content in the atmosphere), a minor level of underconfidence can be observed in the answers (- 3.2%). Furthermore, the Pearson correlation between accuracy and confidence was calculated, which revealed a small positive effect ($r = 0.159$, $p < .001$, *99% CI* [0.045, 0.269]). This positive relationship may seem surprising at first, but can be interpreted that it makes sense to rely on personal confidence, as long as this confidence itself is legitimate (Alba & Hutchinson, 2000).

Three graphical illustrations are used to additionally enhance the understanding of the presented results. First, Fig. 2 shows the frequency distribution of individual accuracy scores, using number-right scoring (correctly guessed answers are counted as correct) and 1-0-0 scoring (guessed answers are counted as incorrect). For true statements, respondents performed better than for wrong statements. Fig. 3 illustrates the mean accuracy of answers per confidence class as compared to the mean confidence per confidence class. In case of accurate calibration, the values should be located at the dashed 45-degree line; meaning that 50% of the answers with a 50% confidence level and 100% of answers with a 100% confidence level would indeed be correct (Keren, 1991). As the figure shows, all means per confidence class lie well below this line, indicating that the answers were overconfident. Overconfidence is more prevalent for false (M = 24.75, *95% CI* [22.36, 27.14] than for true statements (M = 16.9, *95% CI* [14.95, 18.91], and accuracy is lower for false statements.

Finally, Fig. 4 shows the frequency distribution of individual confidence judgments, where the turquoise bars depict correct verifications and the grey bars incorrect verifications. For all confidence classes the number of correct responses is higher than the number of incorrect responses. However, when looking at true and false statements separately, incorrect verifications of false statements are prevalent in the higher confidence classes, i.e. a majority of highly confident respondents incorrectly verify false statements.

4.2. Comparison of sociodemographic groups

Participants were compared on the basis of three sociodemographic factors that have been found to have an influence on knowledge and/or overconfidence in the literature, namely, age, gender and educational background (McCright, 2010; Reser et al., 2012; Selm, Peterson, Hess, Beck, & McHale, 2019). In terms of their gender and educational backgrounds, participants were compared by applying two-sided t-tests (see Table 4). Male participants showed both significantly higher levels of accuracy ($|d| = 0.506$, $p < .001$, |*99% CI*| [0.270, 0.742]) as well as confidence ($|d| = 0.790$, $p < .001$, |*99% CI*| [0.550, 1.031]) compared to females. High school graduates achieved a significantly higher share of correct answers ($|d| = 0.224$, $p = .014$, |*99% CI*| [0.011, 0.459]) than those without high school diploma, but no difference in terms of (over)confidence was observed between these two groups. In terms of age ($M = 43.5$, $SD = 12.3$, $MIN = 18$, $MAX = 72$), pairwise Pearson correlations were calculated regarding the three variables accuracy, confidence and overconfidence; both confidence ($r = 0.306$, $p < .001$, *99% CI* [0.198, 0.407]) as well as overconfidence ($r = 0.163$, $p < .001$, *99% CI* [0.049, 0.273]) significantly increased with age. Still, the absolute differences between all groups were relatively small.

5. Discussion

To summarize the presented results, the two major problems revealed as a result of this study are the generally low levels of literacy regarding climate change, which have also been shown in other studies (Moxnes & Saysel, 2009), as well as the gaps between knowledge and confidence. In the following subsections, the limitations of this study, differences between sociodemographic groups and practical implications are described.

Table 1
Hit rate, miss rate, false alarm rate, correct rejection rate.

	Share of respondents who answer “true”	Share of respondents who answer “false”
True statement	59.56 (6.49)	40.44 (6.21)
False statement	48.90 (5.65)	51.10 (7.66)

Note. Numbers in percent; numbers in brackets represent the share of guessed responses (50% confidence) in percent points.

Table 2

Items	Confidence		Accuracy	Over-confidence
	M	*SD*		
Water vapor is a greenhouse gas.	80.0	17.6	16.4	63.6
A diesel vehicle generates more CO_2 emissions per person and kilometer than a comparable petrol vehicle.	79.0	16.5	36.5	42.5
The ozone hole is the main cause of the greenhouse effect.	80.5	15.8	39.7	40.8
Without humans there would be no greenhouse effect.	80.9	16.9	56.5	24.4
The 1990s were the warmest decade of the 20th century.	72.7	16.7	53.3	19.4
CO_2 is more harmful to the climate than the same amount of methane.	67.9	16.4	57.9	10.0
In the last century, warming in Austria was significantly lower than the global average.	71.1	16.5	64.9	6.1
The global rise in temperature in the last century was the biggest within the last 1.000 years.	77.4	17.5	73.3	4.1
The production of 1 kg of pork produces more greenhouse gas emissions than the same amount of wheat.	79.7	18.1	78.8	0.9
If the current greenhouse gas content in the atmosphere was stabilized, the climate would nevertheless continue to warm up for at least 100 years.	72.7	16.2	76.0	−3.2

Shares of correct answers and confidence per statement.
Note. M = mean, SD = standard deviation, n = 499, numbers in percent.

Table 3
Levels of confidence, accuracy and resulting overconfidence.

	Overall		Easy		Medium		Hard	
	M	SD	M	SD	M	SD	M	SD
Confidence	76.2	11.1	76.6	13.3	73.1	12.4	79.8	12.5
Accuracy	55.3	16.5	76.0	25.6	58.2	25.6	30.9	27.1
Overconfidence	20.9	18.4	0.6	25.8	15.0	28.4	49.0	29.1

Note. M = mean, SD = standard deviation, n = 499, numbers in percent.

5.1. Critical reflection and limitations

Other than previous studies on judgmental overconfidence, this study is, to the best of the authors' knowledge, one of the first ones to address overconfidence with regard to climate change knowledge. The findings are largely in accordance with those presented in the broad body of literature on overconfidence in general, as well as on overconfidence regarding specific knowledge. The representative Austrian sample in the present study exhibited overconfidence when responding to most questions asked, and this overconfidence increased as the difficulty of the questions increased, and vanished or even reversed when easy questions were asked. These results are largely in line with a recent German study by Fischer et al. (2019), who found a representative general population sample to be well-calibrated with regards to their climate knowledge, but only for true statements and not for false statements. While respondents in the German study were on average even slightly underconfident for true statements, overconfidence is dominant for true and false statements in the current study. Such a *veracity effect* can be understood as one relevant bias in the *tragedy of cognition*: Errors are more frequent when incorrect statements on climate change are being judged, i.e. people a priori rather tend to believe a statement than to reject it. This effect was more salient in the German study with a substantial gap between hit rate (73%) and correct rejection rate (48%) (Fischer et al., 2019, supplementary material). In the present Austrian study, the gap between hit rate (60%) and correct rejection rate (51%) was much smaller (see Table 1).

As in any social science study, this study is subject to several limitations, and different aspects may have influenced the findings presented: First, as outlined previously, knowledge in terms of climate change is often fragmentary or subject to misconceptions. This could explain the higher tendency of this population to respond with overconfidence in general. Second, the method used to measure confidence and select specific items might have influenced the results (Brenner, Koehler, Liberman, & Tversky, 1996; Fellner & Krügel, 2012; Griffin & Tversky, 1992). In this study, items related to climate change were selected intentionally and, therefore, they cannot be considered as representative according to the definition of Gigerenzer, Hoffrage, and Kleinbölting (1991). On the other hand, the selected questions had different difficulty levels, and a proper balance between easy, medium and hard questions was maintained. Therefore, it can be argued that the selected questions served the purpose of this study well. Third, the question related to whether water vapor is a greenhouse gas may be considered as a misleading item according to Keren (1991) due to the

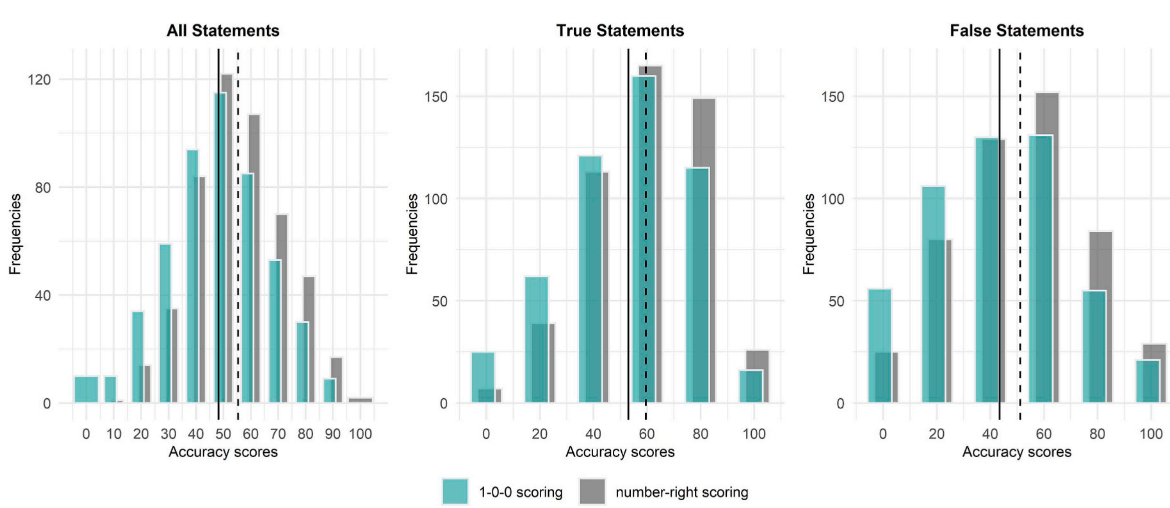

Fig. 2. Frequency distribution of individual accuracy scores with number-right scoring and 1-0-0 scoring, lines represent mean scores (solid – 1-0-0 scoring, dashed – number-right scoring).

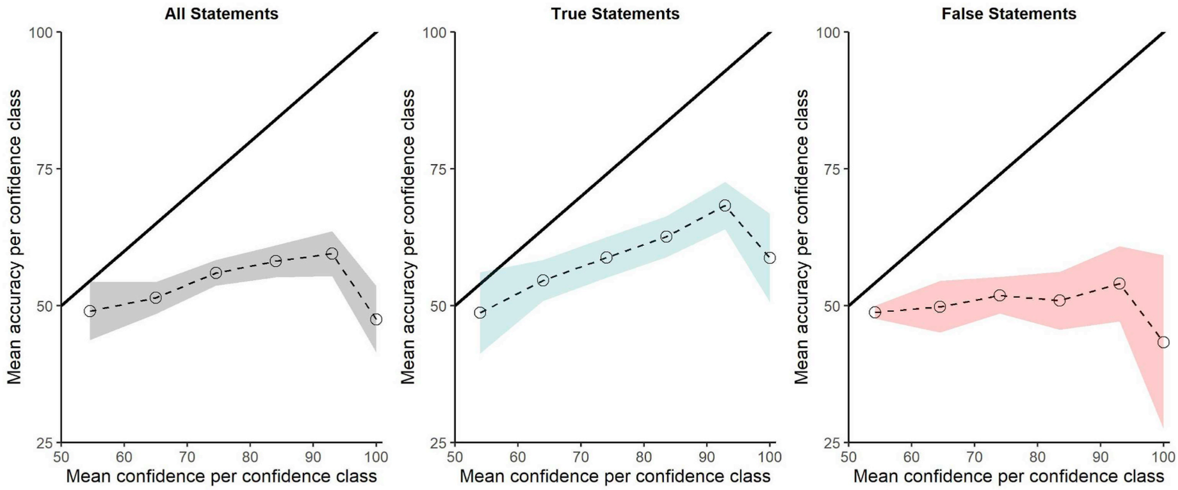

Fig. 3. Calibration curve for all statements (left plot), true statements (middle plot) and false statements (right plot) with 95% confidence bands.

number of incorrect answers given. The reason behind this may be the low salience of water vapor among the greenhouse gases (although actually it is the biggest contributor) or its rather indirect effect on the acceleration of global warming (Held & Soden, 2000). The existence of such misleading items can lead to distortions in the picture, as they alone can be responsible for the occurrence of overconfidence (Brenner et al., 1996; Keren, 1991). Still, this was not the case in this study, as overconfidence was identified for eight of the ten items.

Due to implemental and practical constraints, it was not possible to examine the dimension of knowledge in more detail, although it would be relevant to distinguish between different forms of knowledge to conduct a more detailed analysis (Taddicken et al., 2018; Tobler et al., 2012). In this study, we focused on explicit knowledge, i.e., literacy on facts related to climate change. Other forms of knowledge, such as tacit knowledge or direct experience with climate change impacts, were not addressed. We argue that this is a feasible and, to a certain degree, necessary limitation, when considering that the prime aim of this study was to address the overconfidence bias, and not to measure respondents' various knowledge levels. In terms of methods, this study measured overconfidence by using an absolute indicator. Absolute measures are criticized for confounding confidence with accuracy, and therefore it is suggested to apply relative measures which factor out accuracy. The analysis reported in this paper therefore was supported by applying a relative measure, which confirmed the existence of a confidence bias (M_{ratio}, see Supplementary Material, Part B).

The apparent climate change knowledge deficits in the Austrian general population are in line with what has been found in other countries (Fischer et al., 2019; Shi et al., 2016, supplementary material), but it needs to be kept in mind that such results are always depending on how knowledge is being measured, i.e., which knowledge scale is being used. This also makes a comparison to findings from studies on different topics, such as literacy on genetically modified organisms (Fernbach et al., 2019), difficult. As overconfidence has been found prevalent for a variety of topics (see section 1), it is hard to define how much of the found effect can be actually attributed to the specific domain of climate change knowledge, or what actually causes the miscalibration.

Finally, this study was conducted in Austria and therefore the results first and foremost relate to the Austrian context. However, as the literature shows overconfidence to be a general problem that occurs in different knowledge domains and geographical locations, it is expected that the results and derived implications could also be applicable to other Western countries.

5.2. Differences among sociodemographic groups

The results show variations in the accuracy, confidence as well as overconfidence levels among different groups. In general, overconfidence could be found in all participant groups independently of their sociodemographic characteristics. Overconfidence increased with

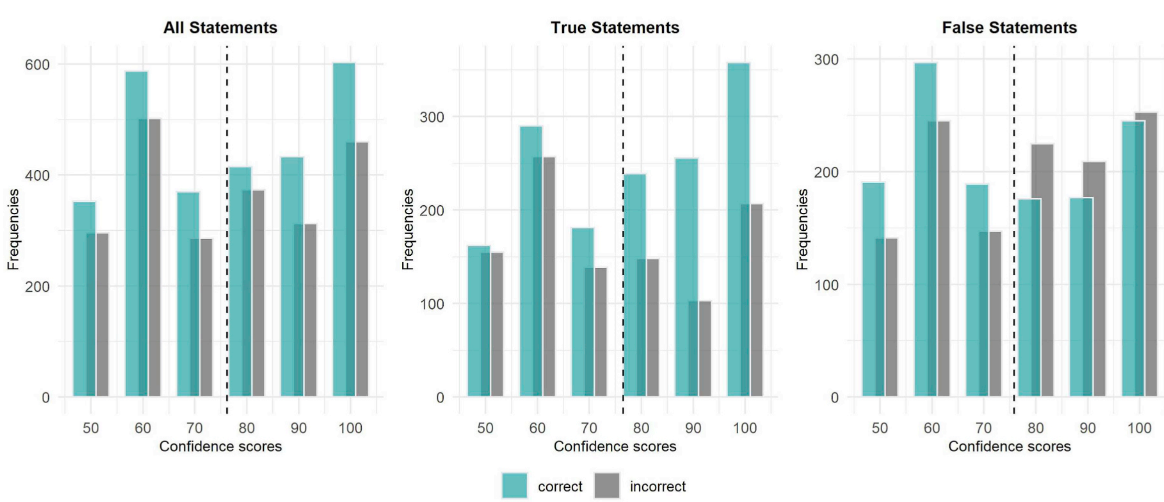

Fig. 4. Frequency distribution of individual confidence judgments of correct and incorrect verifications, dashed lines show mean confidence scores.

Table 4
Differences in means in terms of accuracy, confidence and overconfidence between groups.

	n	Percentage	Accuracy		Confidence		Overconfidence	
			M	*SD*	*M*	*SD*	*M*	*SD*
Gender	497							
Male	244	49.1	59.5**	16.5	80.4**	9.8	20.9	18.5
Female	253	50.9	51.3**	15.6	72.2**	10.8	20.9	18.4
High school diploma	488							
Yes	244	50.0	57.3*	17.1	76.6	11.1	19.3	18.4
No	244	50.0	53.6*	15.8	75.8	11.3	22.2	18.4

Note. M = mean, SD = standard deviation, $^{**}p < .001$, $^{*}p < .05$, pairwise comparison using two-sided t-tests regarding gender and educational background.

age; this finding is in accordance with the findings of Palmer, David, and Fleming (2014), who found a reduction in metacognitive efficiency with increasing age. In terms of gender, men displayed both higher accuracy and confidence in terms of their climate knowledge. Still, both genders were overconfident, and the absolute differences were rather small. Also Lundeberg et al. (2000) found rather small gender differences (in contrast to the larger cultural differences). Jonsson and Allwood (2003) explained this as being dependent on the respective knowledge domains and also found both men and women to be overconfident. On the other hand, McCright (2010) found women to have higher scientific climate literacy levels as compared to general knowledge, a finding that could be neither supported nor denied in this study. Lower levels of confidence expressed by female subjects, nevertheless, were also apparent in the latter study. Regarding perceived knowledge, Selm et al. (2019) found an interaction between education and gender: Women with lower amounts of formal education perceived themselves as more knowledgeable than men with the same amounts of education, but this effect was reversed as the amount of education increased. Furthermore, despite the respective educational backgrounds, minorities in their case study reported having lower levels of perceived knowledge as compared to participants from the white ethnic majority. With regards to the study reported in this paper it is interesting to note that, although greater amounts of formal education seem to lead to an increase in the accuracy of answers provided, overconfidence levels remained salient for subjects with higher amounts of formal education.

5.3. Practical implications

In general, the combination of low overall knowledge on the one hand, and high levels of confidence in answers on the other hand, can hinder the success of awareness-raising campaigns, and can even be problematic regarding the public acceptance of climate policies. Climate knowledge was found to be one central factor for taking climate action as well as for supporting the respective policy measures (Hart, Nisbet, & Myers, 2015; Stoutenborough & Vedlitz, 2014; Tobler et al., 2012), while misperceptions in people's mental models may lead to the support of climate policies that miss the most striking challenges (Moxnes & Saysel, 2009). Furthermore, gaps in knowledge should motivate people, encouraging them to gain better or more knowledge. Ignorance of personal knowledge gaps, therefore, is problematic, as it renders knowledge acquisition needless (Hattie, 2013; Sundblad et al., 2009; Yates et al., 1996).

The observed low levels of knowledge and high levels of miscalibration outline several challenges for education as well as communication about climate change. First, as information about climate change is abundantly available (Kellstedt et al., 2008), a focus should be instead placed on whether the kind of information, the way it is provided (Johnson & Levin, 2009) and the channels that are used for diffusion are appropriate for enhancing climate action. As different subgroups trust distinct sources depending on their values and orientations, various channels will be necessary to reach such diverse audiences; information uptake will be more effective if the information is tailored to the specific person and context (Clayton et al., 2015). This seems to be especially relevant as people possess different levels of cognitive complexity. This refers to the number of perspectives or constructs a person uses when trying to understand a phenomenon such as anthropogenic climate change. Chen and Unsworth (2019) found that people with higher levels of cognitive complexity respond better to information that contains two-sided arguments, namely, presenting misinformation together with correct statements about climate change. For people with lower levels of cognitive complexity, one-sided arguments (that only place a focus on correct facts about climate change) had a higher positive influence on their beliefs. Furthermore, the literature shows that not all kinds of knowledge have the same effect. For example, knowledge about the causes of climate change has been found to have a stronger effect on the level of concern, probably because the connection between human activities and resulting climatic changes evokes feelings of personal responsibility (Shi et al., 2016). Moreover, especially action-related and efficiency knowledge and, namely, knowing how to act to have the highest possible impact, plays a crucial role (Milfont, 2012). In the opinion of the authors, the focus of information campaigns has already been placed on action-related knowledge, but these campaigns currently fail to target the most efficient actions sufficiently.

Second, to tackle the calibration problem, the provision of feedback may close the gap between accuracy and confidence (Ronis & Yates, 1987). For example, Koriat, Lichtenstein, and Fischhoff (1980) stated that the task of listing contradicting arguments – also called counterfactual reasoning (Flannely & Flanelly, 2000) – regarding the chosen answer helps improving the calibration between confidence and accuracy. Moxnes and Saysel (2009) suggested a similar approach in the climate context by raising so-called *cognitive conflicts* to enhance people's interest. They also used a variety of analogies that improved the understanding of participants. In addition, insights from dissonance research can also be useful in this context. Blanton, Pelham, DeHart, and Carvallo (2001) showed that strategies which address motivations as one reason for overconfidence (e.g., for example through lowering the perceived importance of people to appear knowledgeable) can reduce the bias in confidence estimations.

Finally, and referring back to the importance of accurate climate change education in schools that was previously addressed (see section 1), Hattie (2013) summarized additional strategies that can be used to recalibrate confidence and accuracy regarding general learning processes. These include focusing the students' attention on valid (rather than on easy, familiar) cues, providing them with good practice examples and gaining an understanding of the students' prior knowledge of a topic in order to actively intervene. Although they addressed teaching and learning in general, these findings also provide useful insights regarding the specific topic of climate change in education and communication, both inside and outside the classroom. The recalibration tools addressed here are not only relevant in that they can be used to reduce judgmental overconfidence but also possibly 'cure' the underconfidence found for those subjects with the highest accuracy of answers.

6. Conclusions

The results of this study indicate a considerable overconfidence bias with regards to climate knowledge in the Austrian general public. The prevalence of such a bias imposes several challenges to climate change communication. Especially when people confidently hold misbeliefs, it is more likely that they stick to their flawed mental models and selectively process related information rather than accepting knowledge that contradicts their current (mis)beliefs. This tendency is also referred to as *confirmation bias*, and may present a barrier to the acceptance of ambitious climate change policies. In this regard, the findings of this study show substantial room for improvement in terms of climate change knowledge, and calibration between the accuracy and confidence of laypeople. Although some approaches for tackling overconfidence have been outlined, further research in the form of, e.g., experiments and long-term studies with before-after comparisons for the specific climate-related context are necessary in order to increase the knowledge base in this relatively new field of research. From a climate policy perspective, it is definitely not enough to simply provide more information to citizens without taking into account the status quo of knowledge and misinformation in the general public, as well as essential biases in human cognition and decision making.

Notes

The authors declare no conflict of interest. The study was conducted in line with data protection regulations and under consideration of the official statement of the Ethics Committee at the University of Graz (https://www.uni-graz.at/en/researching/organisation-plan/ethics-committee/).

CRediT authorship contribution statement

Annina Thaller: Data curation, Formal analysis, Methodology, Software, Validation, Visualization, Writing - original draft, Writing - review & editing, Funding acquisition. **Thomas Brudermann:** Conceptualization, Methodology, Project administration, Supervision, Validation, Writing - original draft, Writing - review & editing.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvp.2020.101427.

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