Climatic Change (2012) 114:189–209
DOI 10.1007/s10584-011-0393-1

Consumers' knowledge about climate change

Christina Tobler · Vivianne H. M. Visschers · Michael Siegrist

Received: 14 September 2010 / Accepted: 15 December 2011 / Published online: 11 January 2012

Abstract Several studies have unveiled various misconceptions about climate change that the public holds, for instance, confusion about climate change and ozone depletion. However, so far, there has been no uniform and standardized way to measure climate-related knowledge, which complicates comparisons between different countries or samples. To develop an extensive knowledge scale, we therefore examined the Swiss public's understanding of climate change in a mail survey and related this scale to attitudes toward climate change. We thereby aimed to consider a broad range of climate-related knowledge, namely physical knowledge about CO_2 and the greenhouse effect, knowledge about climate change and its causes, knowledge about the expected consequences of climate change, and action-related knowledge. The questionnaire included items of different degrees of difficulty, ranging from knowledge that is covered by newspapers to experts' knowledge. Our findings indicate that people still hold several misconceptions, although people's knowledge related to CO_2 seems to have increased compared to previous studies. Of all knowledge subscales, knowledge about climate change and causes was most strongly related to attitudes toward climate change.

1 Introduction

Past research indicates that accurate knowledge about the causes of climate change is an important determinant of both behavioral intentions and support for climate protection policy measures (Bord et al. 2000; O'Connor et al. 1999). Lack of basic knowledge (e.g., about causes, impacts, and solutions) was also mentioned by laypeople as an important barrier to personal engagement (Lorenzoni et al. 2007). The authors suggested that lack of knowledge might contribute to a feeling of uncertainty about climate change, which ultimately might result in skepticism about the reality of climate change, the human influence, and the need for action. Thus, lack of knowledge might influence people's

C. Tobler · V. H. M. Visschers (✉) · M. Siegrist
ETH Zurich, Institute for Environmental Decisions (IED), Consumer Behavior, Universitaetstrasse 22
CHN J75.2, 8092 Zurich, Switzerland
e-mail: vvisschers@ethz.ch

attitudes toward climate change as well as people's willingness to act and to support mitigation policies. It therefore seems important to investigate what the public currently knows about climate change. Although a large body of research has examined people's understanding of climate change, there has been no standardized way of measuring knowledge, which makes it difficult to compare the results of different studies. Thus, we developed a comprehensive knowledge scale covering a broad range of knowledge about climate change and conducted a large-scale survey in the Swiss population. We also aimed to examine how this knowledge relates to attitudes, such as climate-related concern or skepticism.

1.1 Previous studies on laypeople's knowledge about climate change

When asked about the public's understanding of climate change, people seem to believe that the scientific background is generally poorly understood (Henderson-Sellers 1990). In fact, previous studies examining the public's climate-related knowledge showed that laypersons have a limited understanding of climate and seem to have difficulties distinguishing it from weather (Bostrom et al. 1994; Read et al. 1994; Reynolds et al. 2010). Several other misconceptions about climate change also seem to be rather consistent. People, for instance, often confuse the problems of stratospheric ozone depletion with climate change and seem to have difficulties in differentiating between causes and actions specific to climate and other more general good environmental behaviors (Bostrom et al. 1994; Poortinga et al. 2006; Read et al. 1994; Reynolds et al. 2010). Even highly educated adults showed widespread misunderstanding of the fundamental stock and flow relationships of CO_2 emissions and net removal (Moxnes and Saysel 2009; Sterman 2008; Sterman and Booth Sweeney 2007).

The erroneous understanding of climate change and causes appears to be of a global nature (e.g., Bord et al. 1998; Dunlap 1998; Leiserowitz 2007) and persistent over time (Reynolds et al. 2010). Accordingly, such misconceptions have also been found in Switzerland. In a Swiss survey, 35% of the respondents believed that the greenhouse effect is caused by a hole in the Earth's atmosphere (Diekmann and Meyer 2008). And although a large majority of the respondents (89%) were aware that combustion of oil, coal, and gas contributes to the greenhouse effect, only 42% knew that CO_2 is the main contributor to the greenhouse effect. In an earlier study, even fewer could identify CO_2 as the main greenhouse gas, namely 28% of the respondents (Jaeger et al. 1993). This indicates that the public awareness of CO_2 as a contributor to the greenhouse effect has generally risen in Switzerland in recent years. One reason for this increase might be that the issue has been progressively covered in the mass media. The influence of media on public knowledge will be discussed in Section 1.2.

The public misconceptions found in past research can be assigned to different knowledge domains, such as knowledge about the process of climate change, about its causes, or about its consequences. People's climate-related knowledge seems to vary across these different knowledge domains. Sundblad et al. (2009) found that experts, journalists, politicians, and laypersons all showed the highest level of knowledge about the causes of climate change, followed by the climate's state and the consequences of climate change. The levels of confidence in one's knowledge also varied between the different domains: laypersons felt most confident about their knowledge of consequences, followed by the causes and the climate's state. Generally, people with higher levels of climate-related knowledge tend to be more confident about their knowledge and seem to consider themselves more informed (O'Connor et al. 1998; Sundblad et al. 2009). This relationship, however, was usually very weak. People's confidence in their climate-related knowledge might therefore not be a valid indicator of their actual knowledge and thus no substitute for an objective assessment of climate-related knowledge.

However, past research's focus on knowledge about climate change has also been subject to criticism. For instance, researchers have argued that people might have a more holistic understanding of climate change and that focusing on public knowledge about the science of climate change might therefore lead to misconceptions of public understanding (Bulkeley 2000). Other researchers have argued that lack of knowledge is probably not the main barrier to action and that, therefore, increasing public awareness might not translate into actual behavioral change as various cognitive and structural barriers are involved (Bulkeley 2000; Dunlap 1998). Similarly, past research suggested that a socio-cultural model is more predictive of climatic change commitment than a model focusing on knowledge (Jaeger et al. 1993). We therefore do not claim that knowledge about climate change is a panacea for people to change their behaviors or to support climate protection measures. Simply informing people about climate change most certainly will not suffice to engage the public in the subject of climate change. However, to understand the necessity of climate policy measures or climate-friendly behavior, it is important to have a certain understanding of climate change. If someone, for instance, is unaware of the fact that CO_2 is the main cause of climate change, he or she would probably be very unwilling to accept CO_2 taxes or to reduce car use. We therefore believe that climate-related knowledge represents an important, yet not sufficient, prerequisite for people's willingness to accept climate protection measures or to change their behaviors.

1.2 The influence of media coverage on public knowledge about climate change

Media coverage forms a dominant source of climate science news for consumers (Antilla 2005) and may therefore affect consumers' knowledge and attitudes. Past research examining the influence of media on climate-related knowledge among consumers, however, is mixed. One study indicated that the use of media is positively related to awareness of climate change causes, effects, and solutions (Stamm et al. 2000). Another study, however, found that newspaper use had a negative influence on knowledge about climate change, whereas the number of information sources increased consumers' climate-related knowledge (Kahlor and Rosenthal 2009).

In the case of climate change, the media often present dissent where the science largely agrees, which finally leads to biased coverage of human contributions to climate change (Antilla 2005; Boykoff and Boykoff 2004). A study detected lack of knowledge among journalists, which might be one reason for this bias (Wilson 2000). Furthermore, presenting opposing sides in order to provide balance and objectivity is a journalistic tradition (Corbett and Durfee 2004). As a result, many articles frame climate change in terms of debate, controversy, or uncertainty (Antilla 2005; Zehr 2000). The controversy framing might reduce consumers' perception of the certainty of scientific findings (Corbett and Durfee 2004). As discussed, the feeling of uncertainty about climate change could increase skepticism about the reality of climate change, which ultimately might decrease consumers' willingness to address the issue (Lorenzoni et al. 2007).

1.3 Rationale for this study

Although the public understanding of climate change has been examined in several studies, so far there has been no standardized, uniform measure to assess people's understanding of climate change. Such a comprehensive, quantitatively tested climate-related knowledge scale would allow for comparisons between countries, various samples, and time frames. More importantly, an extensive knowledge scale covering different knowledge domains would enable researchers to examine whether different types of knowledge are important for different types of psychological constructs (such as attitudes, intentions, or support for climate protection measures).

Fietkau and Kessel (1981) suggested in their model of ecological behavior that environmental knowledge has no direct effect on pro-environmental behavior. They assumed that knowledge rather influences people's environmental attitudes, which then, among other variables, has an impact on ecological behavior (see Kollmuss and Agyeman 2002). Thus, we believe that climate-related knowledge plays a role in consumers' attitude formation. We therefore aimed to examine the influence of knowledge on consumers' attitudes toward climate change, which we will describe in the following.

First, we studied the effect of knowledge on *concern about climate change*. The relationship between knowledge and concern seems plausible, as people need to be informed about an issue like climate change to worry about it. Investigating the determinants of concern about climate change also seems worthwhile, as this factor has been identified as an important predictor of consumers' willingness to change climate-related behavior (e.g., Semenza et al. 2008). Second, we examined how knowledge about climate change influenced consumers' *skepticism* about this issue. Human contribution to climate change is widely discussed and not universally accepted as a fact (e.g., Reynolds et al. 2010). It is possible that knowing the scientific findings about climate change might reduce consumers' feeling of skepticism toward this topic. As skepticism might be an influential barrier to addressing climate change (Lorenzoni et al. 2007), it seems important to include this construct in our study. Third, we investigated the relationship between knowledge and *feeling of powerlessness*. As discussed, consumers need to have a basic understanding of the causes of climate change to know how to address the issue. Therefore, knowledge might influence consumers' feeling that they can contribute to climate change mitigation. Furthermore, meta-analyses of past research have shown that the feeling of behavioral control has a positive influence on pro-environmental behavior (Bamberg and Möser 2007; Hines et al. 1986/87).

In sum, we aimed to develop a comprehensive knowledge scale, consisting of several subscales. Our aims were three-fold: First, we aimed to develop a comprehensive knowledge scale, which could be used in further research. The scale should cover a broad range of climate-related knowledge domains (such as causes or consequences of climate change) and include different levels of difficulty. Second, we intended to describe the level of climate-related knowledge among Swiss people with this instrument. Our third aim was to examine how these different knowledge domains relate to different climate-related attitudinal variables (namely concern about climate change, skepticism, and feeling of powerlessness).

2 Method

2.1 Participants

The data were collected in a mail survey between February and May 2010. We randomly selected households from the telephone book in the German-speaking part of Switzerland and addressed the household member who was 18 years or older and whose birthday was next. Non-responders received two reminders, the second one containing another copy of the questionnaire. Overall, 916 persons sent back filled-out questionnaires, which corresponds to a response rate of 39%.

Sixty percent (n=546) of our sample was male, 39% (n=354) female, and 2% (n=16) did not disclose their sex. The mean age of our respondents was 55 years (SD=16), which is somewhat older than the Swiss adult population (M=49 years) (BFS 2009). The self-reported education level ranged from primary school (5%, n=41), lower secondary school (8%, n=75), upper secondary vocational school or business school (41%, n=374), and upper secondary school (17%, n=157) to college or university (27%, n=251). Two percent (n=18) did not indicate their highest level of education. Compared with Swiss census data (BFS 2009), the sample had a slightly higher education level than the general Swiss population.

2.2 Questionnaire

In the beginning of the questionnaire, we defined “climate change” as more recent changes of the climate (in the past 250 years) and excluded climate fluctuations of the entire geological history, such as glacial periods and interglacials. Overall, the questionnaire consisted of 16 pages, covering constructs such as knowledge, concern about climate change, skepticism, or feeling of powerlessness. Only the constructs used in this study are reported here.

To develop the knowledge items, we first consulted the existing literature to detect public knowledge and misconceptions (e.g., Bord et al. 1998; Bostrom et al. 1994; Dunlap 1998; Leiserowitz 2007; Read et al. 1994; Reynolds et al. 2010). To get an impression of the current state of knowledge among Swiss consumers, we additionally conducted semi-structured face-to-face interviews with a convenience sample of 8 laypersons. The interviews covered consumers’ perceptions of causes and impacts of climate change, as well as possible mitigation measures. Based on the misconceptions and notions found in the literature and interviews (e.g., confusion of climate change with the ozone hole or about the harmfulness of CO_2), we developed 41 knowledge items covering a broad range of climate-related knowledge.

The items consisted of 19 correct and 22 wrong statements. We were careful that the positive or negative wording gave no indication of the correctness of the statements. There was no pattern in the order of correct and wrong statements. Respondents could indicate for each statement whether they believed it to be true, wrong, or whether they did not know. We included the latter response option to avoid participants guessing. Furthermore, we believed it to be less discouraging if respondents could indicate they did not know the answer.

Knowledge can be distinguished in declarative (factual) and procedural knowledge (skills that transform declarative knowledge into action) (Frick et al. 2004). Thus, we distinguished between factual knowledge, referring to knowledge about definitions, causes, and consequences of climate change, and action-related knowledge, covering information connected to possible actions (Tanner and Kast 2003). Similarly to past studies (Read et al. 1994; Reynolds et al. 2010; Sundblad et al. 2009), we divided factual knowledge into different knowledge domains and constructed a similar number of items for each domain: (1) physical knowledge about CO_2 and the greenhouse effect (consisting of 9 items), (2) knowledge about climate change and causes (11 items), and (3) knowledge about the expected consequences of climate change (11 items). Action-related knowledge was assessed in 10 items.

For all knowledge scales, we included items of different degrees of difficulty, ranging from basic understanding of climate change that is discussed in the media to expert knowledge. We took care that there were correct and incorrect statements throughout the different levels of difficulty. The items were grouped according to their subject; they were, however, not ordered according to their difficulty level. Although we strived for scientific correctness, we tried to avoid scientific terms, such as “concentration,” “radiative forcing,” or "global warming potential." The items thus represent a compromise between scientifically true, yet generally understandable, statements. The knowledge items were pretested with a convenience sample of 15 people to identify items with low, medium, and high difficulty.

We used the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2007) as a basis for our knowledge scale. Additionally, we sent the knowledge items to 8 climate scientists at the authors' university. We asked the scientists to preview the items to ensure they were unambiguously correct or wrong. These scientists included 4 Ph.D. students of atmospheric and climate science and 3 Ph.D. students with other expertise (environmental engineering, environmental policy and economics, and agricultural sciences). Our expert sample further included a professor of atmospheric and climate science, who was also an IPCC author.

The questionnaire also included items that measured different attitudes related to climate change, such as concern or skepticism. These items were presented as statements (e.g., "I worry about the climate's state" or "Climate change is a racket"; see the Appendix), which respondents could rate on a 6-point Likert scale, ranging from "strongly disagree" to "fully agree." Finally, the respondents indicated their sex, age, level of education, and political affiliation.

2.3 Data analysis

Like the Rasch scale, the Mokken scale analysis is a probabilistic version of the Guttman scaling. In contrast to the Rasch scale, however, the Mokken scale analysis is a nonparametric procedure (Van Schuur 2003). This scale analyzes each participant's response pattern to a set of questions and examines how the items differ in their distribution. Thus, unlike such measurements as reliability or factor analysis, the Mokken scale analysis explicitly allows items to differ with regard to their distribution (or difficulty).

A respondent's probability of solving an item depends on two factors: (1) on his or her latent trait (such as knowledge) and (2) on the item's characteristic (such as level of difficulty) (Molenaar and Sijtsma 2000). Accordingly, the Mokken scale analysis not only ranks respondents according to their probability of a positive response (i.e., their latent trait, such as ability or knowledge) but also orders items regarding their probability of being answered positively. One of the important assumptions is the one of double monotonicity. First, the item response function should be monotonically nondecreasing, meaning that the items order all respondents similarly (Mokken and Lewis 1982). Thus, the expected order of the respondents on the latent trait (i.e., knowledge) is the same for each selection of items (Molenaar and Sijtsma 2000). Second, the item ordering (according to their difficulty) should be the same for each person. If, for instance, person A had a higher probability of solving item x compared to item y, then person B should also show a higher solving probability for item x than for item y. As the Mokken scaling analysis scales both items and respondents, it is subject to stricter conditions than Cronbach's alpha reliability analysis. Thus, the Mokken scaling analysis appeared to be well-suited for testing our factual knowledge scale. We therefore analyzed the factual knowledge items with a Mokken scale analysis using the MSP5 program (version 5.0, Iec ProGAMMA, Groningen, the Netherlands).

Similarly to a principal component analysis, the Mokken analysis can suggest subscales, by grouping subsets of items based on statistical criteria. The Loevinger scalability coefficient thereby is an important indicator; the coefficient indicates the degree to which respondents can be accurately ordered by the suggested set of items (Molenaar and Sijtsma 2000). The larger H, the higher the confidence in this ordering; a perfect scale would result in $H=1$. A set of items with H=.3–.4 is considered a weak scale. A scale with H=.4–.5 would show medium scalability, whereas H=.5–1 would indicate a strong scale. Additionally, the scalability coefficients for all individual items should be H_i>.3.

For all knowledge items consisting of incorrect statements, responses were reversed so that the results indicate whether the answer was correct, wrong, or whether the respondent did not know the answer. The respondents' answers were also recoded as dichotomous variables (1 = "correct", 0 = "wrong" and "don't know"), so that we could distinguish people who knew the correct answers from people who did not.[1] All resulting scales were then tested for their reliability.

We calculated the proportion of correct items for each respondent and each type of knowledge. We then examined the correlations between the different knowledge scales and tested how people's education was related to these types of knowledge. In the second step, we ran three regression analyses to predict concern about climate change, skepticism, and feeling of powerlessness. As predictors for the regression models, we used socio-demographic variables, political affiliation, and the different types of climate-related knowledge.

3 Results

The Mokken analysis yielded three subscales for factual climate-related knowledge, which were in line with our projected knowledge domains: (1) physical knowledge about CO_2 and the greenhouse effect, (2) knowledge about climate change and causes, and (3) knowledge about the expected consequences of climate change. The items measuring action-related knowledge, however, did not result in a Mokken scale. We therefore used principal component analysis to build this scale.

In the following, we report per knowledge domain the response distributions for all knowledge items to examine our sample's knowledge, followed by a description of the resulting scales and their quality. We then report how the knowledge scales correlate among each other as well as the correlations between the knowledge scales and education. Finally, we present the results of the regression analyses predicting concern, skepticism, and feeling of powerlessness using demographic variables, political affiliation, and the knowledge scores as predictors.

3.1 Physical knowledge about CO_2 and the greenhouse effect

Table 1 displays the response distribution and Mokken scale analysis of the knowledge domain physical knowledge about CO_2 and the greenhouse effect. The table shows that the respondents seemed to be well informed about how CO_2 is produced (item 1, see Table 1). A vast majority also knew about the definition of the greenhouse effect (item 2) and was aware that CO_2 is a greenhouse gas (item 3). Only a minority showed knowledge about other greenhouse gases, such as water vapor (item 9) or the climatic effect of methane (item 8). The well-documented misconception involving the ozone hole as the main cause of the greenhouse effect was also prevalent among our participants (item 7).

The Mokken scale analysis of physical knowledge yielded a scale consisting of six items with the Loevinger scalability coefficient H=.39 (see Table 1). Thus, the knowledge

[1] We also conducted analyses using the three answer categories (coded as "correct" = 2, "don't know" = 1, and "wrong" = 0). They resulted in inferior scales, suggesting dichotomous scaling is more adequate.

Table 1 Physical knowledge about CO_2 and the greenhouse effect: response distribution and Mokken scale scalability coefficients (H_i)

Items	Response distribution: correct answer	Response distribution: did not know	Response distribution: wrong answer	H_i
1. Burning oil, among other things, produces CO_2.	90	7	3	.39
2. The warming of the Earth's atmosphere caused by greenhouse gases is called the greenhouse effect.*	86	5	9	–
3. Carbon dioxide (CO_2) is a greenhouse gas.	85	9	6	.40
4. Greenhouse gases partly retain the Earth's heat radiation.	66	20	14	.33
5. CO_2 is harmful to plants. (–)	61	12	27	.39
6. Without humans, there would be no greenhouse effect. (–)*	51	11	37	–
7. The ozone hole is the main cause of the greenhouse effect. (–)	44	18	38	.41
8. At the same quantity, CO_2 is more harmful to the climate than methane. (–)	30	58	13	.41
9. Water vapor is a greenhouse gas.*	10	15	75	–
$n = 868$; $H = .39$; $\rho = .65$				

(-) Denotes items with an incorrect statement. Accordingly, responses were reversed to indicate correct and wrong answers. For the Mokken scale analysis, the items were changed into a dichotomous response format of 0 (wrong or did not know) and 1 (correct). Items marked with * were not included in the Mokken scale as they reduced the scale's quality; therefore, H_i is not reported for these items

subscale is of weak (almost moderate) scalability with an acceptable reliability of ρ=.65, probably due to the broad range of the items' topics. With H_is>.33, the scalability coefficients for all individual items are satisfactory. The means of correct responses indicate that the scale included items with various levels of difficulty (.30<Ms>.90).

3.2 Knowledge concerning climate change and causes

In the knowledge domain of climate change and its causes, the participants were most knowledgeable about the CO_2 increase in the atmosphere (see Table 2, item 1), followed by the changes in the spatial extent of snow cover in the northern hemisphere (item 2). Although the majority was aware that humans seem to be the main cause of the increase of greenhouse gases in the atmosphere (item 3), the participants appeared to be less sure

Table 2 Knowledge concerning climate change and causes: response distribution and Mokken scale scalability coefficients (H_i)

Items	Response distribution			H_i
	correct answer	did not know	wrong answer	
1. The global CO_2 concentration in the atmosphere has increased during the past 250 years.	87	10	3	.40
2. In past centuries, the average spatial extent of the snow blanket in the northern hemisphere remained unchanged. (–)*	83	10	7	–
3. The increase of greenhouse gases is mainly caused by human activities.	82	9	9	.48
4. With a high probability, the increase of CO_2 is the main cause of climate change.	79	12	10	.47
5. In Switzerland, the number of hot days has increased in past centuries.*	72	14	15	–
6. Climate change is mainly caused by natural variations (such as changes in solar radiation intensity and volcanic eruptions). (–)	70	16	15	.39
7. The last century's global increase in temperature was the largest during the past 1000 years.	67	23	10	.36
8. The '90s were globally the warmest decade during the past century.	52	35	12	.33
9. If today's greenhouse gas content in the atmosphere stabilized, the climate would still warm for at least another 100 years.*	48	41	11	–
10. In the last century, the temperature increase in Switzerland was significantly smaller than the global average. (–)*	44	39	17	–
11. Today's global CO_2 concentration in the atmosphere already occurred in the past 650,000 years. (–)	26	50	24	.45

$n = 886$; $H = .41$; $\rho = .70$

0% 20% 40% 60% 80% 100%

■ correct answer □ did not know □ wrong answer

(-) Denotes items with an incorrect statement. Accordingly, responses were reversed to indicate correct and wrong answers. For the Mokken scale analysis, the items were changed into a dichotomous response format of 0 (wrong or did not know) and 1 (correct). Items marked with * were not included in the Mokken scale as they reduced the scale's quality; therefore, H_i is not reported for these items

about the influence of natural variations (item 6). The respondents also seemed to be less knowledgeable about the temperature changes in the past decades (items 5 and 8) and centuries (item 7).

The Mokken scale analysis resulted in a scale of seven items with moderate scalability (Loevinger's scalability coefficient H=.41) and a satisfactory reliability of ρ=.70 (see Table 2). All items showed satisfactory scalability coefficients (H_is>.33). The means of correct responses varied between .27 and .87, indicating a wide range of item difficulties.

3.3 Knowledge regarding the expected consequences of climate change

When it came to the expected consequences of climate change, the majority of participants knew about the increase of extreme weather events (see Table 3, item 1) and the melting of polar ice (item 2). Most of the respondents also knew that the sea level is expected to rise; however, they mainly associated this effect with the melting of polar ice. Only half of the participants were aware that this increase is also (and mainly) due to thermal expansion of sea water (item 9). Respondents seemed to be somewhat less knowledgeable about the expected patterns in climate and precipitation change (items 8 and 10).

Knowledge about the health-related consequences was mixed. Most of the participants knew that health consequences would not exclusively affect people living in tropical areas (item 3). Fewer were aware about the increased risk of infectious diseases in northern regions (item 6) or the increased risk of heat-related cardiovascular problems in Switzerland (item 7). The misconception of increased UV radiation due to CO_2 increase was prevalent among a large fraction of the participants (item 11).

Table 3 shows that the Mokken scale analysis dismissed all health-related knowledge items and yielded a scale of six items with moderate scalability (Loevinger's scalability coefficient H=.44) and a reliability of ρ=.66. All items' scalability coefficients were acceptable (H_is>.38). Again, various levels of item difficulty were apparent from the means of correct responses (.43<Ms>.96).

3.4 Action-related knowledge

As an indicator of knowledge that might affect climate-related actions (such as transportation choice, heating behavior, or energy use), we presented respondents a set of ten items to measure a broad range of action-related knowledge (see Table 4). At least half of the participants answered nearly all items correctly, indicating that, among Swiss consumers, action-related knowledge is generally higher than factual knowledge. A large majority knew how to aerate a room in a climate-friendly way (item 1) and they were also aware that, usually, cars emit more CO_2 than trains (item 2). While most of the participants knew about that the transportation sector belongs to the main emitters of CO_2 (item 3), fewer were aware that, in Switzerland, this is also true for the heating of buildings (item 7). Regarding food-related actions, more respondents knew about the CO_2 emissions due to greenhouse production (item 4) than about the greenhouse gas emissions associated with meat production (item 6). Items comparing CO_2 emissions of diesel-engine and petrol-engine vehicles (item 10), or short- versus long-haul flights (item 9), appeared to be the most difficult ones to answer.

Interestingly, the items did not result in a satisfactory Mokken scale, as the items could not monotonously be ordered difficulty-wise across all participants. We therefore used the mean score of the items as an indicator of action-related knowledge, a higher score indicating more knowledge. Reliability analysis resulted in a Cronbach's alpha coefficient of α=.61, which represents a rather low reliability. This is probably due to the different degrees of difficulty of the items and the fact that the items covered different domains and thus a broad range of knowledge.

Table 3 Knowledge concerning expected consequences of climate change: response distribution and Mokken scale scalability coefficients (H_i)

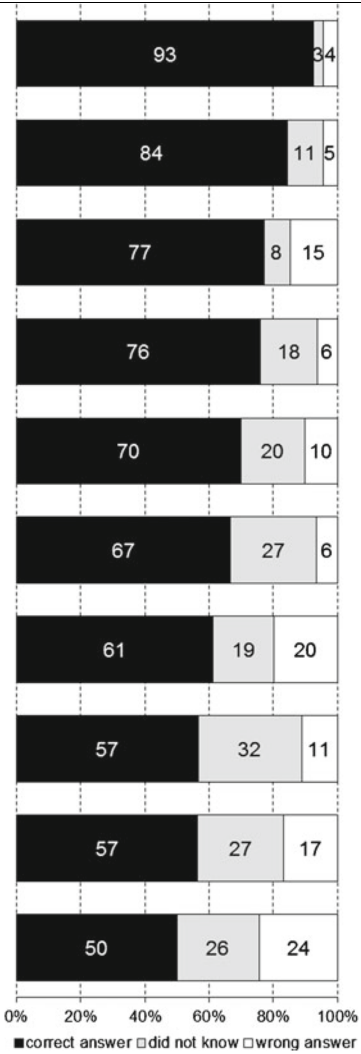
Items	Response distribution	H_i
For the next few decades, the majority of climate scientists expect…		
1. … an increase in extreme events, such as droughts, floods, and storms.	96 / 3 / 1	.61
2. … a warmer climate to increase the melting of polar ice, which will lead to an overall rise of the sea level.	93 / 4 / 3	.60
3. The health effect that might come up due to climate change during the next 50 years concerns only humans who reside in tropical areas. (–)*	82 / 12 / 6	–
4. … a cooling-down of the climate. (–)	82 / 12 / 6	.41
5. … a warmer climate to increase water evaporation, which will lead to an overall decrease of the sea level. (–)	77 / 9 / 14	.38
6. A warmer climate will foster the spread of infectious diseases (such as yellow fever or malaria) in the northern regions.*	69 / 22 / 9	–
7. A warmer climate would lead to an increase of heat-related cardiovascular problems in Switzerland, too.*	67 / 23 / 10	–
8. … the climate to change evenly all over the world. (–)	54 / 24 / 22	.40
9. … that with a warmer climate, the sea water will warm and expand, which will lead to a rise in the sea level.*	51 / 18 / 31	–
10. … a precipitation increase in every region worldwide. (–)	43 / 24 / 33	.43
11. An increasing amount of CO_2 risks will cause more UV radiation and therefore a larger risk for skin cancer. (–)*	20 / 14 / 66	–
n = 896; H = .44; ρ = .66	0% 20% 40% 60% 80% 100%	

■ correct answer □ did not know □ wrong answer

(-) Denotes items with an incorrect statement. Accordingly, responses were reversed to indicate correct and wrong answers. For the Mokken scale analysis, the items were changed into a dichotomous response format of 0 (wrong or did not know) and 1 (correct). Items marked with * were not included in the Mokken scale as they reduced the scale's quality; therefore, H_i is not reported for these items

Table 4 Action-related knowledge: response distribution

Items	Response distribution
1. To get in fresh air in winter, it is most climate friendly to keep a window open for a longer period of time. (–)	
2. A car's average CO_2 emission per person and kilometer exceeds that of a train many times over.	
3. A large part of the CO_2 emissions in Switzerland is caused by the transport sector. *	
4. Lettuce from a heated greenhouse causes less CO_2 emissions than field-grown lettuce. (–)	
5. Reducing the temperature of a gas-heated room by 1 degree decreases CO_2 emissions.	
6. The production of 1 kg of beef produces more greenhouse gases than the production of 1 kg of wheat.	
7. A large part of CO_2 emissions in Switzerland is produced by heating.	
8. On short-haul flights (e.g., within Europe) the average CO_2 emission per person and kilometer is lower than on long-haul flights (e.g., Europe to America). (–)	
9. In a nuclear power plant, CO_2 is emitted during the electricity production. (–)	
10. A diesel-engine vehicle causes more CO_2 per person and kilometer than a comparable petrol-engine vehicle. (–)	



(-) Denotes items with an incorrect statement. Accordingly, responses were reversed to indicate correct and wrong answers. The scale was changed into a dichotomous response format of 0 (wrong) and 1 (correct). The item marked with * was not included in the action-related knowledge scale as it reduced the scale's quality

3.5 Correlations of the knowledge scales with each other and with education

All knowledge scales showed significant positive correlations between each other (see Table 5), although physical knowledge was only weakly correlated with knowledge about climate change and causes. A higher level of knowledge about the expected consequences was associated with more knowledge on the other two factual knowledge scales. There were positive correlations for action-related knowledge with all three subtypes of factual knowledge.

Education was positively related to all knowledge types. It, however, showed only a weak relationship with knowledge about climate change and causes.

Table 5 Descriptive statistics and Pearson correlations for the four knowledge scales and education

	M	*SD*	Physical knowledge	Climate change & causes	Consequences	Action-related knowledge
Physical knowledge	.63	.25				
Climate change & causes	.66	.25	.23**			
Consequences	.74	.23	.46**	.38**		
Action-related knowledge	.68	.22	.51**	.35**	.48**	
Education	–	–	.39**	.17**	.28**	.36**

** $p<.01$

M reports the proportion of correct responses in the respective knowledge scale; *SD* denotes its standard deviation

3.6 Regression analyses predicting concern about climate change, skepticism, and feeling of powerlessness

The attitudinal items were analyzed using a principal component analysis. Based on the eigenvalues (>1), a visual inspection of the screeplot, and interpretability, we selected a solution with three dimensions among our 16 items: (1) concern about climate change, (2) feeling of powerlessness, and (3) skepticism. All three scales showed satisfactory internal reliabilities (αs>.70). The scale items, means, standard deviations, and reliabilities (Cronbach's alpha coefficient), and factor loadings of the items are reported in the Appendix.

Overall, the respondents seemed to be rather concerned about climate change (M=5.18, SD=0.91, on a 6-point Likert scale). They did not appear to feel powerless (M=2.87, SD=1.00) or seemed to be very skeptical about the topic of climate change (M=2.69, SD=1.05).

Table 6 displays the result of the three regression analyses predicting concern about climate change, skepticism, and feeling of powerlessness. Of all the knowledge subscales, knowledge about climate change and causes was the strongest predictor of all these outcome variables. A higher level of knowledge about climate change and causes was related to more concern about climate change, less feeling of powerlessness, and less skepticism about climate change. The second-most powerful predictor of all three attitudes was political affiliation, except for feeling of powerlessness where the respondents' political affiliation was equally predictive as knowledge about climate change and causes. Respondents with right-of-center political views tended to be less concerned about climate change, more skeptical, and felt less powerless to do something about climate change. Concern about climate change was also significantly influenced by knowledge about the consequences; respondents knowing more about the expected outcomes of climate change were more concerned about it. The feeling of powerlessness was reduced by having more action-related knowledge.

4 Discussion

In this study, we aimed to develop a comprehensive climate-related knowledge scale consisting of various subscales measuring different areas of knowledge. We further intended to describe the level of climate-related knowledge that currently exists among the Swiss population. Finally, we examined the relationship between the different knowledge scales and, in the second step, between the knowledge scales and attitudinal variables.

Table 6 Regression analyses for concern about climate change, skepticism, and feeling of powerlessness predicted by socio-demographic variables, political affiliation, and climate-related knowledge

Predictor variables	Concern			Skepticism			Powerlessness		
	B	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*
Constant	4.64	.22		3.02	.25		3.07	.27	
Sex [a]	.13	.06	.07*	−.22	.07	−.10**	−.19	.07	−.09*
Age	.00	.00	.01	.01	.00	.11**	.01	.00	.09*
Education	−.06	.03	−.07*	−.02	.03	−.02	−.06	.03	−.06
Political affiliation [b]	−.14	.02	−.20***	.22	.03	.26***	.15	.03	.18***
Physical knowledge	−.41	.14	−.11**	.39	.16	.09*	.43	.17	.11*
Knowledge: Climate change & causes	1.46	.13	.40***	−1.63	.14	−.38***	−.75	.16	−.18***
Knowledge: Consequences	.53	.16	.13**	−.40	.18	−.08*	−.14	.19	−.03
Action-related knowledge	.16	.17	.04	−.48	.19	−.09*	−.72	.20	−.15***

R^2 = .30 for concern about climate change; R^2 = .36 for skepticism; R^2 = .16 for feeling of powerlessness

* $p<.05$, ** $p<.01$, *** $p<.001$

[a] Sex was coded 0 = male, 1 = female

[b] Political affiliation was measured on a 7-point Likert scale, 1 = left-wing, 4 = center, 7 = right-wing

Our climate-related knowledge scale finally consisted of three subscales measuring factual knowledge (physical knowledge, knowledge about climate change and causes, and knowledge about the expected consequences) and one action-related knowledge scale. Overall, our findings about the Swiss public's understanding confirm several misconceptions among laypeople found in past research (e.g., confusion with ozone depletion), but also indicate that the current knowledge about CO_2 is generally high (e.g., CO_2 is a greenhouse gas). Of all knowledge scales, knowledge about climate change and causes was most strongly related to attitudinal variables, such as concern about climate change, feeling of powerlessness, or skepticism. Our findings are discussed in more detail in the following.

4.1 Climate-related knowledge scale

We developed three reliable factual knowledge scales concerning climate change. The resulting subscales covered physical knowledge about CO_2 and the greenhouse effect, knowledge about climate change and causes, and knowledge about the expected consequences of climate change. We believe the three subscales contribute to the existing literature, as they offer a reliable, statistically tested way of measuring public knowledge about climate change comprehensively. The division into several subscales enables a closer examination of the different factual knowledge domains. Furthermore, all three subscales include items of different difficulty levels.

The Mokken scale analysis proved to be very useful for developing the knowledge scales. First, it allows the use of items with different degrees of difficulty. This way, both ceiling and floor effects can be avoided. Thus, even very well-informed respondents will find some items challenging, while less knowledgeable participants will still find some items they can answer. At the same time, the different levels of item difficulties allow a broad range of knowledge to be assessed with a relatively small set of items. Second, the Mokken scale analysis ranks items according to their difficulty and ensures that all respondents perceive the items in the same rank order (Van Schuur 2003). The uniform ordering of items across (sub)groups of persons makes it particularly suited for international comparisons of knowledge levels. Overall, the use of Mokken scale analysis seems to be very fruitful for future knowledge research.

The development of an action-related knowledge scale proved to be more difficult. The items' difficulty levels seemed to vary across the respondents. One reason might be that action-related knowledge includes a diverse range of activities so that our items covered different dimensions. While some respondents might have been knowledgeable in one domain (e.g., heating) and more nescient in another field (e.g., mobility), this might have been the other way round for other participants. Furthermore, it is also possible that action-related knowledge is evenly distributed throughout the population. This would make it difficult to develop items that are able to discriminate between persons with a high level of knowledge and less knowledgeable people. Although the variance in the items' distributions impaired the scale's internal consistency in the reliability test, the action-related knowledge scale may still function as an indicator for that type of knowledge. For future research, it might be promising to develop an action-related knowledge scale consisting of several subscales (e.g., items covering transportation, heating, and electricity). However, the action-related knowledge domain might be difficult to compare between different populations, since, depending on the country, different types of action might be climate-relevant. As in Switzerland, for instance, electricity is mainly produced by hydro-electric or nuclear power, electricity saving is not a priority for climate-friendly behavior. This might be different for countries generating electricity from coal or gas.

In contrast to the action-related knowledge scale, the resulting Mokken scales covering factual knowledge (i.e., physical knowledge, knowledge about climate change and causes, and knowledge about the expected consequences) included only items that are independent of the participants' country of residence. Thus, these three factual knowledge scales could be applied in an international context, whereas the action-related knowledge scale probably has to be adjusted to the specific country's situation.

We measured climate-related knowledge by counting each respondent's correct answers, without differentiating between incorrect responses and the answer *don't know*. As we were interested only in the participants' knowledge, we interpreted incorrect responses and *don't know* as lack of knowledge. Such a procedure is commonly applied in knowledge surveys (e. g., Connor and Siegrist 2010; DiClemente et al. 1988; Durant et al. 1992), but can be disputed. Uninterested respondents, for instance, might tend to choose the answer *don't know*, which would reflect indifference rather than lack of knowledge (Mondak and Davis 2001). In contrast, participants with high levels of confidence and a propensity to take risks might be inclined to guess and therefore increase their chances of correct answers. Mondak and Davis (2001) therefore suggested eliminating the systematic factor of propensity to guess by omitting the response option *don't know*. For items that are left unanswered by participants, the answers should be randomly assigned to the available response categories. The authors argued that this way, knowledge scales are a function of one systematic factor (i. e., knowledge) and one unsystematic factor, namely chance. Our choice of recoding the *don't know* answers in incorrect responses may have systematically reduced our respondents' knowledge, if these responses were the result of our respondents' cautiousness. Future researchers applying the climate-related knowledge scales might take this recommendation into consideration.

Our scales' categorization and underlying constructs were based on statistical criteria, namely the Mokken scale analysis. It would also be possible to categorize climate-related knowledge differently. Climate-related knowledge could, for instance, be measured as one construct covering different domains. Another possibility would be to subcategorize various domains even further, for instance, one could differentiate between the observation of climatic change and the causes of climate change. However, although the scales were formed by a purely statistical procedure, they appeared congruent with regard to their content. Therefore, we believe the suggested categorizations to be adequate. The inclusion of different items might however have yielded other scales and knowledge domains.

With the climate-related knowledge scale, we aimed to measure a broad range of knowledge about climate change. Although we took a variety of knowledge domains into consideration, there might be also other types of knowledge relevant for people's climate-related behavior or support of climate mitigation policies. Future research might, for instance, also go one step further and consider effectiveness knowledge, addressing the climate-related benefit associated with certain behaviors or policy measures (see Frick et al. 2004).

4.2 Climate-related knowledge among the Swiss population

Overall, our results are in line with past research examining people's climate-related knowledge. In agreement with past studies, many respondents seemed unaware of the fact that the greenhouse effect is a natural process (Read et al. 1994; Reynolds et al. 2010). A large part of our respondents also believed the ozone hole to be the main cause of the greenhouse effect, confirming this misconception's persistent existence (e.g., Bord et al. 2000; Bostrom et al. 1994; Dunlap 1998; Leiserowitz 2007; Read et al. 1994; Reynolds et al. 2010). Our findings also confirmed the misconception that increased UV radiation and risk of skin cancer are a consequence of climate change, which is probably influenced by the confusion with ozone depletion (Bostrom et al. 1994; Read et al. 1994; Reynolds et al. 2010). Similarly, we confirmed the finding that, while people know about the expected sea-level rise due to ice melting, they seem to be less aware of the (larger) contribution of thermal expansion of the oceans (Read et al. 1994; Reynolds et al. 2010).

Generally, our participants were rather knowledgeable about the issue of CO_2. The vast majority knew that CO_2 is a greenhouse gas and that it is emitted when oil is burnt. A similarly high fraction was also aware that the global CO_2 concentration in the atmosphere has increased. The majority of our respondents knew that the CO_2 increase is mostly caused by human activities and that this increase is the main cause of climate change. Compared to past research (e.g., Diekmann and Meyer 2008; Read et al. 1994), this understanding seems to have generally increased. Items regarding other greenhouse gases, namely water vapor and methane, were more challenging for the participants. These findings were somewhat expected, since the media coverage of greenhouse gases usually highlights CO_2 as the most influential contributor to the greenhouse effect and climate change. This might explain why our respondents were quite knowledgeable about CO_2 whereas their knowledge about other greenhouse gases was rather low.

Finally, our findings indicate that Swiss people seem to have only a few misunderstandings regarding action-related knowledge, as virtually every item was answered correctly by at least half of the participants. This finding is plausible, as Swiss environmental organizations mainly try to convey this type of knowledge to raise public awareness and motivate people to engage in climate-friendly behavior. It is also possible that action-related knowledge is easier to memorize for most people since, unlike factual knowledge, it is related to their daily lives and therefore more tangible.

However, men were overrepresented in our sample, and our participants were somewhat older and had slightly more education than the average population. Thus, our sample was not entirely representative of the Swiss population. We cannot exclude the possibility that people indifferent to climate change did not participate in our survey. Therefore, the consumers who did not respond might be less knowledgeable about climate change. Thus, our results might slightly overestimate public knowledge about climate change among Swiss consumers. Future studies might consider using quota sampling to examine climate-related knowledge in a more representative sample.

4.3 Correlations of the knowledge scales with each other and with education

All three factual knowledge scales correlated significantly and positively with action-related knowledge. Having factual knowledge might therefore be beneficial for the acquisition of information related to behaviors and actions. Therefore, it seems worthwhile to equip people with both factual and action-related knowledge.

Knowledge about the expected consequences of climate change was also moderately related to physical knowledge and knowledge about climate change and causes. It therefore appears that, to know what could happen in the future (e.g., rising of the sea level), it is necessary to understand what has happened in the past (e.g., temperature rise) and to know how the physical mechanisms influence these consequences (e.g., warming of sea water leads to thermal expansion).

Higher levels of education were associated with more knowledge in all knowledge domains. This relationship was, however, weak with knowledge about climate change and causes. As most of our respondents received their basic education before climate change was a public issue, this topic was most likely not discussed in school. Our findings indicate that knowledge about climate change and causes is more evenly spread among the population, probably due to the wide media coverage, which provided almost uniform information to a broad segment of people.

4.4 Regression analyses predicting concern about climate change, skepticism, and feeling of powerlessness

Generally, our sample appeared to be rather concerned about climate change. The respondents did not appear to feel powerless, and the average level of skepticism about climate change was rather low. There is a possibility of self-selection bias, leading only concerned people to fill out our questionnaire about this subject. A biased sample would, however, reduce the variance, which means that our results might underestimate the influence of knowledge on attitudes and that, actually, this relationship might be even stronger. Nevertheless, due to the large response rate and the fairly representative sample, we can still conclude that a substantial fraction of the Swiss population currently is worried about climate change. This public awareness might be due to the broad media coverage in the recent past, particularly related to the UN Climate Change Conference 2009 (COP15) in Copenhagen. However, we did not compare the respondents' concern about climate change to other current issues, such as the financial crisis or crime. It is very probable that, despite its high level in our study, concern about climate change is not one of people's main concerns when it is compared to other issues (e.g., see Diekmann and Meyer 2008; European Commission 2009).

Overall, knowledge about climate change and causes was the strongest predictor for the attitudinal variables, such as concern about climate change, feeling of powerlessness, or skepticism. This knowledge domain in particular correlated positively with concern about climate change and negatively with skepticism. People knowledgeable about climate change and causes thus seem to be less prone to believe that climate change is a racket or that its consequences are exaggerated in the media, and therefore tend to show higher levels of concern. However, as these are cross-sectional data, we cannot draw any conclusions about the causal direction of this relationship. It is conceivable that people already skeptical about the matter of climate change know about the scientists' positions but simply do not accept them as true. Persons skeptical about climate change often negate human activities to be a cause of climate change. Since the causes of climate change are an essential part of this knowledge scale, it is of little surprise that this type of knowledge has the highest and most negative correlation with skepticism. This finding is also in line with past research suggesting that climate-related knowledge is not merely a matter of accepting facts but also involves the decision about whom and what to believe (Bulkeley 2000). However, it appears that this type of knowledge should be given priority in climate education, as it is most strongly related to attitudes that might influence people to act or support climate policy measures.

There is a great scientific consensus that the warming of the climate system is unequivocal and that human activities have contributed to climate change (IPCC 2007). At the same time, these findings appear to be the most important notions influencing consumers' attitudes toward climate change. It therefore seems particularly important not only to inform the public about these results but also to illustrate the consensus among climate scientists and the certainty of these findings. As people often acquire climate-related knowledge from the media (Antilla 2005; Kahlor and Rosenthal 2009; Stamm et al. 2000), it would probably be worthwhile to address journalists, as they often act as intermediaries between scientists and the public. It seems particularly important to inform journalists about the large body of research that led to the conclusions about climate change and its causes. Furthermore, it might be helpful if reporters were introduced to the meaning of scientific uncertainty.

Political affiliation was another significant predictor of concern, skepticism, and feeling of powerlessness. People who positioned themselves at the right side of the political spectrum tended to be less concerned, more skeptical, and felt less powerless. This finding is supported by past research indicating a relationship between climate-related attitudes and political ideology (e.g., Leiserowitz 2006; Zia and Todd 2010). Thus, providing right-wing voters with information about climate change probably will not suffice to change their attitudes toward this issue, as it might be outweighed by their political ideology. Relating environmental issues to concerns that are more of interest to them, such as economic concerns, might be more fruitful to arouse interest in environmental issues of people on the right wing of the political spectrum rather than trying to change their political affiliation.

Knowledge about the consequences of climate change was significantly related to increased climate-related concern; thus, people who were aware about the possible (negative) outcomes of climate change tended to worry more about it. Furthermore, having more action-related knowledge appeared to reduce the feeling of powerlessness about contributing to climate change mitigation. Both findings are very plausible and support the validity of the respective subscales.

Overall, the climate-related knowledge scale needs to be tested in further studies, preferably with different populations, to test its general applicability. Generally, our proposed scale could be useful for cross-cultural comparisons to first examine whether the measurement models are identical across countries. Second, the scale would allow for the identification of differences in knowledge across countries. It would also be interesting to expand the knowledge about the relationships of knowledge, attitudes, and willingness to act by using structural equation modeling. As knowledge might not be the most important predictor of behavior, future research could compare the effect of knowledge to the influence of other factors. Based on the outcomes of such studies, one could conclude whether a focus on knowledge acquisition would be worthwhile in future campaigns or educational material or if other methods (such as incentives) might be more promising.

Acknowledgements This article is based on work supported by the project Climate Policy Making for Enhanced Technological and Institutional Innovations (ClimPol), which is funded by the Competence Center Environment and Sustainability of the ETH Domain (CCES). We would like to thank Maria Hakuba for conducting the interviews. We also thank the scientific experts on climate change for their valuable feedback on the knowledge items.

Appendix

Table 7 Items, means, standard deviations (*SD*), internal consistencies (*alpha*), and factor loadings of the attitudinal scales (English translations of original items)

Items	Mean	SD	Alpha	Loadings
Concern about climate change	5.18	0.91	.83	
1. We must protect the climate's delicate equilibrium.				.77
2. Climate protection is important for our future.				.75
3. I worry about the climate's state.				.70
4. Climate change has severe consequences for humans and nature.				.70
Feeling of powerlessness	2.87	1.00	.71	
1. Climate protection measures are determined by a few powerful persons; as a single citizen, I have no effect.				.73
2. With my behavior, I cannot influence the climate, as, in fact, it rests in the hands of the industry.				.69
3. As an ordinary citizen, I can influence governmental decisions regarding climate protection. (-)				.66
4. I feel able to contribute to climate protection. (-)				.49
5. If I tried to behave in a climate-friendly way, that would surely have a positive effect on the climate. (-)				.49
Skepticism	2.69	1.05	.83	
1. Climate change and its consequences are being exaggerated in the media.				.74
2. Climate change is a racket.				.68
3. As long as meteorologists are not even able to accurately forecast weather, climate cannot be reliably predicted either.				.68
4. There are larger problems than climate protection.				.62
5. I do not feel threatened by climate change.				.61
6. The impacts of climate change are unpredictable; thus, my climate-friendly behavior is futile.				.58
7. Climate protection needlessly impedes economic growth.				.56

(-) Reversed in coding. Ratings ranged from 1 ("strongly disagree") to 6 ("fully agree")

References

Antilla L (2005) Climate of scepticism: US newspaper coverage of the science of climate change. Global Environ Change Part A 15(4):338–352. doi:10.1016/j.gloenvcha.2005.08.003

Bamberg S, Möser G (2007) Twenty years after Hines, Hungerford, and Tomera: a new meta-analysis of psycho-social determinants of pro-environmental behaviour. J Environ Psychol 27(1):14–25

BFS (2009) Statistisches Lexikon der Schweiz (ESPOP) [Statistical Lexicon of Switzerland]. Bundesamt für Statistik, Neuchâtel

Bord RJ, Fisher A, O'Connor RE (1998) Public perceptions of global warming: United States and international perspectives. Clim Res 11(1):75–84
Bord RJ, O'Connor RE, Fisher A (2000) In what sense does the public need to understand global climate change? Publ Understand Sci 9(3):205–218
Bostrom A, Morgan MG, Fischhoff B, Read D (1994) What do people know about global climate change? 1. Mental models. Risk Anal 14(6):959–970
Boykoff MT, Boykoff JM (2004) Balance as bias: global warming and the US prestige press. Global Environ Change Part A 14(2):125–136. doi:10.1016/j.gloenvcha.2003.10.001
Bulkeley H (2000) Common knowledge? Public understanding of climate change in Newcastle, Australia. Publ Understand Sci 9:313–333
Connor M, Siegrist M (2010) Factors influencing people's acceptance of gene technology: the role of knowledge, health expectations, naturalness, and social trust. Sci Commun 32(4):514–538
Corbett JB, Durfee JL (2004) Testing public (un)certainty of science: media representations of global warming. Sci Commun 26(2):129–151
DiClemente RJ, Boyer CB, Morales ES (1988) Minorities and AIDS: knowledge, attitudes, and misconceptions among black and Latino adolescents. Am J Public Health 78(1):55–57
Diekmann A, Meyer R (2008) Klimawandel, ökologische Risiken und Umweltbewusstsein in der Schweizerischen Bevölkerung. Kurzbericht. [Climate change, ecological risks and environmental awareness in the Swiss public. Short report.]. Zurich: Chair of Sociology, ETH Zurich
Dunlap RE (1998) Lay perceptions of global risk - Public views of global warming in cross-national context. Int Sociol 13(4):473–498
Durant J, Evans G, Thomas G (1992) Public understanding of science in Britain: the role of medicine in the popular representation of science. Publ Understand Sci 1(2):161–182
European Commission (2009) Eurobarometer 71 "Public opinion in the European Union", http://ec.europa.eu/public_opinion/archives/eb/eb71/eb71_std_part1.pdf
Fietkau H-J, Kessel H (1981) Umweltlernen [Environmental Learning]. Koenigstein: Hain
Frick J, Kaiser FG, Wilson M (2004) Environmental knowledge and conservation behavior: exploring prevalence and structure in a representative sample. Personal Individ Differ 37(8):1597–1613
Henderson-Sellers A (1990) Australian public perception of the greenhouse issue. Clim Chang 17(1):69–96
Hines JM, Hungerford HR, Tomera AN (1986/87) Analysis and synthesis of research on responsible environmental behaviour: a meta-analysis. J Environ Educ 18(2):1–8
IPCC (2007) Climate change 2007: Synthesis report. Contribution of working groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva
Jaeger C, Dürrenberger G, Kastenholz H, Truffer B (1993) Determinants of environmental action with regard to climatic change. Clim Chang 23(3):193–211
Kahlor L, Rosenthal S (2009) If we seek, do we learn? Predicting knowledge of global warming. Sci Comm 30(3):380–414
Kollmuss A, Agyeman J (2002) Mind the gap: why do people act environmentally and what are the barriers to pro-environmental behavior? Environ Educ Res 8(3):239–260
Leiserowitz A (2006) Climate change risk perception and policy preferences: the role of affect, imagery, and values. Clim Chang 77(1):45–72
Leiserowitz A (2007) Global public perception, opinion, and understanding of climate change: current patterns, trends, and limitations. Thematic paper for: Human Development Report 2007: Climate Change and Human Development – Rising to the Challenge. United Nations Development Program. Retrieved 22.10.2008, 2008, from http://hdr.undp.org/en/reports/global/hdr2007-2008/papers/leiserowitz_anthony.pdf
Lorenzoni I, Nicholson-Cole S, Whitmarsh L (2007) Barriers perceived to engaging with climate change among the UK public and their policy implications. Glob Environ Chang 17(3–4):445–459
Mokken RJ, Lewis C (1982) A nonparametric approach to the analysis of dichotomous item responses. Appl Psychol Meas 6:417–430
Molenaar IW, Sijtsma K (2000) MPS5 for windows. A program for Mokken scale analysis for polytomous items. iec ProGAMMA, Groningen
Mondak JJ, Davis BC (2001) Asked and answered: knowledge levels when we will not take "don't know" for an answer. Polit Behav 23(3):199–224
Moxnes E, Saysel A (2009) Misperceptions of global climate change: information policies. Clim Chang 93(1):15–37
O'Connor RE, Bord RJ, Fisher A (1998) The curious impact of knowledge about climate change on risk perceptions and willingness to sacrifice. Risk Decis Pol 3(2):145–155
O'Connor RE, Bord RJ, Fisher A (1999) Risk perceptions, general environmental beliefs, and willingness to address climate change. Risk Anal 19(3):461–471

Poortinga W, Pidgeon NF, Lorenzoni I (2006) Public perception of nuclear power, climate change and energy options in Britain: Summary findings of a survey conducted during October and November 2005. Technical report. Center for Environmental Risk, Norwich

Read D, Bostrom A, Morgan MG, Fischhoff B, Smuts T (1994) What do people know about global climate change? 2 Survey studies of educated laypeople. Risk Anal 14(6):971–982

Reynolds TW, Bostrom A, Read D, Morgan MG (2010) Now what do people know about global climate change? Survey studies of educated laypeople. Risk Anal. doi:10.1111/j.1539-6924.2010.01448.x

Semenza JC, Hall DE, Wilson DJ, Bontempo BD, Sailor DJ, George LA (2008) Public perception of climate change: voluntary mitigation and barriers to behavior change. Am J Prev Med 35(5):479–487. doi:10.1016/j.amepre.2008.08.020

Stamm KR, Clark F, Eblacas PR (2000) Mass communication and public understanding of environmental problems: the case of global warming. (Publ Understand Sci 9(3):219–237

Sterman JD (2008) Risk communication on climate: mental models and mass balance. Science 322 (5901):532–533

Sterman JD, Booth Sweeney L (2007) Understanding public complacency about climate change: adults' mental models of climate change violate conservation of matter. Clim Chang 80(3):213–238

Sundblad E-L, Biel A, Gärling T (2009) Knowledge and confidence in knowledge about climate change among experts, journalists, politicians, and laypersons. Environ Behav 41:281–309

Tanner C, Kast SW (2003) Promoting sustainable consumption: determinants of green purchases by Swiss consumers. Psychol Mark 20(10):883–902

Van Schuur WH (2003) Mokken scale analysis: between the Guttman scale and parametric Item Response Theory. Polit Anal 11(2):139–163

Wilson KM (2000) Drought, debate, and uncertainty: measuring reporters' knowledge and ignorance about climate change. Publ Understand Sci 9(1):1–13

Zehr SC (2000) Public representations of scientific uncertainty about global climate change. Publ Understand Sci 9(2):85–103

Zia A, Todd AM (2010) Evaluating the effects of ideology on public understanding of climate change science: how to improve communication across ideological divides? Publ Understand Sci. doi:10.1177/0963662509357871