Public Perception of Climate Change

Voluntary Mitigation and Barriers to Behavior Change

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Abstract: Mitigating global climate change requires not only government action but also cooperation from consumers. Population-based, cross-sectional surveys were conducted among 1202 respondents in Portland OR and Houston TX between June and September 2007 regarding awareness, concern, and behavior change related to climate change. The data were subjected to both quantitative and qualitative analyses. Awareness about climate change is virtually universal (98% in Portland and 92% in Houston) with the vast majority reporting some level of concern (90% in Portland and 82% in Houston). A multivariate analysis revealed significant predictors of behavior change: individuals with heightened concern about climate change ($p<0.001$); respondents with higher level of education ($p=0.03$); younger compared with older individuals ($p<0.001$); and Portlanders more likely to change behavior compared with Houstonians ($p<0.001$). Of those who changed behavior, 43% reported having reduced their energy usage at home, 39% had reduced gasoline consumption, and 26% engaged in other behaviors, largely recycling. Qualitative data indicate a number of cognitive, behavioral, and structural obstacles to voluntary mitigation. Although consumers are interested in global climate change–mitigation strategies and willing to act accordingly, considerable impediments remain. Government policy must eliminate economic, structural, and social barriers to change and advance accessible and economical alternatives. Individual-level mitigation can be a policy option under favorable contextual conditions, as these results indicate, but must be accompanied by mitigation efforts from industry, commerce, and government.

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Introduction

Humans are now unequivocally implicated in triggering global climate change, and the impacts on human and natural systems will be severe, far reaching, and affect the most physically and economically vulnerable people around the world disproportionately.[1,2] Society can respond to these threats through two distinct strategies: adaptation and mitigation.[3] Adaptation involves preventive measures to avoid, prepare for, or respond to potential impacts from climate change.[4] The goal of adaptation is to reduce the associated risk to population health through a wide range of interventions including health behaviors, clinical procedures, or technical/structural measures.[5] Adaptation, which tends to act in the short-term and is intuitive, tangible, and direct (e.g., the use of air conditioning during a heat wave),[6] can also involve long-term planning of a public health response to climate change (e.g., a heat emergency plan) and can thus also be more abstract, impersonal, and indirect.[7]

Mitigation efforts are focused on reducing the sources and augmenting the sinks (areas that absorb carbon dioxide, such as forests and oceans) of greenhouse gases.[8] Effective mitigation benefits not only human systems but also all natural systems. Reduction in greenhouse gas emissions requires concerted efforts nationally and internationally and is likely to be slow, due to the inertia of the global climate system. Therefore, timely action to mitigate drivers of global climate change is critical but hampered by a lack of political commitment, institutional barriers, and technical hurdles. Furthermore, large-scale mitigation requires international cooperation and support from the public, commerce, and industry, which limits rapid implementation. Opportunity for immediate action lies in increasing voluntary mitigation by individuals engaging in more sustainable, low-carbon lifestyle choices. If consumers are receptive and responsive to behavior-change messages, greenhouse gas emissions from do-

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mestic consumption and personal transportation could be reduced substantially. In 2006, 32% of total energy consumption was industrial, 28% was transportation, 21% was residential, and 18% was commercial. Leaving industrial energy consumption out of the total, transportation then becomes the biggest category, responsible for 41% of energy use, followed by residential with 31%.[9] Although government plays an essential role in mitigating global warming through legislation and regulatory action, voluntary consumer reduction in energy usage is also important, especially in the absence of large-scale government interventions. More attention is needed to understand the potential and limitations of individuals' contributions to mitigation.

Voluntary reduction in energy consumption by individuals is contingent on their state of awareness and concern about climate change, their willingness to act, and their ability to change.[10] The theoretical underpinning of such a perspective is the transtheoretical model of behavior change.[11] In health education and health promotion, behavior change is believed to occur along a temporal gradient that builds on both cognitive and performance-based components.[12] This model proposes that individuals move through five stages of change: pre-contemplation, contemplation, preparation, action, and maintenance.[12–14] At the end of this process the individual reaches a stage of termination where the previous behavior is no longer desirable.

Adopting low-carbon lifestyle choices requires cognitive and behavioral stages of change that can collide with a number of societal barriers. Are individuals willing to engage in voluntary mitigation of climate change, despite these barriers, and adjust their lifestyles accordingly? The current study examined public awareness and concern about climate change in Portland OR and Houston TX and documented self-reported behavior change, as well as barriers to behavior change. Quantitative and qualitative data on these variables are presented, and commonly experienced barriers and constraints to engage in behavior change are identified. This study aims to provide insights into public perception of climate change in these two metropolitan areas and assess potential barriers to individual-level reductions of greenhouse gas emissions.

Methods

Perception about global climate change and related behavior change was assessed through random-digit-dial telephone surveys on nine occasions, four in Portland and five in Houston, between June 6 and September 11, 2007 (Table 1). The interviews were conducted at Portland State University (PSU)'s Survey Research Laboratory (SRL) in both Spanish and English.[15] The SRL is equipped with a state-of-the-art computer-assisted telephone interviewing (CATI) system with 20 telephone interviewing stations. The questions appeared on a computer screen and were read by the interviewer. Such an approach allowed for the establishment of complex contingency patterns of questions, where subquestions were automatically branched off to generate skip patterns. Invalid responses were identified by the CATI system, thereby enhancing data accuracy. Further, the need for subsequent data entry was eliminated because the data were entered directly into the database. Quality control was assured by a centralized facility monitored by the supervisor. The optimum time for calling was established through call-back procedures (three call-backs per number) and interview scheduling. Selection of numbers for the two metropolitan areas was based on area codes and prefixes, and participants were subsequently screened by ZIP codes to assure the geographic specificity of respondents. The questionnaire also contained screening questions for age, language, and comprehension and was approved by PSU's Human Subjects Research Review Committee (HSRRC Proposal #04157). The instrument collected 16 demographic variables and questions regarding awareness, concern, and behavior change related to climate change as well as questions about air quality and ambient temperature on the day of the survey.

Table 1. Sampling days, sample size, and heat index in Portland OR and Houston TX, 2007

City	Date	*n*	Heat index (°C/°F)
Portland	July 10	116	36.2/97.2
Portland	July 11	135	35.9/96.6
Portland	August 29	206	32.7/90.9
Portland	September 11	156	29.4/84.9
Houston	June 6	102	35.7/96.3
Houston	June 21	122	34.1/93.4
Houston	July 12	119	40.3/104.5
Houston	August 8	121	41.0/105.8
Houston	August 13	125	39.7/103.5

A total of 1234 individuals were interviewed; 32 respondents were dropped from the data set because of difficulties in understanding the questions, lack of cooperation, distractions, or language barriers, as reported by the interviewers. Of the 1202 individuals included in this analysis, 613 lived in Portland and 589 in Houston with 410 and 371 refusals, respectively (participation rate: 59.9% and 61.4%, correspondingly). The samples from each city were similar with regard to age ($p=0.515$); gender ($p=0.106$); and home ownership ($p=0.413$) but differed in demographic profile, including income ($p=0.003$); race/ethnicity ($p<0.001$); employment ($p=0.001$); and education ($p=0.002$) (Table 2). These differences reflect, in part, the diversity of the general population of Houston and Portland; the population in Portland is predominantly white, whereas the population in Houston is more ethnically and racially mixed. Overall, the demographic profile from each sample was reasonably representative of these city populations (according to population data from the 2000 census; www.census.gov/main/www/cen2000.html), although there was a certain sampling bias across both cities. Both samples reflected the populations that were more likely to be home during the day.

The demographics of the survey respondents in Portland differed from the 2000 census demographics of Portland in the following ways: median age (53 vs 34.9); more female (68.1% vs 50.4%); higher income (53% >$50,000 income vs 46.9%); more highly educated (84.9% some college or more

Table 2. Demographic characteristics of study population, for Portland OR and Houston TX, 2007[a]

	Portland (%) (*n*=613)	Houston (%) (*n*=589)
Age (mean)	53.4 (SD=16.52)	50.8 (SD=16.85)
Gender (female)	68.0	63.0
Race/ethnicity		
White	91.5	59.4
Nonwhite	7.0	40.6
Annual household income		
≤$30,000	20.4	24.3
>$30,000	67.4	71.2
Highest level of education		
High school diploma or below (includes GED)	15	23.3
Some college and beyond	84.7	75.7
Home ownership		
Own	76.8	75.4
Rent	19.1	22.4
Employment		
Employed (full- or part-time)	51.2	56.0
Not employed (unemployed, stay at home, retired)	47.8	42.8

[a]Not all demographic percentages add up to 100% because some participants refused to disclose all demographic information.

vs 63.9%); more likely to be homeowners (91.3% vs 62%); less likely to be employed (51.7% vs 65.6%); and more likely to report race as white (92.9% vs 83.6%).

Similarly, the demographics of the survey respondents in Houston differed from the 2000 census demographics of Houston in the following ways: median age (51 vs 31.9 years); more female (63% vs 50.2%); higher income (52% >$50,000 income vs 45.2%); more highly educated (76.5% some college or more vs 53.5%); more likely to be homeowners (91.7% vs 60.7%); less likely to be employed (56.7% vs 61.3%); and less likely to report race as white (59.4.% vs 62.6%). This bias is common in phone surveys, and the city samples still reflected most of the key differences in the demographics between the populations of the two metropolitan areas.[16–18]

Logistic regression models were used to analyze the demographic characteristics of each city's respondents and the recorded heat index to determine what factors predicted changes in behavior regarding global climate change. The regression models used backward elimination at a 0.08 criteria, and categoric demographic variables were dichotomized because of sample size constraints. (See Table 2 for a breakdown of how variables were dichotomized.) Logistic regression was not performed for awareness or concern due to limited variability or the ordinal nature of the data, respectively. Chi-square analyses, and a Pearson correlation in the case of age, were conducted to explore the univariate relationships among awareness, concern, and demographics. Additional qualitative information was collected from a subset of participants whose responses to questions about what behaviors they had or had not changed did not fall within prescribed categories. These qualitative data were subjected to a content analysis with behavior-change categories (or barriers thereof) as well as categories of stages of change from the transtheoretical model.[19] This analysis was conducted to improve the understanding of the types of behavior changes and the barriers to behavior change reported by participants. Because the qualitative data were not collected from the entire sample, due to the skip pattern of the survey instrument (see above), the results of the content analysis should not be quantified but rather provide content.

Results

Awareness and Concern About Climate Change

Virtually all respondents (92%) had heard about global climate change or global warming. Low-income individuals (≤$30,000/year) in both cities were less likely than higher income individuals (>$30,000/year) to be aware of climate change (Portland, χ^2 = 7.72 [1], p=0.013; Houston, χ^2 = 50.38 [1], p<0.001). Although most people across all income categories had heard about climate change, 36 of the 48 who had not heard of global climate change were low-income individuals.

Of the 92% of respondents who had heard of global warming, most respondents in Portland (90%) and Houston (82%) were very or somewhat concerned (Table 3). Across all three levels of concern, a statistically significant difference in concern was observed between the two cities (χ^2 = 15.56 [2], p<0.001). Respondents were asked to classify the previous day as mild, hot, or extremely hot, and their perceptions of heat were related partly to their reported concern about climate change (Portland, χ^2= 9.68 [4], p=0.046; Houston, χ^2= 9.38 [4], p=0.052).

Gender and income were the only demographics that predicted concern about climate change across both cities or within either city. Women in both cities were significantly more concerned about climate change than men (Portland, χ^2 = 8.84 [2], p=0.012; Houston, χ^2 = 10.07 [2], p=0.007), which was also the case for the entire sample (χ^2 = 19.8 [2], p<0.001). Across Portland and Houston a relationship was observed between income and concern about climate change, with lower-income individuals reporting greater concern (χ^2 = 6.71 [2], p=0.035). The statistical significance of this relationship did not hold within cities (Portland, χ^2 = 3.86 [2], p=0.145, ns; Houston, χ^2 = 3.76 [2], p=0.153, ns), although the pattern of percentages showed the same trend of less concern among higher-income individuals (Table 3). Higher-income earners may perceive less risk from climate change

Table 3. Concerns about climate change as a function of income and gender: Portland OR and Houston TX, 2007

City	Demography	Category	How concerned are you about global climate change? (%) Not at all concerned	Somewhat concerned	Very concerned	χ^2	p
Both	Entire sample		13.6	38.1	48.3		
	Gender	Male	18.8	40.5	40.7	19.8	<0.001
		Female	10.9	36.9	52.2		
	Income	≤$30,000	9.2	36.2	54.6	6.71	0.04
		>$30,000	15.1	38.0	46.9		
Portland	All of Portland		9.9	39.0	51.2		
	Gender	Male	13.2	44.2	42.6	8.84	0.01
		Female	8.4	36.6	55.0		
	Income	≤$30,000	5.1	38.5	56.4	3.86	0.15
		>$30,000	10.8	39.5	49.8		
Houston	All of Houston		17.8	37.1	45.1		
	Gender	Male	24.1	36.9	38.9	10.1	0.01
		Female	14.0	37.2	48.8		
	Income	≤$30,000	13.4	33.9	52.7	3.76	0.15
		>$30,000	20.2	36.3	43.6		

Comparison between Portland and Houston: χ^2=15.56, p<0.001

because they have the financial means to respond to immediate or longer-term threats.

Behavior Change Related to Climate Change

Of those who were aware of climate change, large percentages of Portland (63%) and Houston (47%) respondents reported having changed their behavior. A logistic regression analysis was conducted to determine what contextual (downtown maximum heat index and city) and sociodemographic (age, education, ethnicity, owner/renter status, gender, income, and employment; see Table 2) factors predicted reported change of behavior. Individual concern about global climate change was also added into the final set of factors from the backwards elimination models.

A number of factors were significant predictors of behavior change related to climate change. The model predicted that the following respondents would be more likely to change their behavior: those with increasing levels of concern (p<0.001); those with a higher level of education (some college and beyond; p=0.03); younger more than older individuals (p<0.001); and Portlanders compared with Houstonians (p<0.001) (see Table 4). Controlling for each of the other variables, Portlanders were 20% more likely than Houstonians to report changing their behavior. Additionally, people with a college-level education were 11% more likely than those with a high school degree or below to report changing their behavior to reduce personal contributions to climate change; individuals at each increase in level of concern were 30%–40% more likely; and individuals at an SD below the mean age were 9% more likely.

In terms of specific behavioral changes, of those who changed behavior, 43% decreased their energy usage at home, 39% reduced gasoline consumption, and 26% cited *other behaviors* and offered open-ended responses. Again, among those reporting behavior change, Portlanders were significantly more likely to reduce consumption of energy in their home than Houstonians, 48% compared to 37% (χ^2 = 15.13 [1], p< 0.001). Portlanders were also significantly more likely than Houstonians to lower their consumption of gasoline, 48% compared to 29% (χ^2 = 44.63 [1], p< 0.001).

Table 4. Significant predictors of behavior change in response to climate change, in Portland OR and Houston TX, 2007

Predictors[a]	Reference group[b]	β	SE	OR[b]	Sig. (p)
City	Portland	−0.77	0.18	0.46	<0.01
Age	NA *continuous*	−0.02	0.01	0.98	<0.01
Gender	Male	0.15	0.17	1.16	0.37
Education	High school education	0.49	0.22	1.64	0.03
Ethnicity	White	0.16	0.23	1.17	0.49
Concern	Not concerned	1.98	0.14	7.27	<0.01

Constant: β=−3.29, SE=0.70, OR=0.04

[a]Nine predictors were initially entered into the logistic regression model, including city (Portland or Houston), concern about global climate change (Not Concerned, Somewhat Concerned, Very Concerned) and the seven demographic characteristics listed in Table 2.

[b]OR of the categorical variables represents the odds of finding a change in behavior when moving away from the reference group.

NA, not applicable

Recycling was the most commonly cited other behavioral change in response to climate change. Other behaviors reportedly engaged in by individuals included conserving water, purchasing a fuel-efficient car, purchasing renewable power options, not using aerosol cans, taking fewer airline flights, and altering eating habits (e.g., not eating meat, consuming local foods; Table 5, Question 1). The survey revealed the convergence of climate change with other general environmental issues that has been observed in other studies[20] and is clearly exemplified in a statement such as: *I try not to use pesticides.* Reducing use of aerosol cans was mentioned by a number of respondents, although chlorofluorocarbons (CFC gases) are linked mainly to stratospheric ozone depletion, not climate change.

No difference was observed between high- and low-income earners in terms of behavior change as a response to hearing about climate change (Portland, χ^2=0.246 [1], p=0.348; Houston, χ^2 = 0.004 [1], p= 0.517).

Barriers to Behavior Change

Of the 507 respondents in both cities who did not change their behavior, not knowing how to change behavior to reduce one's contribution to climate change was the most commonly cited reason (n=122). The next most common reason cited was that changing one's own behavior will not make any difference anyway (n=90). Not having enough money (n=55) and not having enough time (n=28) to change one's behavior followed as reasons for not changing. Very few people, all from Houston, cited concerns that changing one's behavior would affect other's opinions of them (n=6). No reason was cited for a lack of behavioral change for 88 respondents. The remainder of participants who did not change their behavior cited other reasons (n=118). A number of reasons were reported such as skepticism about climate change; fatalism was another barrier to engagement since the problem was perceived too big for individuals to tackle.[21] Selected quotes are presented in Table 5 (Question 2).

There were similarities and variability among the barriers to changing behavior across income levels (≤$30,000 vs >$30,000). The two income groups were similar in rationale for not changing behavior due to a lack of knowledge of what behaviors to change (χ^2 = 0.000 [1], p=0.537); a sense that changing one's behavior will not make a difference (χ^2 = 0.014 [1], p=0.514); and concerns that changing behavior will affect other's opinions of them (χ^2 = 2.602 [1], p=0.166).

The income categories differed in reporting of barriers to change in that low-income earners were more likely to report knowing what behaviors to change, but not knowing how to change them (χ^2 = 20.824 [1], p<0.001). Low-income earners were also more likely to report not having enough time (χ^2 = 4.468 [1], p=0.036) or enough money (χ^2 = 9.763 [1], p=0.002) as barriers to changing their behavior in response to global climate change.

Limitations

This study was conducted prior to the announcement of the awarding of the Nobel Peace Prize in October 2007 to the UN Intergovernmental Panel of Climate Change (IPPC) and former Vice President Al Gore. The subsequent media attention dedicated to climate change has been unprecedented and has undoubtedly shifted public perception on this topic; thus, awareness and knowledge about climate change in the general public must have increased since.

The study might suffer from selection bias, because it was conducted with random-digit dialing, although the level of nonresponse bias does not appear to change significantly if the response rate is in the range of 40%–70%.[22,23] This study is based on self-reported behavioral changes and not actual measurements or underlying motivations; therefore, it is possible that respondents overstated their engagement in light of the publicity about climate change. Only a subset of respondents provided open-ended responses, which limits the quantification of these qualitative observations; moreover, the phone survey did not lend itself to an in-depth interview to assess precisely their stage of change in the transtheoretical model. Thus, not all study participants could be categorized with the available data.

Discussion

The respondents from these two metropolitan areas demonstrated familiarity with climate change and even motivation to act on mitigation. Almost all respondents (>90%) in Portland and Houston were aware of global climate change, with slightly reduced self-reported knowledge in the lower-income groups. These findings are largely consistent with lay environmental beliefs and values about climate change collected in the U.S.[24–29] Similarly, 86% of respondents in the two cities were concerned about climate change. Since 2003, time–series data have shown an increase in the level of concern.[30] We did not rank the risk perception of climate change with other ecologic concerns, or security or health threats, but comparative studies rank climate change concern secondary to others.[31,32] Nevertheless, in the current study, the majority of respondents (55%) claimed to have changed their behavior in response to climate change. Certain segments of the population were more likely to report behavior change than others, such as those who were more concerned, more educated, and younger. Noting some differences in constructs and measures, these findings are largely

Table 5. Categories and selected comments of content analysis of 319 open-ended interviews in response to two questions asked of respondents in Portland OR and Houston TX, 2007

Question 1: How have you changed your behavior?	
Transportation	
Walking	I walk more places now even though I have asthma.
Biking	I stopped using my car and started using my bike to go to work instead.
Public transportation	I use more public transportation.
Car	
Fuel efficiency	We use renewable energy sources, recycle, and we're shopping for a new green line car, possibly with alternative fuel sources.
Fewer trips	I do regular tune-ups on all vehicles and we consolidate errands so we can reduce our driving trips.
Reduced flying/travel	We spend less time traveling on vacations.
Energy	
Light bulbs	I changed to fluorescent light bulbs to decrease energy consumption and carbon emissions.
Renewability	We switched our home to green mountain energy, which is wind energy.
Conservation	Nature conservation; it takes energy to make anything, so I basically just conserve everything, such as paper and plastic.
Air conditioning	We set the AC upstairs at a higher temperature during the day.
Insulation	I put in [a] radiant barrier and added insulation.
House improvements	I turned the pool into solar panels, put more insulation in the house, got a more efficient furnace, and purchase energy efficient products.
Water	
Reduced use	Energy trust came in and evaluated my home. I installed low flow in sinks and shower heads, and put drip irrigation on timer.
Food	
Local	We are trying to eat locally more. Canning and growing our own foods, to avoid trucking issues.
Meat	I eat less meat. It takes a lot of energy to produce that.
Education	I educate people about global warming.
Carbon offset	We purchased carbon offsets to offset a vacation we took.
Waste reduction	I reduce my waste output.
Gardening	I'm also a gardener, so I eat from my garden, and I think that all of those things help.
Recycling	We try to recycle, but there is no public recycling in our apartment. So if I do, I have to do it at my aunt's house.
Consumption	We are conscious about our consumption of used goods, where our goods come from and we take public transportation more.
Question 2: Why have you not changed your behavior in response to global climate change?	
Skepticism/uncertainty	I'm just not sure if I'm convinced that global warming is the problem they make it out to be. There are too many conflicting opinions on global warming.
	I don't think it's clear whether global warming is negative. It may actually improve things. People are concluding prematurely that it's a bad thing.
Distrust	Global warming is just a political ploy.
	Tell whoever to stop biasing the information regarding global warming. They are not giving the public all of the relevant information. They are only giving the information that helps their argument, and I don't like that.
Fatalism	Individual behavior change won't affect global climate change.
Accountability	I don't feel what I would do make a difference when corporations are not controlling their part of it.
Lack of knowledge	
General	I don't understand a lot about it.
Behavior-specific	I use propane gas to help utilities.
	I heard that it's better to get gas at certain times, so I pump my gas early in the day before it gets hot.
	We try not to use aerosols with ozone-depleting ingredients and I vote for politicians that stress the environment.
Saturation	I already practice environmentally friendly behavior.
	I feel that I am doing everything that I can do.
Inability to change	I have been disabled for the past 13 years, so I just stick to my daily routine.
Inconvenience	The constraints of my lifestyle and my family prohibit it.
Self-interest	I want to maintain a personal level of comfort.
Lack of motivation	Laziness.
Apathy	I am too old to care; I'll be dead before anything happens.
	I am 59 and I will be dead before it affects me.

consistent with other surveys of public perception and engagement in climate change conducted in the U.S.[24,25,28,32,33] In contrast, a survey of behavior change in relation to extreme weather events and heat or air quality advisories in these two cities did not detect any behavior change in the general public.[34] Even though behavior change is not evident during potentially hazardous weather and environmental conditions, the results presented here indicate that knowledge about climate change can produce self-reported behavioral changes.

Interestingly, the behavioral responses to climate change differ significantly in the two surveyed metropolitan areas and are reflected in the multivariate analysis: Portlanders claim to have actively engaged with this issue, Houstonians to a lesser extent. This difference might be due partly to the fact that much of the economy in Houston is driven by the oil and gas industry, inadvertently affecting residents' opinion about the issue. On the other hand, the discrepancy between level of awareness/concern and actual behavioral modification in both cities might indicate structural barriers. Portland and Houston differ with respect to urban planning policies, political orientation, and many sociodemographic indicators. Compared to Houston, the Portland infrastructure may be more conducive to low-carbon living, with its accessible, efficient, and diverse (e.g., streetcar, light rail, buses) public transportation system, which reduces driving. For every gallon of gasoline that is consumed, approximately 24 pounds of global warming pollution are released into the air. Portland is also renowned for its availability of locally grown food, and dense mixed-use neighborhoods resulting from an urban growth boundary.

Further, residential recycling rates for 2006 were 2.6% in Houston and 51.7% in Portland.[35] Although recycling is only indirectly related to greenhouse gas emissions, the Environmental Protection Agency (EPA) estimates that a recycling rate of 32% nationwide would be equivalent to removing nearly 40 million vehicles from the road.[36] According to the U.S. Department of Transportation, the average Portland resident drives 23.6 miles per day compared with 36.9 miles for Houston area residents.[37] The average distance from home to public transportation access is 3100 feet and 27,000 feet for Portland and Houston, respectively.[38] The discrepancy between the two metropolitan areas observed in our quantitative models can be explained partially by these structural differences. This hypothesis is supported by a recent study by Lorenzoni and colleagues,[39] investigating barriers to individual engagement with climate change in the UK. The study uncovered many similar barriers to those described in our study, such as social- and structural-level constraints. This framework would imply that the level of social/structural support for a lower-carbon lifestyle would be in accord with levels of behavior change. The difference in behavior change in the two cities surveyed in this study lends support to this notion.

Another significant finding of the Lorenzoni study[39] was that barriers such as skepticism, distrust, fatalism, and lack of knowledge also operate at the individual level, which is reflected in our qualitative findings described in Table 5. To promote effective behavior change in light of these individual-level barriers, we relied on a theoretical model of behavior change to interpret the data. The responses were subjected to an analysis according to the transtheoretical model.[12] The qualitative analysis revealed a series of cognitive and behavioral stages that could explain individual-level barriers to change, in addition to the structural barriers discussed above. The categories of change of the transtheoretical model[11] were superimposed on the qualitative data. Selected quotes exemplifying each stage are presented below:

- **Pre-contemplation** (does not believe in climate change or the usefulness of behavior change): *I don't have control over something like global warming, that's not something a person can change.*
- **Contemplation** (believes in climate change but no action considered): *I can't move unless I'm in an automobile, and I still have to farm with tractors. Other than that, I can't change what I'm doing. I just can't change my behavior. I'm not going back to farming with horses.*
- **Preparation** (steps considered but no behavior change yet): *I know what things I could do to change, but because I live where I live and I work where I work, I cannot make the change, specifically, driving to work.*
- **Action** (minimal individual attempts but sees limitations and difficulties): *I don't tolerate the heat very well. I use the fans for as long I can stand it, and then I turn the air conditioner on.*
- **Maintenance** (maintains several actions): *I feel that I am doing what I can right now and can't do any more. I am happy with what I do now.*
- **Termination** (maintains low-carbon lifestyle and identifies with ideology): *I was already concerned about the environment and doing what I could to not pollute. We were already aware and conscientious about our actions.*

These data indicate a wide range of cognitive and performance-based stages of change among respondents, in terms of intentional behavior change.[40] Because we did not conduct in-depth interviews with the respondents, it is difficult to place individuals unequivocally into one of these categories and to define the stage distribution in the population. Future research should aim to quantify the population distribution across the different stages, to direct behavior-change messages to individuals effectively at different stages of change. For example, data presented in response to Question 2 in Table 5 document considerable obstacles

to change, and it has been documented that individuals in pre-contemplation or contemplation stages are less likely to change compared with those in the action stage.[41] To recruit these individuals to a behavior-change intervention, appropriate educational messages need to be developed, which increase awareness about the causes and consequences of climate change. These obstacles may be due partly to media portrayal of scientific disagreement about the issue.[42] Despite wide agreement in the peer-reviewed literature on this subject, journalists and others seem to be of the opinion that there is confusion and disagreement within the scientific community. Media advocacy should be evidence-based, with unequivocal messages tailored directly to these segments of the population.

Climate change also provokes negative emotional affect among certain individuals (Table 5, Question 2), which could be attenuated through personal testimony in the media (e.g., news coverage, documentaries) or dramatic re-enactment in the arts (e.g., film, theatre, literature) and schools. Further, the transtheoretical model stresses the need to consider individuals in more advanced stages by responding to their specific needs in order to assure their retention in an intervention. For example, maintaining low-carbon behavior is supported by more favorable structural and environmental conditions in Portland than in Houston, which might in part explain the difference in behavior change between the two cities (Table 4). Thus, environmental interventions and action-based initiatives such as the Safe Routes to School (SR2S) program (http://safety.fhwa.dot.gov/saferoutes/); car-share programs; or bike-to-work initiatives are mitigation initiatives that support people in the action, maintenance, and termination stages. These initiatives also have considerable co-benefits for public health by reducing air pollution and the associated respiratory problems (e.g. asthma, chronic obstructive pulmonary disease), or reducing sedentary lifestyle and thus such conditions as obesity, diabetes, and cardiovascular disease. From a public health perspective, both mitigation and adaptation interventions can have far-reaching benefits, and a stepwise process to advance community interventions by building social capital has been described.[5,43,44]

Adoption of voluntary mitigation can be enacted only if the general public and other stakeholders see the benefits of such sacrifices.[45] Thus, media advocacy should be framed to advance both behavioral and policy changes. Findings from this and other studies suggest that the majority of consumers desire to be part of the solution to climate change.[24,25,27,46,47] However, voluntary mitigation by the public to adjust lifestyles can be maximized only with legislative and regulatory measures to support such actions. For example, more stringent fuel economy standards of 35 mpg can reduce yearly greenhouse gas emissions corresponding to 206 metric tons (227 tons) of carbon dioxide. Further, other greenhouse gas emitters have to be brought to the table in a broad dialogue among all societal stakeholders, including the public, commerce, industry, interest groups, and government. Ultimately, effective mitigation of global warming requires both structural and behavioral changes toward a more sustainable society.

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