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SI: BEHAVIOR SCIENCE CONTRIBUTIONS TO PUBLIC POLICY

The Dismal State of Federal Funding for Experimental Evaluations of Interventions to Reduce Greenhouse Gas Emissions

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Abstract

The threats of climate change to human well-being are well-documented and are growing in number and intensity. Despite the international community investing heavily in technological innovation and policy initiatives to solve the problem, emissions continue to rise. Experts are recognizing that eliminating emissions cannot be achieved without modifying the human behavior of which emissions are a function. However, little attention has been allocated to expanding the use of strategies developed by the behavioral-science community to reduce emissions on large scales. One possible reason is that federal funding has not been arranged to select such research. Therefore, we conducted an analysis of six sources of information about federal funding to fight climate change (the Government Accountability Office, the National Science Foundation, the Environmental Protection Agency, the Department of Energy, the National Institutes of Health, and the Center for Disease Control) and examined the extent to which they are funding behavioral science research to reduce emissions. Our results show an appalling lack of funding for behavioral science research to reduce emissions, especially experimental evaluations of strategies for reducing them. Implications and recommendations for funding of future research are discussed.

Keywords behavioral science · experimental evaluations · funding · interventions

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The threats of climate change to human well-being are well-documented (Intergovernmental Panel on Climate Change [IPCC], 2014) and are growing in number and intensity (IPCC, 2018). NASA announced earlier this year that 2020 tied with 2016 for the hottest year on record. In 2020 alone, 30 named storms in the Atlantic basin—more than double the average season's activity—produced $37 billion in damage. Wildfires in Australia destroyed 46 million acres before a series of fires ravaged the U.S. West Coast creating more than $16 billion in damage. Meanwhile, Death Valley observed the hottest temperature ever reliably recorded at 129.9°F (54.4°C)—until, of course, 2021 came along and that record was surpassed. The year 2020 also included a record number of billion-dollar weather disasters in the United States (25 in total; Yale Climate Connections, 2020). And 2021 is shaping up to be just as extreme. In light of a 2018 report from the IPCC that showed emissions have shown no signs of abatement, imagine the state of affairs in 2050, or worse, 2100. Indeed, we are in serious trouble. In fact, a 2020 report from the National Bureau of Economic Research predicted that by the year 2100, "the impact of climate change on mortality will be comparable globally to leading causes of death today, such as cancer and infectious disease" (p. 45). If we fail to do what is needed to solve this problem, we allow this slow-moving (but accelerating) catastrophe to change human society beyond anything that has happened in the past 10,000 years.

Accelerated climate change is a direct result of human behavior that produces greenhouse-gas emissions or that prevents the sequestration of carbon from the atmosphere (e.g., deforestation of the amazon rainforest to graze cattle or grow food to feed them; IPCC, 2021; Skidmore et al., 2021; Swim et al., 2011). Thus, one would hope that governments around the world would be investing heavily in behavioral science research to develop precise and cost-effective strategies to influence behaviors and organizational practices that contribute to greenhouse-gas emissions. The present article reports an analysis of federal funding for such research.

The work was commissioned by the Coalition of Behavioral Science Organizations (CBSO),[1] which was created to influence societies to make more effective use of behavioral science research. Its formation was predicated on the observation that significant advances have been made in the science of human behavior and public health in the past 70 years (e.g., Biglan, 2015), but the translation of that knowledge into widespread benefit has been limited. Given the growing problem of climate change, the coalition made the review of the state of behavioral science research on greenhouse-gas emissions one of its first priorities.

The first report of the CBSO (Biglan et al., 2020) showed that little attention has been given to the conduct of experimental evaluations of multisectoral community interventions to reduce emissions. Our hypotheses for why this might be the case were that (1) the methodology for doing so has not be explicated, and (2) that there is little funding to support such comprehensive and large-scale interventions. In

[1] When our efforts were initiated, the CBSO consisted of the Association of Behavior Analysis International, the Association of Contextual Behavior Science, the Association of Positive Behavior Support, The Evolution Institute, the National Prevention Science Coalition, and the Society for Behavioral Medicine.

service of (1) above, Bonner and Biglan (2021) described how experimental evaluations of comprehensive community interventions may be conducted. In service of (2) above, the CBSO commissioned the current article. The goal of the current article is to attract additional funding to reduce emissions using knowledge gained from the last 50 years of behavioral science research in this area. Said funding could stimulate the behavioral science community working in this area to, among other things, focus their attention on large-scale efforts to reduce emissions. Namely the development and implementation of comprehensive and multisectoral community interventions.

We examined the extent to which the U.S. government is investing in research on how to reduce greenhouse-gas emissions through behavior change. Funding is the contingency that shapes and maintains research practice. The United States is the largest funder of research in the world, both in terms of total expenditures and per capita expenditures (United Nations Educational, Scientific, and Cultural Organization, n.d.). Data on U.S. expenditures relevant to GHG emissions research are readily available. Thus, it seemed appropriate to analyze the extent to which research on reducing greenhouse-gas emissions is being funded by the federal government. We were particularly interested in whether experimental evaluations of strategies for reducing emissions using behavioral science are being funded. Our focus on experimental evaluations stems from that fact they identify increasingly more effective strategies over time.

We analyzed six sources of information about federal funding of behavioral science research on reducing emissions. These six sources were selected because together they represent a comprehensive assessment of federal funding priorities to fight climate change. The first was a report from the Government Accountability Office (GAO), which monitors and audits federal programs and services. The second was the portfolio of projects funded by the National Science Foundation (NSF), which accounts for roughly 25% of all federally supported basic research. The third was the Environmental Protection Agency, and the fourth was the Department of Energy. The fifth was the National Institutes of Health (NIH), the primary funder of research on public health. And the sixth was the Centers for Disease Control and Prevention (CDC) Climate and Health Program. In each case, we were attempting to find funded research on how to affect human behavior that affects the emission of greenhouse gases.

Report of the Government Accountability Office

We began by examining a 2018 report of the GAO on federal expenditures on climate change. The report documented the annual federal expenditures on climate change of the six agencies that the GAO determined had received most (89%) of the federal funding on climate change in 2014. They were the Department of Commerce, the Department of Defense (DOD), the Department of Energy (DOE), the U.S. Department of Agriculture (USDA), the National Aeronautics and Space Administration (NASA), and the National Science Foundation (NSF). The GAO report had little to say about the agencies that accounted for the remaining 11% of

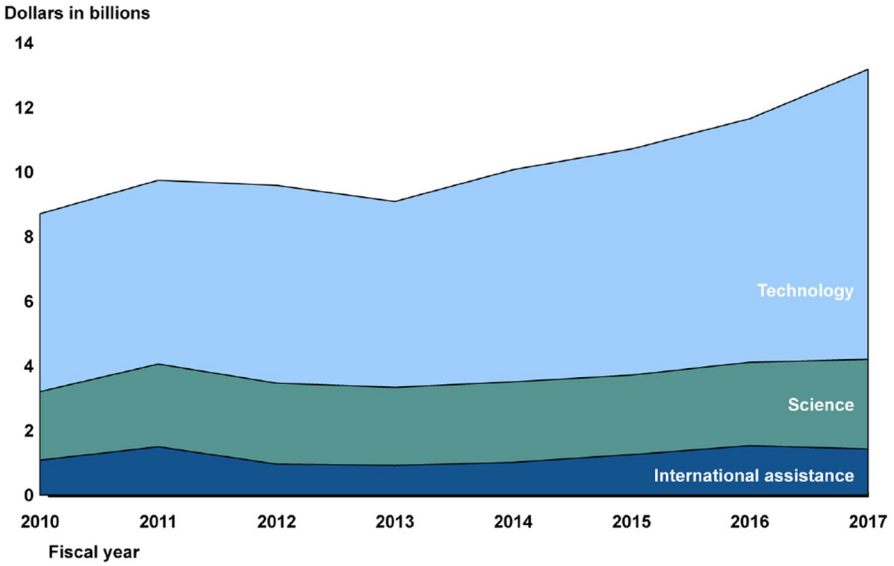

Fig. 1 Reported Federal Climate Change Funding by Category—FISCAL YEARS 2010–2017

federal funding on climate change. It is possible some of those remaining monies were used to fund behavioral science research. As a result, we supplemented our analysis by including federal agencies that may have garnered some of those funds (e.g., the EPA; see below).

Figure 1 shows spending for the years 2010 through 2017. Funding has increased substantially since 2010. By far the largest increases have been on technologies to reduce greenhouse-gas emissions and to provide "clean" energy (USD 3.5 billion). Funding towards projects categorized as "science" has increased by significantly less (USD 653 million).

The report indicated that of the 533 federal programs that claim to have anything to do with climate change only 18 of them were primarily focused on the problem of climate change. In other words, staff at the GAO analyzed the budget justifications for these 533 programs and ascertained that just 18 of them met their definition for a primary-purpose climate change program. A primary-purpose program was defined as "programs that agencies described as having addressing climate change as their main focus" (GAO, 2018, p. 4). The remaining 515 programs were coded as multiple-purpose programs, which were defined as those "programs agencies described as having several goals in addition to addressing climate change" (p. 4). To ameliorate the likelihood that some of the multiple-purpose programs were incorrectly excluded from their analysis, steps were taken to ensure that all programs with a large emphasis on climate change were included. Despite this, it is still possible that some efforts to reduce emissions using behavioral science went undetected in the excluded 515 programs. However, an examination of those 18 primary-purpose programs indicated that *none of them* involved behavioral science research. Given this,

it is unlikely that a large number of efforts would have been found by scouring programs even further removed from climate change as a primary focus.

Table 1 presents descriptions of the 18 primary-purpose programs. As can be seen, none of the projects involved research on how the behavior of individuals, organizations, or communities could be influenced to reduce emissions. A limitation associated with our analysis of this GAO report is that these 18 programs were included in the GAO analysis owing to their self-reported primary focus on climate change or some element of earth science. And it is possible (though in our view, unlikely) that some behavioral science research has been undetected due to the GAO's focus on primary-purpose climate change programs.

The National Science Foundation

Although the GAO report indicated that the National Science Foundation was one of the agencies whose expenditures they studied, none of the 18 programs the GAO said were focused on climate change involved the NSF. Therefore, we conducted our own independent analysis of the NSF research portfolio. Said in a different way, none the data described below were extracted from the GAO report.

The NSF has 11 research funding areas spanning a large range of scientific research. Three of these research areas could involve behavioral research on greenhouse-gas emissions, so we sought to clarify whether any of them were funding research related to the evaluation of behavior-change strategies to reduce emissions. The three funding areas were Social, Behavioral and Economic Sciences, which listed 125 funding opportunities, Environmental Research and Education, which listed 74 funding opportunities, and Education and Human Resources, which listed 101 funding opportunities. It should be noted that these funding areas were not mutually exclusive and funding opportunities commonly appeared in multiple funding areas. As a result, we removed 115 duplicate funding opportunities from our final tally. The remaining 185 funding opportunities contained over 60,000 projects for deeper analysis (described below).

For each research area, we reviewed all funding opportunities to identify those that might plausibly contain projects that propose to evaluate a strategy to reduce emissions using behavioral science. This was accomplished by having two coders (the first two authors) read the title/description of each funding opportunity and then code each opportunity as relevant or irrelevant. Relevant opportunities were those that referenced social science or human behavior; for example, the following NSF funding opportunities met this criterion: Coastlines and People; Perceptions, Actions and Cognition; and Arctic Social Science Program. In an effort to err on the side of caution, funding opportunities whose title or description was ambiguous were also coded as relevant; for example, the following opportunities met this criterion: Future Manufacturing; Innovation Corps; and Science of Organizations. This approach errs on the side of caution by including ambiguous funding opportunities for full coding to determine if any of them contained relevant proposals. Funding opportunities were coded as irrelevant and removed from the search if they obviously precluded proposals to evaluate strategies to reduce emissions using behavioral science; for

Table 1 The 18 Federal Programs Identified by the Government Accountability Office Whose Primary Focus Is on Climate Change

Program	Focus of the Program
Climate Research	The Department of Commerce's National Oceanic and Atmospheric Administration's (NOAA) Climate Research program conducts observations and research to predict long-term changes in climate as well as shorter-term variations that are of societal and economic importance.
Atmospheric Systems Research	The Department of Energy's (DOE) ASR quantifies the interactions among aerosols, clouds, precipitation, and radiation to improve fundamental understanding of these processes and reduce uncertainty in global and regional climate projections.
Atmospheric Radiation Measurement (ARM) Climate Research Facility	The Department of Energy's (DOE) ARM Climate Research Facility provides researchers with observation facilities to improve the understanding and model representation of clouds and aerosols, as well as their interactions with the Earth's surface.
Terrestrial Ecosystem Science (TES)	The Department of Energy's (DOE) TES seeks to improve the representation of terrestrial ecosystem processes in Earth system models to improve climate projections and inform energy decisions.
Terrestrial Carbon Sequestration Research	The Department of Energy's (DOE) Terrestrial Carbon Sequestration Research supported efforts to identify, understand, and predict the fundamental physical, chemical, biological, and genetic mechanisms controlling carbon sequestration in terrestrial ecosystems.
Climate and Earth System Modeling (CESM)	The Department of Energy's (DOE) CESM develops model components as well as Earth system models that include human impacts and natural systems to simulate climate variability (e.g., El Niño) andpredict change from decades to centuries at regional and global scales.
Climate Change Technology Program (CCTP)	The Department of Energy's (DOE) CCTP supported efforts to accelerate the development and reduce the cost of new and advanced technologies that could significantly avoid, reduce, or capture and store greenhouse gas emissions
CLARREO Pathfinder (CPF) Mission	The National Aeronautics and Space Administration's (NASA) CPF Mission's goal is to demonstrate the essential measurement and calibration technologies for one of the instruments needed for the full CLARREO mission.
Glory Mission	The National Aeronautics and Space Administration's (NASA) Glory Mission's goal was to examine how aerosols and solar energy affect the climate, by collecting data on atmospheric aerosol propertiesand incoming solar energy.
The Ice, Cloud, and Land Elevation Satellite (ICESat)	The National Aeronautics and Space Administration's (NASA) ICESat measured changes in ice sheet mass and elevation to understand how changing conditions affect ice and sea level.

Table 1 (continued)

Program	Focus of the Program
The Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2)	The National Aeronautics and Space Administration's (NASA) ICESat-2 will continue ICESat's mission to measure changes in ice sheet mass and elevation to understand how changing conditions affect ice and sea level.
Orbiting Carbon Observatory-2 (OCO-2)	The National Aeronautics and Space Administration's (NASA) OCO-2 measures carbon dioxide concentrations, to better understand the carbon cycle.
Orbiting Carbon Observatory-3 (OCO-3)	The National Aeronautics and Space Administration's (NASA) OCO-3 will continue OCO-2's mission measuring carbon dioxide concentrations, to better understand the carbon cycle
Solar Radiation and Climate Experiment (SORCE)	The National Aeronautics and Space Administration's (NASA) SORCE measures solar radiationproperties to better understand solar variability and its effects.
Total Solar Irradiance Sensor-1 (TSIS-1)	The National Aeronautics and Space Administration's (NASA) TSIS-1 continues SORCE's mission measuring solar radiation properties to better understand solar variability and its effects.
Total Solar Irradiance Sensor-2 (TSIS-2)	The National Aeronautics and Space Administration's (NASA) TSIS-2 will continue TSIS-1's mission measuring solar radiation properties to better understand solar variability and its effects.
Agroclimatology	The U.S. Department of Agriculture's (USDA) Agroclimatology (formerly Global Change, Ultraviolet Monitoring and Research Program) supports an ultraviolet radiation observing network, and uses the data to inform climate forecasting models and assess ultraviolet radiation effects.
Climate Change Program Office (CCPO)	The U.S. Department of Agriculture's (USDA) CCPO coordinates agricultural, rural and forestry-related climate change program and policy issues department-wide

example, the following opportunities were coded as irrelevant: Biological Anthropology; Disrupting Operations of Illicit Supply Networks; Ethical and Responsible Research. This process yielded a total of 57 funding opportunities which contained almost 10,000 projects for further analysis.

Following identification of funding opportunities that might plausibly contain a relevant proposal, we exported the titles and abstracts of all funded projects from each relevant opportunity to an Excel spreadsheet. We used an Excel formula[2] to identify funded projects that contained words in their title or abstract relevant to both climate change *and* experimental evaluations. The specific search terms are

[2] The exact Excel formula, (as well as the raw data for the entire analysis) are available in an open access online repository—see data availability for details.

Table 2 Search Terms for NSF and DOE Office of Science

Words Relevant to Climate Change	Words Relevant Experimentation
Carbon	Experiment or Experiments
Climate	Interrupted
Emission or Emissions	Multiple Baseline
Greenhouse	Random
Methane	Regression Discontinuity
Nitrous Oxide	Reversal
Sustainable or Sustainability	Time Series
Warming	Trial

Note. Relevant projects contained at least one word from each list.

shown in Table 2. These search terms match those used in Biglan et al. (2020) and were developed in collaboration with members of the Coalition of Behavior Science Organization's Climate Change Task Force. The terms were designed with the intention of capturing any research aimed at the evaluation of a strategy to reduce emissions. Funded projects that met our search criteria were then coded to determine whether or not they contained a proposal to experimentally evaluate a behavior-change strategy to reduce emissions in the natural environment.

Our search returned 589 unique funded projects that met our search parameters. The abstracts for each project were then curated into a single spreadsheet for further analysis. In-depth coding of each funded project that met our search criteria was conducted by reading the title and abstract for each project. If the abstract contained a proposal to conduct an experimental evaluation of a behavior-change strategy to reduce GHG emissions, it was coded as relevant. All other projects were coded as irrelevant. Abstracts whose relevance was ambiguous or difficult to judge were analyzed closely by the authors and a final decision was made regarding its relevance based on information contained in the abstract.

Coding was completed by six independent coders (the authors of this manuscript and three others). The first two authors developed a training module consisting of 20 projects that were selected pseudo-randomly to include a mix of obviously relevant projects, ambiguous projects that were more difficult to judge, and projects that were obviously irrelevant. Coders were given instructions on how to conduct the coding and descriptions of relevant and irrelevant projects. They independently coded these 20 projects according to those instructions and returned their coded spreadsheet for comparison to an expert record. In order for training to be considered complete, coders needed to produce an agreement coefficient (described below) of at least 80%. All coders achieved this criterion on their first try.

To increase confidence that our findings were reliable, a second independent coder rated 100% of the 589 projects. The agreement coefficient was calculated by scoring each project as an agreement (100% agreement) when both coders scored the project as either relevant or irrelevant. Projects where coders disagreed were counted as complete disagreements (0% agreement). The individual coefficients for each project were then averaged across all projects to produce an overall agreement coefficient.

Overall agreement equaled 97%. In other words, coders agreed that a project was either relevant or irrelevant for 569 of the 589 projects. For the 20 projects where coders disagreed, the authors closely reviewed each project and made a final determination of its relevance.

Three projects were identified that focused on using behavioral science to enhance water conservation. But because water conservation, although relevant to sustainability in general, does not directly contribute to reducing emission of GHG, these projects were removed from our final tally. Altogether, just 11 of the 589 funded projects that met our criteria were judged to contain a proposal to experimentally evaluate a behavior-change strategy to reduce GHG emissions. This represents 1.9% of our sample. Despite so few relevant projects, the ones we did find showed promise. The title and a brief description of each of the 11 projects that met our criteria are listed in Table 3.

For example, several projects proposed using data analytics to enhance the design and impact of new metrics and incentives on climate-relevant behavior. Another project contained a proposal to evaluate the impact of several interventions on energy consumption in two representative U.S. communities. Another project aimed to provide households in Alaska with real-time data on their consumption and expenditures for heat as a means to reduce consumption. And one project proposed to determine the impact of wearable air quality sensors and cocreated community messaging campaigns on air pollution and air pollution exposure.

However, given such a small sample of relevant proposals, these projects appear to the be exceptions as opposed to the rule. Furthermore, the specific nature of the proposed experimental evaluations could not be determined from the abstracts alone. In all cases, the experimenters described their intention to conduct an experimental evaluation (or demonstrate the effectiveness of the program) but did not describe exactly how that evaluation would be carried out. Moreover, other questions about measurement of the dependent variables and the precise nature of the independent variables was difficult to determine. This is not surprising, however, considering the brevity of abstract descriptions of proposed projects (see discussion of limitations below).

A shortcoming of our approach specifically related to the NSF section was that we judged funding opportunities based on the likelihood they might contain relevant proposals. Funding opportunities with ambiguous titles were included for analysis to avoid incorrectly excluding relevant research. However, we did not track how many funding opportunities were included due to ambiguous titles. We felt this was unnecessary given that all opportunities that, perhaps on the face of them, were difficult to judge were subsequently subjected to our full coding process.

The Environmental Protection Agency

There is no better federal agency to tackle the broad range of climate change issues than the EPA. They sit at the intersection of a warming climate and the plethora of strategies to ameliorate its deadly impact. Therefore, we wanted to know if any of their funding was being dedicated to behavioral strategies to reduce emissions.

Table 3 Description of NSF Funded Projects that Proposed to Conduct an Evaluation of a Strategy to Reduce Emissions Using Behavior Science

Title	Description	Comments
Building a Smart City Economy and Information Ecosystem to Motivate Pro-Social Transportation Behavior	Experimenters proposed to develop a web-based platform to nudge commuters toward the use of public transportation by providing them with real-time information on arrival and departures and through the use of incentives.	The nature of experimentation is unclear form the abstract, and how (if at all) the experimenters plan to assess the impact on GHG emission is also unclear.
Collaborative Research: Acquisition, Collection and Computation of Dynamic Big Sensory Data in Smart Cities	Experimenters proposed to develop and employ Big Sensory Data (BSD) to monitor and enhance climate relevant metrics such as air quality, pollution, and traffic flow. Experimenters also proposed to carry out experimental studies on real-world Smart City projects in Washington, DC.	How this project may be used to enhance climate relevant metrics and the nature of the proposed experiments is unclear.
Smart Air: Informing Driver Behavior through Dynamic Sensing and Smart Messaging	Experimenters proposed to develop wearable, calibrated, low-cost air quality sensing nodes that will support members of smart and connected communities to minimize pollution exposure. Experimenters also proposed providing feedback to individuals about idling behavior and to workers that seek to minimize pollution exposure. Behavior-change experiments and the cocreation of community-crafted messaging will be evaluated to influence individual choices.	How the behavior-change experiments would be conducted, and the precise nature of dependent variables were not expounded.
Data-Informed Modeling and Correct-by-Design Control Protocols for Personal Mobility in Intelligent Urban Transportation Systems	Experimenters proposed to use a model-based and data-driven framework for describing and influencing three components of urban transportation: parking, ride-sharing, and traffic flow. The models use individual driving behavior to inform experimental trials which may then inform effective parking policy changes.	How the outcomes may actually be used to inform effective policy was unclear.

Table 3 (continued)

Title	Description	Comments
Analyzing the Emergence of a Complex Land Management System	Experimenters proposed to travel to two remote communities in Central America to determine practices that contribute to effective land management and resource use. Experimenters also proposed to conduct behavioral economic experiments to determine the impact of cooperation and punishment in these communities on resource use.	We could not determine if the proposed behavioral economic experiments were real-world applications of cooperation and punishment, or hypothetical purchase tasks common in behavioral economics
Inequalities, Institutions and Sustainability: An Experimental Study of Local Efforts to Govern the Commons	Experimenters proposed to examine community forest management in Nepal and India and focused on determining how inequalities in governance impact environmental outcomes, and then what interventions can reduce inequality and improve environmental outcomes. Experimenters proposed four randomized controlled trials to determine the impact of three inequality-reducing interventions	The relationship between inequality in governance and environmental outcomes was not exactly clear, nor were the type of interventions that were proposed.
Reducing Household Food, Energy and Water Consumption: A Quantitative Analysis of Interventions and Impacts of Conservation	Experimenters proposed to evaluate the impact of possible intervention strategies for reducing household food, energy, and water consumption in two representative U.S. suburban communities.	The types of intervention strategies and the particular dependent variables were unclear.
Using Field Experiments to Understand Household Barriers to Energy Efficiency in Alaska	Experimenters proposed to measure the behavioral impact of performance feedback on rural Alaskan consumers consumption of, and expenditures on, heat energy.	How the impact of feedback would be determined was unclear.
Integrated Local Sustainability Strategies, Capacities and Performance Management	Experimenters proposed to assess the integration of sustainability planning, capacity-building, and performance management toward identifying and meeting sustainability goals in the midwestern United States. Experimenters also proposed experiments to determine the impact of performance management and adjustment sustainability outcomes.	The precise nature of the types of sustainability goals or how they would be measured was unclear.

Table 3 (continued)

Title	Description	Comments
Behavioral Analytics and Field Experiments in Sustainable Innovation Policies	Experimenters proposed to use big-data analytics to experimentally evaluate the design and impact of incentives for resource conservation policies.	The type of experiments and the particular strategies being evaluated were unclear.
Automated Learning of Vehicle Energy Performance Models	Experimenters proposed enhance the acceptability of electric vehicle used by developing and evaluating an online platform that delivers predictions about electric vehicle performance on an per-vehicle, per-driver, and per-route basis.	How the impact of the online platform would be measured were unclear

Unfortunately, their online funding archive did not permit searching by keywords. Instead, their portfolio was organized according to categorical units. Two categories were relevant for our purposes. The first was titled "Climate Change" and the second was titled "Environmental Justice." Together, these two categories contained 364 funded projects. We removed 11 duplicates leaving 353 projects for detailed coding. Unfortunately, we were only able to export the project titles and a link to their online descriptions to Excel. As a result, we were unable to filter projects based on the keywords found in Table 2. Instead, we coded every funded project according to the same criteria used for the NSF projects. That is, if the description contained a proposal to conduct an experimental evaluation of a behavior-change strategy to reduce GHG emissions, it was coded as relevant. All other projects were coded as irrelevant. Descriptions whose relevance was ambiguous or difficult to judge were analyzed closely by the authors and a final decision was made regarding its relevance based on information contained in the abstract. One project did not contain a description; therefore, it was coded as irrelevant.

Coding was completed by six people, the authors and three others. All coders either completed training during the NSF portion of the project or were trained using procedures similar to the NSF training protocol. The only difference between the NSF training protocol and the EPA protocol were that the EPA training module consisted of 10 abstracts instead of 20 and the abstracts for the EPA protocol were allocated to trainees 10 at a time in sequential order (whereas the abstracts the NSF portion were chosen using a pseudo-random method). All coders satisfied the mastery criterion of 80% agreement with an expert record on their first try. A second observer coded 33% of all projects. Agreement was calculated using the same method used to calculate agreement for the NSF portion of the project. Overall agreement equaled 99%.

Altogether, we identified just three projects that proposed to conduct an experimental evaluation of a method to reduce emissions using behavior science. A brief description of each project can be found in Table 4. Two projects aimed to evaluate the impact of several different methods for influencing the adoption of clean cook stoves as a means of reducing pollution and improving health. Another project aimed to evaluate the impact of informational advisories on tailpipe emissions. We found numerous proposals looking at the impact of voluntary and mandatory environment management systems (e.g., the Toxic Reporting Inventory), but all of them were retrospective correlational studies as opposed to pure experimental evaluations. Despite this, the value of such work has an important place in the development of effective policies to reduce emissions. However, here to, experimental evaluations stand to significantly accelerate progress toward identifying the most effective tactics to nudge corporate entities toward reduced emissions.

The Department of Energy

The DOE has a long history of supporting social science research. According to Stern and Aronson (1984) in *Energy Use: The Human Dimension,* "By 1979 DOE had developed a scattering of projects addressing social issues that are related to

Table 4 Description of EPA Funded Projects that Proposed to Conduct an Evaluation of a Strategy to Reduce Emissions Using Behavior Science

Title	Description	Comments
Experimental Interventions to Facilitate Clean Cookstove Adoption, Promote Clean Indoor Air, and Mitigate Climate Change	Experimenters proposed to examine the impacts of several interventions on the adoption rates of cleaner cook stoves while concurrently measuring the impact of stove adoption on indoor and outdoor air pollution.	The precise nature of experimentation was not described.
How will cleaner cooking and lighting practices impact regional air quality and climate in the Sahel of Africa?	Experimenters proposed to evaluate the impact of different cooking technologies on behavior and emissions on a local level in the Sahel of Africa.	Experimenters describe conducting trials using random assignment of 200 households.
Information, Altruism, and Regulation: Evidence from "Spare the Air" Using a Regression Discontinuity Approach	Experimenters proposed to examine the impact of an information advisory program ('Spare the Air') on commuting behavior as a means of reducing tailpipe emission from gas powered vehicles.	The regression discontinuity approach cited by the experimenters is less ommon, but none the less, a valid experimental design.

particular programs, but it could still accurately be said . . . that 'the social sciences are the only major category of the sciences in which DOE funds'" (p. 11). Despite the DOE being included in the GAO report analyzed above, we included the DOE in our analysis in order to examine how much behavioral research is currently being funded to address climate change given their historical attention in this area.

We first searched the DOE's online footprint for publicly available archives of funded projects. Across 12 offices of the DOE, we found 3 offices who had archives of funded projects available: The office of Science, The Advanced Research Agency-Energy, and the office of Energy Efficiency and Renewable Energy. For the Office of Science, we first searched all abstracts for each of the keywords in the left column of Table 2. We took the 1628 projects that contained at least one of the keywords and curated them into a single spreadsheet. We then removed 665 duplicate projects, leaving 963 projects. We then used the same Excel formula as the one we used in the NSF project to find abstracts that contained at least one word from both columns of Table 2. The remaining 473 projects were coded according to the same criteria as the NSF project; a second trained observer coded 59% of projects and exact agreement equaled 100%. We found zero relevant projects being funded by this office of the DOE.

We next searched the Advanced Research Project Agency-Energy. The archive available did not permit us to automatically export keyword searches to Excel, therefore we copied and pasted the titles and descriptions of each project into an Excel spreadsheet. However, only a truncated description was available without clicking on a hyperlink to view the entire description. In other words, the entire description for each project was not easily copied into the Excel spreadsheet. As a result, we were unable to run the same Excel formula as in the NSF project because were concerned that relevant key words may have appeared outside the truncated description. Therefore, we coded all 1,054 available projects in the archive according to the same criterion as the NSF project. A second trained observer coded 24% of projects and overall agreement equaled 99%. We found seven relevant projects being funded by this office of the DOE.

A brief description of each project is listed in Table 5. Five of the seven projects involved using a web-based application to provide users of road vehicles the most efficient routes to their desired destinations. One project in particular showed significant promise, again using a web-based platform to transform the way consumers interact with their energy data. Researchers planned to evaluate the impact of several interventions on home energy usage. Of note, none of these projects described how said programs would be evaluated, only that expected results would demonstrate the efficacy of the program. In lieu of contacting these researchers directly to determine how they planned to demonstrate the impact of their program, we gave them the benefit of the doubt and included them as relevant projects for our purpose.

Finally, we searched the office of Energy Efficiency and Renewable Energy. There was no archive of funded research projects available as in the former two offices, but we did locate list of 14 funded initiatives. We examined these initiatives to determine if any of them involved using behavior-change strategies to reduce emissions, and only one appeared relevant to our analysis: Cities Leading Through Energy Analysis and Planning (Cities–LEAP). According to the description available on the

Table 5 Description of DOE Funded Projects that Proposed to Conduct an Evaluation of a Strategy to Reduce Emissions Using Behavior Science

Title	Description	Comments
Integration of Renewables via Demand Management	Experimenters proposed to demonstrate the impact of automated control software that helps manage real-time demand for energy by supplying personalized price signals to consumers as a means of motivating changes in consumption in response to grid conditions.	The precise nature of experimentation was not described.
Network Performance Monitoring and Distributed Simulation	Experimenters proposed to evaluate the impact of a program that supplies drivers with information and incentives to reduce energy consumption. In particular, providing drivers with cues to alter their departure times, take specific routes, or use alternate modes of transportation.	The precise nature of experimentation was not described.
Sustainable Travel Incentives with Prediction, Optimization and Personalization (TRIPOD)	Experimenters proposed to examine the impact of a program that uses a smartphone application and token reinforcement to incentivize users to adopt energy-efficient travel options based on real-time information about their travel plans	The precise nature of experimentation was not described.
The Connected Traveler: A Framework to Reduce Energy Use in Transportation	Experimenters proposed to examine the impact of a program that creates personalized energy-saving opportunities for drivers to pursue energy-efficient routes based on the traveler's preferences and personal incentives.	The precise nature of experimentation was not described.
Collaborative Optimization and Planning for Transportation Energy Reduction (COPTER)	Experimenters proposed to examine the impact of a program that sends drivers recommendations for energy-efficient trips before departure and provide real-time guidance to adjustment trips as needed.	The precise nature of experimentation was not described.
Traveler Information and Incentive Technology	Experimenters proposed to examine the impact of a program that encourages drivers to alter routes, departure time, and driving styles, or to use alternative modes of transportation or ride-sharing services.	The precise nature of experimentation was not described.

Table 5 (continued)

Title	Description	Comments
Behavioral Initiatives for Energy Efficiency	Experimenters proposed to examine the impact of several interventions (e.g., financial incentives, performance feedback) on household energy and energy efficiency.	The precise nature of experimentation was not described.

website, the Cities–LEAP project aims to provide standardized and localized energy data and analysis to cities in order to better inform policies and decision making in the area of climate and energy action. The project allows cities to develop and pilot data-informed frameworks to support climate and energy goals at the policy level, as well as measure the impacts of these decisions. Cities may be eligible to qualify for financial assistance in order to achieve the resources necessary to integrate energy data and analysis into local policies, and several cities in the United States are currently receiving funding to meet their energy and climate goals. Behavioral science could further broaden the scope of strategies used to meet climate goals locally while affecting behavior on a community level. This area of research could more thoroughly understand what incentives are feasible and effective at the policy level to affect change in local GHG-emissions. Through better understanding of the large range of interventions and policies that influence behavior change, local governments can develop individualized policies that hold value among constituents in order to achieve the goals unique to the community.

Altogether, our analysis revealed that, 0% of funding of the Office of Science is being allocated to behavioral science research. Less than 1% of funded projects through the Advanced Research Project Agency-Energy is funding such research. And just 1 of 14 initiatives funded through and Office of Energy Efficiency and Renewable Energy is focused on using behavioral science to reduce emissions. Despite having a long history of supporting social science research in energy and climate action, the DOE does not appear to be prioritizing this area of research as significantly as it used to.

The National Institutes of Health and the Centers for Disease Control and Prevention

The GAO report did not include funding by the National Institutes of Health or the Centers for Disease Control, and Prevention. We therefore investigated these possible sources of funding separately.

National Institutes of Health

We asked the Office of Disease Prevention at the NIH for help in identifying NIH research relevant to climate change and human behavior. They searched their database of NIH grants from fiscal year 2012 through fiscal year 2019 for any projects that used the Medical Subject Heading "Behavioral Sciences" and “Behavioral Disciplines and Activities.” These Medical Subject Headings were recommended to us by our contact at the NIH because of their broad scope and capacity to capture any type of research that includes human or animal behavior. They sent us the titles and abstracts of 567 projects for in depth coding. We used the same Excel formula as the NSF project to search these 567 projects for keywords found in Table 2. We found 108 projects that contained at least one word from each column of Table 2 in the title or abstract. These projects were then coded according to the same criterion

as that used for the NSF project. Relevant projects were those that contained a proposal to conduct an experimental evaluation of a strategy to reduce emissions using behavioral science. All other projects were coded as irrelevant. Coding was completed by two people (the first two authors). A second trained person coded 28% of projects and overall agreement equaled 100%.

We found zero relevant projects. One project involved the development of a curriculum that would teach elementary school K–12 students about climate change. Another involved a study of increasing community engagement about the threats of climate change, although the emphasis in that project was on prompting the community to take steps to cope with likely climate-related environmental problems rather than on how communities could reduce emissions. And the vast bulk of the projects were focused on assessing the impact of climate change on a wide variety of health conditions or risk factors for health conditions, such as algae blooms, chemical contamination, and extreme heat.

Centers for Disease Control and Prevention

The mission of CDC involves their working with the network of state and local governments to prevent injury and disease. It is thus in a position to influence the public health community to increase its involvement not just in preventing ill health due to climate change, but in increasing efforts to reduce the emissions that are causing climate change. The CDC has a Climate and Health Program where we hoped to find evidence of such efforts.

According to the CDC website (https://www.cdc.gov/climateandhealth), the program "works to prevent and adapt to the possible health effects of climate change." The mission of the program is as follows: (1) Lead efforts to identify populations vulnerable to climate change; (2) prevent and adapt to current and anticipated health impacts; and (3) ensure that systems are in place to detect and respond to current and emerging health threats.

The program has four stated objectives: (1) "Serve as a resource for federal, state, local and tribal health agencies on climate change and health"; (2) "Prepare public health practitioners to address the health effects of climate change"; (3) "Provide tools, guides and processes that help assess vulnerability to possible health effects of climate change"; and (4) "Serve as a reliable leader in planning for the public health effects of climate change."

The description of this CDC program enumerates specific actions they have undertaken. They include (1) working to help states and cities address "the challenges associated with climate change"; (2) creating a framework for increasing resilience against climate change effects; (3) conducting research and development to understand the relationship between climate change and health; (4) training in the use of the health impact assessment CDC has developed; and (5) adding data on heat to the National Environmental Public Health Tracking Network.

After looking closely at their website for funding priorities, an archive of funded projects, or funded initiatives to tackle climate change, we could not find any

evidence that the CDC is supporting research or practical steps that might reduce greenhouse-gas emissions.

Discussion

Although there are limitations to our analysis, it revealed a surprising lack of research on how to affect the behaviors and organizational practices that are the cause of accelerating climate change. The GAO analysis of federal funding for climate change research indicates that none of the federal agencies they audited are funding research to test strategies for getting people, organizations, or communities to reduce their GHG emissions. As of 2017, the 18 federal programs the GAO reviewed were funding more than USD $12 billion annually on research on climate change. The main way in which funding has increased over the past 20 years is in the funding of technology (it accounted for about $9 billion of expended funds in 2017). There are projects to predict long-term changes in climate and projects to better understand and model how aerosols, clouds, and precipitation are interrelated in order to better predict climate changes. Projects are improving satellite technologies to measure changes in ice sheets, carbon dioxide, and solar radiation. There are projects to develop technologies to "avoid, reduce, or capture and store greenhouse gas emissions." Yet we could find no projects focused on efforts to affect the human behaviors and organizational practices involved in the emissions that are causing and indeed continuing to accelerate global warming and climate change.

The NSF portfolio is impressive in its extent, its complexity, and its efforts to build both diversity and collaboration in the scientific community. Our analysis of NSF projects identified numerous projects relevant to climate change. There are numerous projects studying the interrelations among of food, energy, and water systems. Studies are being funded to improve the measurement and prediction of climate change, sea level rise, emission rates, soil salinity and carbon emissions, and phosphorus use. There are studies of waste-water treatment, including studies of technologies for "improving communication of urine-derived fertilizers for food production." There are also numerous projects designed to involve undergraduates in STEM research. However, despite the fact that greenhouse-gas emissions are causing climate change and the fact that it is imperative that every American community reduce its emissions, there are few NSF funded projects experimentally evaluating strategies for getting people, organizations, or communities to modify their emissions-producing behavior or practices.

The EPA is funding a number of promising areas that will surely pay dividends in years to come. Some of the most impressive lines of research entailed retrospective correlational analyses of policy mechanisms and their relationship to emissions. Much of this work involved understanding the factors that contributed to compliance with policy mechanisms or that were underlying the success (or failure) of a policy to produce the desired outcome. It is interesting that many of the factors evaluated in these analyses were malleable as dependent variables. And therefore, could be subjected to experimental manipulations. For example, one project planned to determine if community or political pressure influenced compliance with environmental

regulations in paper mills, steel mills, and electric utilities. If results showed that community support for regulation influenced the corporation's tendency to comply, then behavioral strategies to influence community support could be experimentally evaluated to determine the best way to induce corporations to comply with regulations. However, we found little evidence that this type of experimentation is being funded by the EPA.

Likewise, the DOE is funding an enormous amount of thrilling research in the areas of energy generation, efficiency, storage, building efficiency, and transportation. Some of the most impressive research involved the creation of new and better batteries to power road and commercial vehicles. In addition, a large body of research has been dedicated to retrofitting buildings to make them more energy efficient including occupancy-sensing technology to automate heating and cooling. But little of their entire budget is dedicated to modifying human behavior in the name of emission reductions. This is somewhat surprising considering the history that the DOE brings to bear on this pressing issue. They were one of the early government agencies to begin working in this area with a significant emphasis on the social sciences.

Our analysis of the NIH research portfolio relevant to climate change indicated that it is funding research to better understand how climate change is affecting health and how communities can take steps to reduce the impact of climate change on health. However, there are no programs focused on getting people or communities to change policies and behaviors that would reduce emissions. Some might argue that it is not the job of NIH to study how to change emission-relevant behavior. However, public health research on prevention has always identified the most important risk factors for disease and targeted the reduction of those risk factors for intervention (National Research Council, 2009). For example, the discovery that smoking caused cancer led to funding for research on influencing smokers to quit and preventing youth from starting to smoke. Evidence that cigarette marketing (a distal risk factor) influenced youth to smoke made the reduction of advertising a target for change (Prevention CfDCa, 2000). In the same way, NIH research is documenting the extensive impact of climate change (a distal risk factor) on human health. But in light of recent data that shows the mortality rate and economic impact of climate change has been significantly underestimated (National Bureau of Economic Research, 2020), it is imperative for NIH to fund research on how to reduce the chief risk factor for climate change. Namely human behavior that leads to greater levels of greenhouse-gas emissions.

Likewise, although the CDC is doing important work on how the health of Americans can be protected from climate change, it is not working on how American communities can be influenced to reduce their emissions. The CDC has been the leading government agency working to reduce tobacco use throughout the nation because of the impact of tobacco use on health. In a similar way, given growing evidence of the impact of climate change on health (a 2020 report from the National Bureau of Economic Research showed that come 2100, climate change will be associated with mortality rates comparable to the leading causes of death today), the CDC should be mobilizing the public health sector to prevent climate change from endangering lives, and to reduce emissions. If we fail

to do this, communities will be increasingly unable to prevent harm from climate change because continued emissions guarantee that those harms will intensify.

In light of the conclusions above, some limitations of our approach should be addressed. First, Tables 3–5 included a description of lingering questions and concerns regarding each relevant project uncovered in our analysis. Many of these concerns could have been alleviated, we think, by reading the full proposals. However, we did not solicit full proposals from the experimenters. Doing so would have gone beyond the scope of the current project. Our goal was not to judge the quality of proposed research in terms of the types of experimental designs, measurement procedures, and intervention strategies. Instead, our goal was to determine the extent to which behavioral strategies to reduce emissions were being employed and evaluated. For this purpose, abstract descriptions were sufficient.

Second, the Excel formula we used to search funded projects for keywords was designed to trigger a hit for each column of Table 2 when a keyword was detected in the title or the abstract of a funded project. (If a hit was detected for each column, the project was pulled for full coding.) Unfortunately, words that contained our search words also triggered a hit according to the Excel formula. For example, "trial" was a search word used to capture projects that described experimental evaluations. However, titles or abstracts that contained the word, "industrial," or "terrestrial," for example, also triggered a hit for the right column of Table 2. As a result, we may have inadvertently pulled (and subsequently coded) more abstracts than we needed to.

Third, our focus on carbon emissions was designed to broadly capture any evaluation that modified some type of climate-relevant behavior. But it is possible that despite casting such a wide net, we may have still excluded some research that modified emissions-relevant behavior. For example, it is possible that the NIH is funding research that focuses on persuading people to make the transition to a whole-food plant-based diet (it is, after all, the only diet proven to reverse heart disease; Campbell, 2017; Esselstyn, 2001, 2017; Greger, 2015; Ornish et al., 1998), which would have a direct impact on carbon emissions. But such research would not have been captured in our search unless the experimenters talked about emissions as a secondary byproduct of the evaluation.

Fourth, and relatedly, our analysis failed to analyze funding for research on getting strategies for the sequestration of carbon widely adopted. This too is an area in need of more funding. For example, changes in agriculture production have the potential to sequester carbon. Development and evaluation of strategies for increasing relevant practices could greatly accelerate their use.

Finally, our results suggest that the federal agencies we analyzed are not funding behavioral science research to reduce emissions. However, we did not attempt to quantify the extent to which proposals for behavioral research were being rejected by these agencies. In other words, it is unclear from our analysis if these federal agencies are actively rejecting proposals to use behavioral science to reduce emissions or if little behavioral research is being proposed. Without knowing where in the funding pipeline the break down is occurring, the most prudent course to remedy the problem lies at the feet of federal agencies *and* behavioral scientists alike.

The Urgent Need for Experimental Research

The most concerning problem with the state of research on reducing greenhouse-gas emissions is the lack of experimental evaluations of strategies for affecting emissions. The present analysis of federal funding coupled with our recent review of community intervention research on climate change (Biglan et al., 2020) are consistent in showing that little is being done to experimentally test strategies for affecting emissions on large scales.

Our conclusion is bolstered by Wolske and Stern's (2018) review of household actions that have the potential to reduce emissions. They cite numerous studies of correlates of such actions, but few experimental evaluations of strategies for affecting these actions. Identifying correlates of these behaviors provides a useful foundation for developing and testing large-scale behavior-change strategies, especially if the correlates are malleable. However, while it may be the case that people's beliefs and attitudes about climate change predict behaviors that reduce emissions, the relationship between attitudes and behavior is not sufficiently strong that we can have confidence in the efficacy of an intervention that only affects attitudes and intentions (Nielsen et al., 2021); we need interventions that are demonstrated to change actual human behavior. A study that shows a correlation between attitudes and behaviors is remote from what is needed. Moreover, there is no guarantee that we can change the attitude, let alone that changing the attitude will result in behavior change.

The limited funding for experimental evaluations of strategies for reducing emissions leads us to believe that decision makers are unaware of the power of behavioral science. It also leads us to believe that behavioral scientists have not advocated strongly enough for support of their work. Where experimental methods have been used to test strategies for affecting behavior, enormous progress has been made.

Over the past 40 years, such research has produced effective strategies for treating or preventing most of the psychological and behavioral problems that undermine human well-being (Bandelow et al., 2015; Biglan, 2015; Carr, 2019; Cuijpers et al., 2008; Jacob et al., 2018; Magill et al., 2019; Pfammatter et al., 2006; National Academy of Sciences, Engineering, Medicine, 2019; Suls et al., 2012; Van Ryzin et al., 2015). Moreover, there are excellent examples of the value of experimental analyses of strategies for affecting climate-relevant behavior that come from the field of behavior analysis (Gelino et al., 2021). Experiments show that information, prompting, goal setting, feedback, incentives, and fines (or some combination) can reduce consumption of electricity (Hayes & Cone, 1981), gasoline (Foxx & Hake, 1977), water (Aitken et al., 1994), and meat (Brunner et al., 2018) and can reduce the volume of trash production (Austin et al., 1993). And with respect to the reduction in electricity use, these strategies have been scaled by numerous electric utilities, producing substantial reductions in use (Ayres et al., 2012). It is unfortunate that much of that work was done several decades ago. It dwindled in recent years possibly because there was no funding for research that would have enabled scaling up of these strategies to affect

entire populations. And little attention has been dedicated to embedding these interventions as components in large-scale multisector community interventions (e.g., Biglan et al., 2000; Bonner & Biglan, 2021), possibly because funding has not been sufficiently arranged to support such broad-scale interventions.

Examples of Needed Experimental Work

Assessing the Impact on Emissions

Every study needs to measure the impact on actual emissions or behaviors whose relationship to emissions is well-established. Studies showing how to affect knowledge and attitudes could be useful, but only if changes in these cognitive processes are accompanied by evidence of corresponding changes in emissions or the behaviors that are known to produce emissions (Nielsen et al., 2020).

One large category of behaviors to target comes from the article by Wolske and Stern (2018). They enumerate numerous household actions that can reduce emissions and rank them in terms of the degree to which an action will reduce emissions. They point out that some of the most commonly researched actions, such as reducing electricity consumption, have a relatively small impact on emissions. Actions with greater impact, such as weatherizing a home, purchasing a fuel-efficient vehicle, or entire communities making the transition to plant-rich diets have been less studied. Increased investment in research on influencing these actions—with the greatest investment in the most effective areas—could greatly accelerate progress in reducing emissions, especially if the research portfolio includes studies on scaling up effective interventions.

Technology Adoption

Experimental work is also relevant to technology adoption. Our review of the GAO report shows that the United States is betting heavily that we can reduce emissions through technological innovations. It is true that there are numerous projects testing technologies that could reduce emissions or sequester carbon. These projects have great potential. Yet even in the case of technological solutions, there are numerous obstacles to their adoption and dissemination that involve human behavior. Research is needed to evaluate different strategies for getting technologies adopted. Examples of such strategies would include strategies for getting communities to accept wind turbines or other new technologies and interventions to assure that technologies are adopted by households or organizations. But even if we do identify the most effective ways to import technological innovations at the community level, this only addresses half the puzzle. Experts are increasingly agreeing that technological innovation is not a silver bullet to solve the climate crisis (Faber et al., 2012; Harrabin, 2020). Getting down to brass tacks necessarily requires modifying the human behavior of which GHG emissions are a function. A goal that can only be achieved through appropriate funding of behavioral science research in this area.

Assessing the Impact on Policy Adoption and Implementation

Change will require the adoption of numerous policies that require every corporation and every community to monitor its emissions and take steps to reduce them. That, in turn, will require persuading millions of people to support such policies. This is a matter of social influence, a topic that behavioral scientists know a lot about (Cialdini & Goldstein, 2004; McKenzie-Mohr, 2000). We need to develop effective media campaigns to gain public support. We can build these campaigns using much of the evidence that organizations like the Yale Program on Climate Change Communication have already accrued. However, we can steadily improve our ability to persuade people to support these policies if we routinely evaluate the impact of campaigns using well-accepted experimental methods (Flay et al., 2005).

Once policies are adopted, they need to be implemented. But often they are met with resistance. Research is needed not only on which policies are acceptable, but on how we ensure that, when a policy is adopted, people adhere to it. Here too, experimental comparisons of different policies and different ways of promoting adherence to them, will make us increasingly successful (McConnell, 2021).

Scaling Up

Where there is experimental evidence of an intervention that effects emissions (see Gelino et al., 2021, for many examples), the critical question is whether we can scale the intervention to reach millions of people and if so, whether the intervention will produce outcomes as robust as the initial evaluation indicated. The quintessential example of how this process may unfold comes from research on home energy consumption. Early work by Hayes and Cone (1981) and others demonstrated that home energy consumption could be curtailed when subjects were provided with feedback on their energy usage. Much of this early work was conducted with small samples of community members. When these strategies were scaled up (via utility providers) to include hundreds of thousands of people (e.g., Allcott, 2011; Ayres et al., 2012), reductions in energy consumption were observed. In the last decade, similar programs have been rolled out nationwide to provide households with knowledge and information about their energy consumption in the name of energy conservation. However, similar examples of intervention scaling pertaining to other emissions-relevant behavior are difficult to find.

Large-scale research is needed to experimentally evaluate strategies for scaling up interventions in this way. Recent work in prevention science on dissemination and implementation provides a model for what needs to be done (Brown et al., 2017). And the extant literature on small scale interventions to reduce emissions is ripe for the picking. For example, some work has been done to try and nudge consumers toward plant-rich diets. According to Hawken (2017), making the transition to a plant-rich diet is one of the most significant things any one person can do to help the environment (let alone entire communities). Plant-rich diets currently rank number 3 (out of 100) on Project Drawdown's list of most effective strategies to reach

net-zero emissions. Small-scale evidence (e.g., Brunner et al., 2018) has shown that providing restaurant patrons with information on the carbon footprints associated with menu items leads to a reduction in sales of carbon-heavy dishes and increases in sales carbon-light dishes. Moreover, a growing body of research is being dedicated to the experimental study of such interventions in the area of diet change (see Harguess et al., 2020 for a recent meta-analysis). What's needed next, are efforts to scale the most effective strategies to the community level. One way to do this would be by imbedding them in multisectoral community interventions (Bonner & Biglan, 2021).

Developing and Testing Comprehensive Community Interventions

Given that every community needs to reduce its emissions, there is a dire need for large-scale experimental evaluations of comprehensive interventions to reduce emissions. In a systematic review of the literature on climate change research in communities, we were unable to find any such studies targeting the highest impact areas for reductions (Biglan et al., 2020). This is despite the fact that hundreds of communities are attempting to reduce their emissions (e.g., Broto & Bulkeley, 2013). Comprehensive community interventions have been developed and validated for other problems such as adolescent substance use (Biglan et al., 2000; Oesterle et al., 2018; Spoth et al., 2007). A recent article from Bonner and Biglan (2021) described how they might be conducted in the context of GHG emissions. We believe that comprehensive community interventions are particularly well-suited because they have the potential to produce synergistic effects due to multiple sectors of the community taking actions that promote action in other sectors.

Engaging the Behavioral Science Community

We hope that we have convinced you that behavioral science research that can contribute to reducing greenhouse-gas emissions is lacking. As noted above, this is not due to the failure of behavioral science research to show that it can affect climate-relevant behavior. It is due to the lack of funding for further research and the potential reluctance of behavioral scientists to advocate for such funding.

The Coalition of Behavioral Science Organizations Climate Change Task Force has established links to thousands of behavioral scientists. There is enormous motivation to help address this problem. The skills and motivations of this community can only be put to use if there is a sizable increase in federal funding for experimental research on reducing emissions. However, the behavioral science community should not wait for policymakers to decide to fund such work. It is as much the responsibility of the behavioral science community to educate policymakers and the leadership of federal agencies on the ways in which experimental research can accelerate progress on this critical problem.

Declarations

Conflicts of interests/competing interests On behalf of all authors, the corresponding author states that there is no conflict of interest.

Availability of data and material All coding and associated materials are available at https://osf.io/5kjyx/

Code availability Not applicable

Ethics approval Not applicable

Consent to participate Not applicable

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