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RESEARCH ARTICLE

Environmental Risk (and Benefit) Information Seeking Intentions: The Case of Carbon Capture and Storage in Southeast Texas

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ABSTRACT
Americans remain relatively unaware of the risks and benefits associated with carbon capture and storage (CCS) technology, including its role in combating CO_2 emissions as a means to address climate change. Our goal is to determine factors that might help build awareness and knowledge of CCS so that citizens can make informed decisions about it. Specifically, we focus on perceived risks, benefits and emotions associated with CCS and intentions to seek information about it. We surveyed 970 adults from a region of Texas that has seen recent growth in the application of CCS technology. Consistent with prior research, most respondents were not aware of CCS or the risks and benefits associated with it. To explore CCS-related information -seeking intent, we sought guidance from the planned risk information -seeking model, which identifies factors that contribute to intentions to seek information about risk-related topics. The majority of the hypothesized relationships were supported, and the model accounted for 48% of the variance in intent to seek information about CCS risks and benefits. Furthermore, perceived benefits and hope played significant roles in explaining information-seeking intent. Implications for better engaging the public with the topic of CCS are discussed.

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Carbon capture and storage (CCS); information seeking; environmental risks

1. Introduction

In the quest to address climate change, carbon capture and storage (CCS) has surfaced as a viable technology for capturing up to 90% of carbon dioxide (CO_2) emitted from power plants and industrial sources. The technology is designed to capture the CO_2 emitted from burning fossil fuels – mainly coal, petroleum and natural gas, which are the primary greenhouse gases contributing to global climate change – and store it deep underground in porous rock where it cannot enter the atmosphere (Bayar, 2015; Figueroa, Fout, Plasynski, McIlvried, & Srivastava, 2008; Leung, Caramanna, & Maroto-Valer, 2014; Parson & Keith, 1998). According to U.S. Congressional reports, since 2010, Congress has provided more than $5 billion in appropriations for the Department of Energy to fund CCS-related activities (Folger, 2018). However, this technology is still nascent, which means that it also provides a unique and novel context for studying public risk perception and information seeking intentions related to emerging climate change solutions more generally, and CCS specifically.

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When it comes to new technologies, public awareness often lags behind development, such that even in communities where a technology is evolving in situ, community members may know little about of the technology and its risks and benefits (McComas, Besley, & Yang, 2008). CCS is one such technology; despite strides made to bring the technology to fruition, a myriad of studies suggest that the public remains relatively unaware that the technology exists. For example, public awareness of CCS is estimated to be about 10% in the U.S. and around 28% in Europe (Reiner et al., 2006; Seigo, Arvai, Dohle, & Siegrist, 2014; Xenias & Whitmarsh, 2018). Low public awareness is not necessarily a problem while new technology is being developed, but once it reaches the implementation stage, the public becomes an important stakeholder and public opinion can hold sway in the funding, policy and location decisions that can impact the scalability of the technology.

Studies have shown that public perceptions of the risks and benefits of CCS in particular have an impact on support for CCS technology (Boyd, Hmielowski, & David, 2017; Huijts, Midden, & Meijnders, 2007; Tokushige, Akimoto, & Tomoda, 2007; Wallquist, Visschers, & Siegrist, 2010; Wallquist, Visschers, Dohle, & Siegrist, 2012). In general, benefit perceptions about CCS – such as climate change mitigation – are positively linked to greater support for CCS, while risk perceptions about CCS – such as CO_2 leakage, blowouts and earthquakes – are negatively linked to support for CCS (Boyd et al., 2017; Seigo et al., 2014). Moreover, other variables such as perceptions of climate change have surfaced as influential on public perceptions of CCS (Boyd et al., 2017). For instance, Boyd et al. (2017) found that participants who view humans as responsible for climate change are more likely to support CCS projects. Therefore scientists, agencies and organizations seeking to develop and implement new technologies such as CCS need to have a solid understanding of what is likely to drive information seeking down the road when citizens are asked to weigh in on relevant policy decisions and – ultimately – whether they will welcome the technology into their community.

The United States is the second highest emitter of greenhouse gases, second to China; within the U.S., the state of Texas is the biggest emitter of CO_2 (Energy Information Administration, 2018). Current efforts to develop CCS technology are focused on coastal Texas, where large amounts of CO_2 can be captured from power plants and refineries and stored nearby. One promising storage option is deep under the seafloor (House, Schrag, Harvey, & Lackner, 2006). This option is promising for two reasons: 1) the geology of the area is well documented as a result of a century of oil and gas exploration, and 2) the subsurface offshore of south Texas shows characteristics that are ideal for the storage of CO_2, including abundant storage potential and good sealing potential to prevent leakage. Therefore, the Texas General Land Office has invested in research on the CO_2 storage potential of the Texas offshore State lands, which extend from the coastline to 16.2 km offshore, and the U.S. Department of Energy National Energy Technology Laboratory has funded two projects over seven years to characterize the storage potential of the area. Most recently, in April 2017, NRG Energy opened its Petra Nova project near Houston, the world's largest post-combustion carbon capture system to combat CO_2 emission (Duffy, 2018). In addition to the U.S., CCS technology also has been successfully deployed in other countries including Norway and Canada (Boyd et al., 2017).

The increasing application of CCS technology in Texas, coupled with the state's identity as an energy powerhouse in the nation, make the state an ideal context for studying emerging CCS awareness, risk and benefit perceptions, and information seeking intent related to CCS. Our current study explores risk and benefit perceptions, related emotions, and information seeking intent related to CCS in a southeast region of Texas that has seen growth in the application of CCS technology. Our goal is to isolate factors that contribute to intentions to seek information about this emerging technology, including the specific role that perceived benefits, risks and emotions play in those intentions. A better understanding of the drivers of information seeking intentions related to CCS can offer policy makers and stakeholders a clearer path forward for sharing information with the public as it becomes available, and in a way that is relevant and speaks to what matters to the community.

2. Background

2.1. Risk information seeking

Given the role of perceived risks and benefits in shaping public perceptions of and support for CCS, we next turn to the research on risk-related information behaviors. The study of risk information seeking is focused on factors that make individuals more or less likely to actively seek information about a given risk. Here, we define risk as "things, forces, or circumstances that pose danger to people or to what they value" (Stern & Fineberg, 1996, p. 215). Although we are interested in risk and benefit perceptions, the bulk of the research to date has focused on risk perceptions, thus we first summarize that body of work. As Kahlor (2007) suggests, in the case of emerging technologies, it is crucial to understand the ways people seek risk information because the "information seeking strategies people apply … make a difference in what they take away from messages and how they use messages in the long run, including whether messages impact risk-related behaviors" (p. 414).

Information seeking behaviors – particularly in the context of risk – have garnered a great deal of attention in the last 20 years within the fields of mass, interpersonal and organizational communication, and information science (c.f., Afifi & Weiner, 2004; Griffin, Dunwoody, & Neuwirth, 1999; Johnson, Donohue, Atkin, & Johnson, 1995; Kahlor, 2007, 2010; Leckie, Pettigrew, & Sylvain, 1996; Mai, 2016; Wilson, 1999). This literature has produced several theoretical models that map individual and social cognitive motivators of risk information seeking. The characterization of risk information seeking is consistent across these models. It is motivated by a) an unmet need for more information or knowledge, b) perceived self-efficacy related to information seeking, c) risk perceptions and related emotional responses, and d) perceived social pressure to seek information. The models tend to define risk perception in terms of the perceived likelihood and potential severity of a given risk event (Kasperson et al., 1988; Slovic, 1987; Yang, Aloe, & Feeley, 2014). Risk perceptions are often strongly correlated with emotional responses to risk and the most common relationship is between risk perception and negative emotions such as worry (Yang et al., 2014). These risk information-seeking models have been applied across various contexts.

Specifically within mass communication research, the planned risk information seeking model (PRISM; Kahlor, 2010) has emerged as an appropriate framework for studying risk information seeking intent within the context of energy-related and environmental risks. Support for the model (or the relationships therein) has been robust across contexts including hydraulic fracturing (Eastin, Kahlor, Liang, & Abi Ghannam, 2015), earthquakes (Kahlor, Wang, Olson, Li, & Markman, 2019; Li et al., 2017), nuclear energy (Zeng, Wei, Zhao, Zhu, & Gu, 2017) and climate change (Ho, Detenber, Rosenthal, & Lee, 2014). As such, the model offers a viable starting point for understanding risk information seeking intent in the context of CCS.

2.2. The planned risk information seeking model

PRISM emphasizes the deliberate nature of information seeking and draws heavily from the theory of planned behavior (Ajzen, 1991) and the risk information seeking and processing (RISP) model (Griffin et al., 1999). The theory of planned behavior holds that human action is guided primarily by three factors. These are: (1) favorable/ unfavorable evaluations of the behavior, also referred to as attitude toward the behavior; (2) perceived social pressure to perform or not perform the behavior, also known as subjective norms; and (3) perceived ability to perform the behavior, also known as perceived behavioral control (Ajzen, 1991, 2012). These factors contribute to the generation of behavioral intention, which is a direct antecedent to actual behavior. The RISP model generally supports the inclusion of these theory of planned behavior concepts, alongside two risk related variables – risk perception and affective response to risk – and a variable they label information sufficiency (Griffin et al., 1999). Information sufficiency refers to the *gap* that exists (or doesn't exist) between the knowledge one has and the knowledge one desires (Griffin et al., 1999). The concept is based on the sufficiency principle (Eagly & Chaiken, 1993), which posits that "perceivers who are motivated to determine accurate judgments will exert as much cognitive effort as is necessary (and possible) to reach a sufficient degree of confidence that their judgments will satisfy their accuracy goals" (Chen & Chaiken, 1999, p. 74).

PRISM adopts the original RISP model variables, tailors them more closely to the three theory of planned behavior concepts of attitudes, norms and control, re-labels the aforementioned gap, information sufficiency, as perceived knowledge insufficiency, and allows for more paths of influence across the model variables. However, in this effort, while we abide by the theoretical principle of perceived knowledge insufficiency, consistent with earlier PRISM work, we label the constructs within the model (see Figure 1) "perceived knowledge" and "perceived knowledge sufficiency threshold," and their juxtaposition in the model captures the gap between the two, or the perceived knowledge "insufficiency." The PRISM has been tested within the contexts of both personal and impersonal risks. Personal risks are risks that pose a direct threat to the individual, while impersonal risk are risks that are more likely to directly threaten something other than the self, such as the environment (Kahlor, Dunwoody, Griffin, & Neuwirth, 2006). The model was tested in the personal risk contexts of sexual health and cancer risk (Ahn & Kahlor, 2019; Hovick, Kahlor, & Liang, 2014; Willoughby & Myrick, 2016) and the impersonal risk contexts of energy and environmental risk (Eastin et al., 2015; Ho et al., 2014), and in both types of contexts it performed well and accounted for a considerable proportion of the variance in information seeking intent (R^2s ranged from .34 to .64).

Our current project tests the fit of PRISM to the context of CCS. While previous studies using PRISM have focused primarily on perceptions of risk, we propose that perceptions of benefits (resulting from CCS) may also play a significant role in explaining risk information seeking behavior, considering that the oil industry is an economic driver in Texas and that the technology is being developed as a solution to climate change – thus it carries with it a promise of positive resolutions and hope. Recent research (Chadwick, 2015) has begun to explore the role of hope in information behaviors and shows that hope increases interest in messages related to climate protection. Chadwick

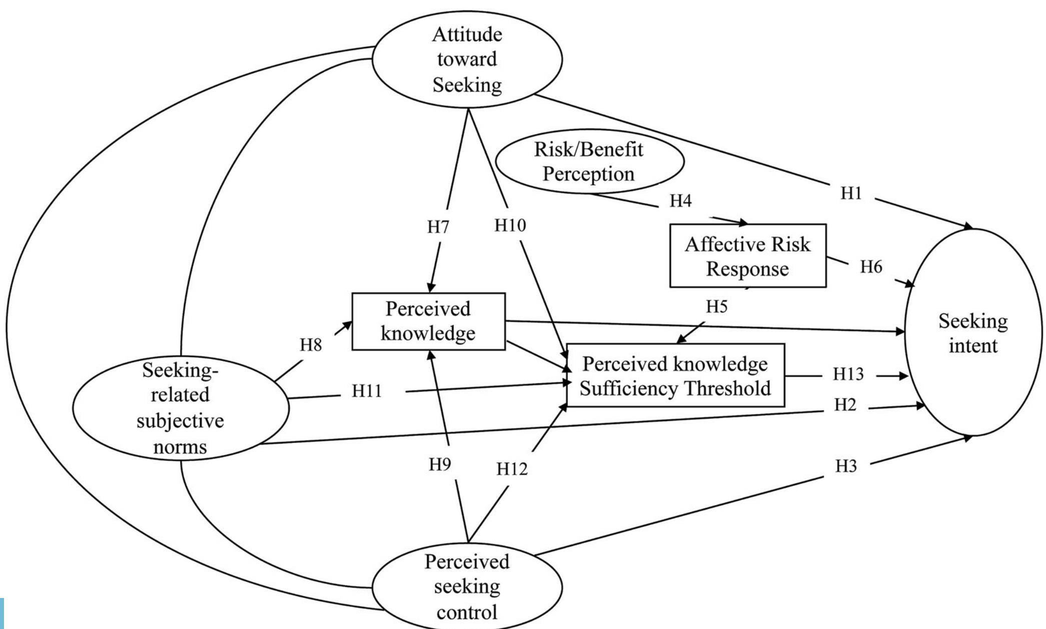

Figure 1. The planned risk information seeking model and accompanying hypotheses.

(2015) suggests that, "the increase in interest caused by hope may facilitate the sustained attention and effort necessary to address complex problems such as climate change" (p. 608).

Yang and Kahlor (2013) also examine the role of positive affect, in addition to negative affect, on information seeking and avoidance in the context of climate change; their results indicated that while negative affect heavily influenced information seeking, information avoidance was driven by positive affect. This result is consistent with the literature on information avoidance to sustain hope by avoiding potentially negative information (Case, Andrews, Johnson, & Allard, 2005). In our current study, we also attempt to divide our attention equally between positive and negative emotions to provide a fuller understanding of the role of emotion in risk information seeking, because CCS technology clearly involves both risks and benefits. The next section spells out important variables and relationships in PRISM in more detail.

2.3. PRISM concepts and related hypotheses

The key dependent variable in PRISM is risk information seeking intent, which is the intent to engage in the purposeful gathering of information about a risk of perceived relevance to the seeker. Much of the early work related to behavioral intent and behaviors has shown that intent, in general, accurately predicts actual behavior (Ajzen, 1991) "when behaviors pose no serious problems of control" (p. 186). As such, PRISM treats seeking intent as a key outcome variable that can be captured in cross-sectional data and used as a proxy for subsequent information seeking, which is appropriate given CCS is a novel topic with low public awareness and this study provides a much-needed baseline for information seeking motivations in this context.

As indicated above, the independent variables in the model are iterations of the three core variables in the theory of planned behavior (Ajzen, 1991) – attitudes toward seeking, seeking-related subjective norms, and perceived seeking control– as well as affective responses to the risk (which is itself predicted by risk perceptions) and perceived knowledge sufficiency threshold. The conceptual justification for these variables in the model is detailed below and the corresponding hypotheses are noted in Figure 1. Note that some relationships are mentioned more than once, to give a sense of how the variables work together in the model as exogenous and endogenous variables.

Our working definitions of the theory of planned behavior concepts are as follows: (1) attitude toward seeking is the extent to which a person holds a positive or negative evaluation of risk information seeking, (2) seeking-related subjective norms are perceived social pressure from important others who think the individual should or should not seek risk information; and (3) perceived seeking control is perceptions related to whether one can access the given information and whether one can process the information if he/she finds it. All of these are posed as positive predictors of information seeking intent.

The risk-specific variables in the PRISM are also found in RISP and Slovic's (1987) work related to affect and risk perception. Similar to this prior work, risk perceptions are conceived of as perceived likelihood that the risk will occur, and the perceived severity or magnitude of the risk (Brewer et al., 2007). Studies have generally supported that these two dimensions are positively correlated with affective responses to risk, such that stronger risk perceptions lead to stronger affective responses. In PRISM, affective risk response is predicted by risk perception and directly impacts perceived knowledge sufficiency threshold (consistent with Griffin et al., 1999) and information seeking intent (consistent with Afifi & Weiner, 2004; Witte, 1998). To date, the most studied affective response in the risk information seeking literature is worry (Yang et al., 2014).

As noted earlier, information seeking is a planned, purposive knowledge acquisition process and it is, in part, driven by a perceived need for more information (e.g. Griffin et al., 1999; Johnson et al., 1995; Marchionini, 1997). This need, previously labeled in PRISM as perceived knowledge insufficiency, is here depicted with a unidirectional arrow leading from perceived knowledge to perceived knowledge sufficiency threshold. According to the health information acquisition model (Freimuth, Stein, & Kean, 1989), perceived current knowledge is, in part, determined by one's attitudes toward seeking, seeking-related subjective norms and perceived seeking control (further explained in Kahlor, 2010). In PRISM, several factors contribute to perceived knowledge insufficiency in addition to perceived knowledge: seeking-related subjective norms (consistent with Griffin et al., 1999), attitude toward seeking and perceived seeking control (consistent with Witte, 1998), and affective response to risk (consistent with Griffin et al., 1999). And, as the RISP and PRISM models further suggest, perceived knowledge sufficiency threshold contributes directly to information-seeking intent (Ho, Liao, & Rosenthal, 2015; Hovick et al., 2014; Kahlor, 2010).

Figure 1 illustrates the hypotheses that have been tested in prior PRISM studies (c.f., Eastin et al., 2015; Ho et al., 2014; Hovick et al., 2014; Kahlor, 2010; Kahlor et al., 2019; Kahlor, Yang, & Liang, 2018; Willoughby & Myrick, 2016), and are again expected to be supported in our current study:

Although prior PRISM research has focused primarily on risk perceptions and negative affective responses, in this study we also acknowledge that CCS is framed as a mitigation strategy for climate change and thus will likely be perceived as carrying benefits. Further, the importance of the oil and natural gas industry in Texas suggests that Texans may be likely to perceive benefits (e.g. a potential increase in employment opportunity) attached to the deployment of CCS in Texas. Therefore, we sought to explore whether benefit perceptions can be accommodated within PRISM, as well as the positive emotions that may be linked to benefit perceptions. To our knowledge there is very little research out there exploring the role of benefit perceptions in risk information seeking (Bessette, Zwickle, & Wilson, 2019).

Decision-making researcher have long been interested in the motivational value of positive assessments, attractiveness, and perceived success, utility and value – and tend to consider such variables alongside concepts consistent with risk perception (Maiman & Becker, 1974). However, in the risk perception literature, which gives ample nods to benefits perceptions, the time spent defining the concept of benefit is minimal (see, for example, Siegrist, Cvetkovich, & Roth, 2000). However, at least one study has attempted to explore benefit perceptions in detail. In a qualitative study of public attitudes of technology (the front-end of a scale development study), Frewer, Howard, and Shepherd (1998) elicited terms to describe the benefits of technology. Respondents used terms such as "necessary, beneficial, long-term, good, safe, trust, controllable and interesting" (p. 225).

Benefits also have been explored in the context of health communication and behavior research – indeed perceived benefits are central to the health belief model (Janz & Becker, 1984) – but the concept of perceived benefits lacks conceptualization there as well. Albeit brief, we did find one definition in the literature: In the context of the perceived benefits and barriers of engaging in physical activity, researchers defined perceived benefits as "an individual's evaluation of the potential gains" from engaging in the behavior (Brown, 2005, p. 107).

Despite the lack of explication, in the fields of health research and a social work research, benefit perceptions have been explored amply, often in relation to adverse life events, within the context of a phenomena known as adversarial growth or benefit-finding. In these contexts, people make sense of negative events through personal growth or finding an "upside" after the negative event has occurred (Cassidy & Doyle, 2018; McMillen & Fisher, 1998). But again, the concept of perceived benefits remains undefined for the most part. Benefit-finding is, however, defined, "as consisting of a number of dimensions including greater acceptance of one's life situation, a strengthening of family bonds experience of growing psychologically as a person, affirmation of relationships, a sense of greater empathy with others, and a reappraisal of one's life and reprioritization of goals" (Cassidy & Doyle, 2018, p. 8). Thus, the study of benefits alongside risks or barriers is consistent across the literature.

Indeed, research suggests that people often do not analyze risks separately from benefits when making their judgments about a perceived risk (Alhakami & Slovic, 1994; Saba & Messina, 2003; Siegrist et al., 2000) or when considering the acceptability of a new technology (Bearth & Siegrist, 2016; Covello, 1983). Furthermore, these risk-benefit judgments are likely further intermingled in terms of the affective response that they co-generate. As Finucane, Alhakami, Slovic, and Johnson (2000) explain, "it is plausible that perceived risk and benefit are linked via some sort of affective commonality … a parsimonious explanation is that the positive and negative feelings attached to the images people associate with hazards are available and influential when risk and benefit are judged" (14). It is this perspective that drove our investigation and we explored these relationships as research questions:

RQ1: What contribution does perceived benefits make to the overall PRISM model?

RQ2: What contribution does positive emotions, in this case hope, make to the overall PRISM model?

3. Methods

3.1. Sampling

We sampled the southeast region of Texas that has seen (and likely will continue to see) the most growth in the U.S. in the application of CCS technology (EIA, 2017). The region included eight Texas counties: Brazoria, Chambers, Liberty, Galveston, Jefferson, Orange, Fort Bend and Harris. The Harris County sample came from GfK's KnowledgePanel, a large national, probability-based online panel that randomly selects members to statistically represent the US population (GfK, nd; Yeager et al., 2011). For recruited KnowledgePanel members without Internet access, computers and access are provided by the panel. The smaller counties were more difficult to sample, as GfK did not have a sizable presence in those communities; thus, our KnowledgePanel sample was supplemented with samples from nonprobability panels.[1] The final sample consisted of general population adults residing in the selected Texas counties who were screened to confirm residency. Sampling from the smaller rural areas of Texas proved challenging given that GfK has less of a presence in those communities; as a result, 70% of our sample was from Harris County, 12% from Fort Bend, 1% from Orange, 4% from Jefferson, 5% from Galveston, 2% from Chambers and Liberty Counties, and 6% from Brazoria. The survey was fielded in English from July to August in 2017. Our response rate was 65% for Harris County, but we were unable to calculate the rate for the other counties.

Respondents received an email invitation to complete the survey and were asked to do so at their earliest convenience. The median completion time of the survey was 14 min. Of the 973 qualified respondents, 3 cases were removed for data inconsistencies (up to 90 percent missing responses), resulting in a final dataset that contains 970 valid survey responses.

3.2. Measures

Measures were based on the key variables and operationalizations that are recommended by PRISM (Kahlor, 2010) and RISP (Griffin et al., 1999). Table 1 shows item wording and descriptive statistics related to model variables. At the beginning of the survey, after answering some initial questions, respondents read the following, "We'd like you to think about carbon dioxide gas (or CO2). There are many sources for CO2, but one source is the burning of fuels like coal, gasoline, diesel, and natural gas. Capturing and storing the CO2 has been proposed as one way to reduce the impact on the earth's atmosphere from CO2 that is emitted from power plants and industrial sources. This technology is called carbon capture and storage. Carbon capture and storage is a process where the carbon dioxide is trapped, transported and injected into rocks deep underground. The stored CO2 is then unable to affect the atmosphere. Offshore in Southeast Texas (under the ocean bed) is one of the locations being explored for storage." They then moved on to questions about CCS perceptions and related information behaviors.

Attitude Toward Seeking. We asked respondents to indicate, "to what extent you feel that seeking information about the risks and benefits associated with carbon capture and storage is … " Response options were three 5-point semantic differential pairs: harmful/beneficial, unhelpful/helpful, foolish/wise (Cronbach's $\alpha = .85$).

Table 1. Means, standard deviations and reliability statistics for scale items ($N = 970$).

		M	*SD*	*Factor Loading*
Information Seeking Intent (1-5 scale)	I will try to seek information about risks and benefits posed by carbon capture and storage in the next six months.	2.62	1.06	0.78
	I will look for information about risks and benefits posed by carbon capture and storage in the next six months.	2.68	1.04	0.91
	In the next six months, I am going to search for information related to the risks and benefits posed by carbon capture and storage.	2.72	1.09	0.91
	I intend to seek out information related to the risks and benefits associated with carbon capture and storage in the next six months.	2.66	1.08	0.90
	α	.93		
Attitude toward Seeking (1-5 scale)	*Using the following adjective scales, please indicate to what extent you feel that seeking information about the risks associated with* carbon capture and storage *is …*			
	Harmful . . . . Beneficial	3.59	0.93	0.69
	Unhelpful . . . . Helpful	3.58	0.97	0.80
	Foolish . . . . Wise	3.55	0.94	0.78
	Unproductive . . . . Productive	3.40	1.01	0.77
	α	.85		
Seeking-related Subjective Norms (1-5 scale)	People who are important to me think that I should seek information about the risks and benefits posed by carbon capture and storage.	3.26	1.11	0.76
	People whose opinions I value expect me to seek information about the risks and benefits posed by carbon capture and storage.	3.25	1.08	0.85
	Others expect me to seek information about the risks and benefits posed by carbon capture and storage.	3.33	1.09	0.83
	My family expects me to seek information about the risks and benefits posed by carbon capture and storage.	3.52	1.11	0.84
	α	.89		
Perceived Seeking Control (1-5 scale)	I know where to look for information about the risks and benefits posed by carbon capture and storage.	2.68	1.07	0.92
	I know how to search for information about the risks and benefits posed by carbon capture and storage.	2.61	1.04	0.88
	I can readily access all the information I need about the risks and benefits posed by carbon capture and storage.	2.70	0.97	0.75
	α	.84		
Risk Perception (1-5 scale)	How likely is it that society will be impacted by the potential risks posed by carbon capture and storage?	3.07	1.06	0.72
	If society were impacted by the potential risks posed by carbon capture and storage, how serious would that impact be?	3.08	1.10	0.85
	How likely is it that you will be impacted by the potential risks posed by carbon capture and storage?	2.75	1.12	0.81
	If you were impacted by the potential risks posed by carbon capture and storage, how serious would that impact be?	2.97	1.16	0.83
	α	.88		
Affect Responses (1-5 scale)	Positive Affect (hope) I feel hopeful about the potential benefits associated with carbon capture and storage.	2.80	0.94	–
	Negative Affect (worry)			
	I feel worried about the potential risks associated with carbon capture and storage.	2.96	0.94	–
Perceived Knowledge (1-5scale)	How much do you already know about the risks and benefits posed by carbon capture and storage?	2.05	1.01	–
Perceived Knowledge Sufficiency Threshold (1-5 scale)	How much do you need to know about the risks and benefits posed by carbon capture and storage?	3.37	1.20	–

Seeking-related Subjective Norms. Four items measured norms on a 5-point Likert scale, ranging from 1 = *strongly disagree* to 5 = *strongly agree:* (a) "People who are important to me think that I should seek information about the risks and benefits posed by carbon capture and storage," (b) "People whose opinions I value expect me to seek information about the risks and benefits posed by carbon capture and storage," (c) "Others expect me to seek information about the risks and benefits posed by carbon capture and storage," and (d) "My family expects me to seek information about the risks and benefits posed by carbon capture and storage" (Cronbach's α = .85).

Perceived Seeking Control. Three items on a 5-point Likert scale, ranging from 1 = *strongly disagree* to 5 = *strongly agree*: (a) "I know where to look for information about the risks and benefits posed by carbon capture and storage,"(b) "I know how to search for information about the risks and benefits posed by carbon capture and storage," and (c) "I can readily access all the information I need about the risks and benefits posed by carbon capture and storage" (Cronbach's α = .84).

Risk and Benefit Perceptions. Perceptions of risk are often captured as perceived likelihood of the risk occurring and perceived seriousness of the risk if it were to occur. We captured risk likelihood with four questions, "how likely is it that you will be impacted by the potential risks posed by carbon capture and storage," "if you were impacted by the potential risks posed by carbon capture and storage, how serious would that impact be," "how likely is it that society will be impacted by the potential risks posed by carbon capture and storage," and "if society were impacted by the potential risks posed by carbon capture and storage, how serious would that impact be?" (Cronbach's α = .88). Response options were on a 5-point Likert scale ranging from "*1 = not at all likely/serious*" to "*5 = extremely likely/serious.*" To gain a more balanced perspective, we also asked respondents: "Overall, how beneficial will carbon capture and storage be for you personally," and "Overall, how beneficial will carbon capture and storage be for society?" (Cronbach's α = .80). Response options were on a 5-point Likert scale ranging from "*1 = not at all beneficial*" to "*5 = extremely beneficial.*"

Affective Risk Responses. Affect is an important component of risk perception – and the most often studied risk information seeking-related emotion is worry (Yang et al., 2014). We sought to stay consistent with this approach, but also expand our exploration to include a positive emotion: hope. We assessed hope using a 5 point-Likert scale that ranged from "*1 = strongly disagree*" to "*5 = strongly disagree.*" Respondents were prompted: "I feel hopeful about the potential benefits associated with carbon capture and storage." Worry was measured similarly with "I feel worried about the potential risks associated with carbon capture and storage." Although the use of single-item measures is not ideal for multivariate analyses such as structural equation modeling, we selected items with strong face validity and that were consistent with the research on climate change information behaviors and policy support (Smith & Leiserowitz, 2014).

Perceived Risk Knowledge. Consistent with Kahlor (2010), respondents were asked to indicate how much they already knew about the risk and benefits posed by CCS. Unlike prior research, which tends to measure this item with a 100-point scale, in this study we employed a 5-point scale that ranged from "*1 = nothing*" to "*5 = all there is to know.*" This choice was made to offer greater consistency among response options (most of which are 5-point scales) throughout the survey and to reduce the cognitive burden on participants.

Perceived Risk Knowledge Sufficiency Threshold. This threshold is captured by the gap between perceived risk knowledge and perceived knowledge needed. To measure knowledge needed, we asked, "How much do you need to know about the risks and benefits posed by CCS?" As with perceived knowledge, this item was a 5-point Likert scale ("*1 = nothing*" to "*5 = all there is to know.*")

Seeking Intent. Information seeking intent was measured with four items on a scale ranging from "*1 = strongly disagree*" to "*5 = strongly agree*" (Kahlor, 2010): (a) "I will try to seek information about the risks and benefits posed by carbon capture and storage in the next six months," (b) "I will look for information about the risks and benefits posed by carbon capture and storage in the next six months," (c) "In the next six months, I am going to search for information related to the risks and benefits posed by carbon capture and storage," and (d) "I intend to seek out information related to the risks and benefits associated with carbon capture and storage in the next six months" (Cronbach's α = .93).

3.3. Data analysis

Structural equation modeling was conducted with Mplus 7.3 to test hypotheses and examine paths and model fit of PRISM in the context of CCS. A maximum likelihood robust estimator was employed to account for potential issues with multivariate normality and as a method of missing data treatment; however, it should be noted that the normality assumption was not violated for any observed variable. Two-step modeling verified the measurement model before adding proposed paths to test the structural model (Anderson & Gerbing, 1988; Kline, 2015). All factor loadings in the measurement model were close to or above .70. Because of the increased statistical power of larger sample sizes, several indicators of model fit supplemented the chi-square goodness-of-fit (Hu & Bentler, 1999). Those were the comparative fit index (CFI; values greater than .90), tucker-lewis index (TLI; values greater than .90), root mean square error approximation (RMSEA; values lower than .08), and standardized root mean residual (SRMR; values lower than .08) (Brown & Cudeck, 1993; Hu & Bentler, 1999).

4. Results

4.1. Descriptive analysis

Our sample was 54% female. Nineteen percent of the sample was aged 18-29, 27% between 30-44, 27% between 45-59, and 27% were 60 or older. About 39% had a high school diploma or less education, 31% had some college, and 30% had a bachelor's degree or higher. In addition, 41% of the respondents identified themselves as white non-Hispanic, 19% self-identified as black non-Hispanic, 30% self-identified as Hispanic and the rest self-identified as "other." In terms of income, 14% earned less than $25,000, 20% earned $25,000 to $49,999, 31% earned $50,000 to $99,999, and 35% earned $100,000 or more.

The data indicate that our respondents were generally not familiar with CCS technology. We asked respondents (using 5-point agreement scales) if they had heard about CCS before they took the survey, and whether they had come across information about the topic in conversations with others or in the media or online. Forty-four percent said that they had not heard about CCS before they took the survey and about 19% were not certain if they had heard about it (thus 63% were unfamiliar with CCS). Sixty-one percent had not come across CCS-related information in conversations and about 21% were not sure (thus 82% did not recall talking about CCS with others). Forty-nine percent had not come across CCS-related information in the media or online and about 19% more were not certain whether they had (thus 68% did not recall media coverage of CCS). These data suggest that respondents had limited exposure to information about CCS at the time of this survey.

4.2. Model fit and relationships

To test how well the measures were mapped onto theoretical constructs, model fit statistics were examined (see Table 2). Overall, the measurement model showed a good fit to the data, χ^2 (210) = 8618.303, $p < .001$; RMSEA = .053, CFI = .943, TLI = .932, SRMR = .039. In other words, the measures of the latent variables (i.e. perceived social norms) are correctly specified. We then ran a structural model to test the relationships between latent variables. Overall, the structural model

Table 2. Fit statistics for measurement model and structural model for PRISM with benefit and hope.

Model	X^2	*df*	CFI	TLI	RMSEA [90% C.I.]	SRMR
Benefit-Hope						
Measurement model	8618.303	210	.943	.932	.053 [.049, .057]	.039
Full model	942.017	251	.928	.914	.053 [.050, .057]	.066

fit the data well, χ^2 (251) = 942.017, $p < .001$; RMSEA = .053, CFI = .928, TLI = .914, SRMR = .066. The model accounted for 48% of the variance in seeking intent, which is comparable to past applications of the PRISM model (46-56% in Eastin et al., 2015; p. 64% in Hovick et al., 2014; p. 59% in Kahlor, 2010).

Overall, eight of the 13 hypothesized relationships in the original PRISM held up. Supported relationships surfaced between seeking-related subjective norms and seeking intent (H_2, β = .35, $p < .001$), perceived seeking control and seeking intent (H_3, β = .41, $p < .001$), worry and risk perception (H_4, β = .46, $p < .001$), worry and perceived knowledge sufficiency threshold (H_5, β = .16, $p < .001$); worry and seeking intent (H_6, β = .11, $p < .01$), perceived knowledge and perceived seeking control (H_9, β = .19, $p < .001$), attitude toward seeking and perceived knowledge sufficiency threshold (H_{10}, β = .48, $p < .001$), and perceived knowledge sufficiency threshold and seeking intent (H_{13}, β = .10, $p < .01$).

The unsupported relationships were: attitude toward seeking and seeking intent (H_1, β = -.05, $p = .19$); attitude toward seeking and perceived knowledge, (H_7, β = .02, $p = .60$); perceived knowledge and seeking-related subject norms (H8, β = -.19, $p < .001$); seeking-related subjective norms and perceived knowledge sufficiency threshold (H11, β = -.14, $p < .001$); and perceived seeking control and perceived knowledge sufficiency threshold (H_{12}, β = -.02, $p = .60$). Note that although the relationships predicted in Hs 8 and 11 were supported, they surfaced as negative, rather than positive. As expected, the relationship between perceived knowledge and seeking intent was not significant (β = - .01, $p = .67$) – this relationship, although not hypothesized, was included in the model to show the effect of sufficiency threshold on intention, while controlling for perceived knowledge. Figure 2.

We were also focused on exploring the role of benefit perceptions and hope in PRISM. Comparatively speaking, the relationship between benefit perception and hope (β = .50, $p < .001$) performed as well as the relationship between risk perception and worry (β = .46, $p < .001$), and the relationship between hope and seeking intent (β = .11, $p < .01$) performed identically as worry with seeking intent (β = .11, $p < .01$). The relationship between hope and worry was positive and significant (β = .43,

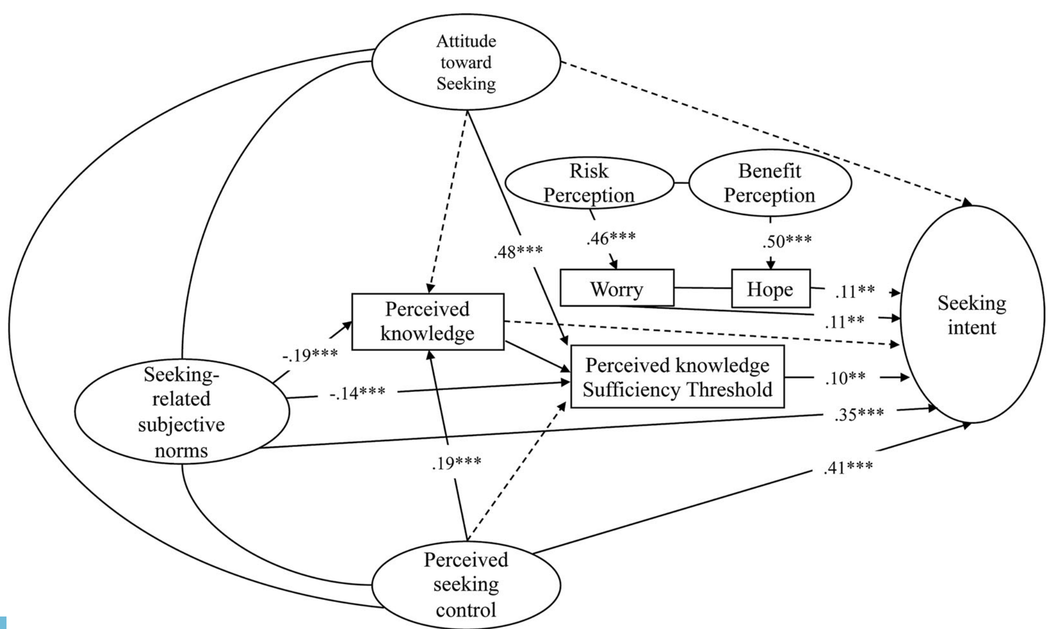

Figure 2. Structural equation model of PRISM with benefit and hope. Note. Dotted line represents non-significant relationships, * $p < .05$. ** $p < .01$. *** $p < .001$.

$p < .001$), as was the relationship between risk and benefit ($\beta = .38$, $p < .001$). Lastly, the relationship between hope and perceived knowledge sufficiency threshold was not supported, while its comparable relationship between worry and perceived knowledge sufficiency threshold was ($\beta = .16$, $p < .001$).

5. Discussion

Prior research suggested that CCS technology is not a well-known solution for addressing climate change among the U.S. public. With this in mind, our goal was to determine factors that could help build awareness and knowledge of CCS so that citizens can make more informed decisions about CCS expansion in the future. To this end, we surveyed adults who live in eight counties near CCS-related development activities in southeast Texas. This is an area in the U.S. where CCS technologies are implemented. Our data collection allowed us to explore whether risk perception, worry, benefit perception, and hope, alongside several other sociopsychological variables consistent with our guiding theory (PRISM) played a role in shaping future intent to seek information about CCS technologies.

5.1. Theoretical and practical implications

The results suggest that PRISM, with the addition of benefit perceptions and hope, is an appropriate framework for exploring what drives the public's intent to seek information about the risks and benefits associated with CCS. The model fit was acceptable across most fit indicators and it accounted for 48% of the variance in risk information seeking intent. Out of the 13 proposed relationships, eight were supported. The supported relationships offer multiple avenues for addressing low awareness of CCS within communities in which the technology is likely to expand. The unsupported relationships offer avenues for future research as we continue to explore the contributions to PRISM made by positive affect and benefit perceptions.

The main goal of models such as PRISM is to identify direct and indirect motivators of information seeking intentions in risk contexts. In this specific risk context, carbon capture and storage, we sought to recognize the technology's potential related to both risks and benefits. Thus, consistent with prior research suggesting that people consider risks and benefits simultaneously (Bearth & Siegrist, 2016; Covello, 1983), and that risk-benefit judgments are likely intermingled in terms of the affective responses that they co-generate, we added benefit perceptions and hope into the PRISM alongside risk perceptions and worry. Not only did benefit and hope perform well alongside risk and worry, but the constructs also showed promise for future studies to explore how risk and benefits may work as tradeoffs and/or how positive and negative emotions may covary in sometimes unexpected ways. For example, in our study, hope and worry had a positive, moderate and significant relationship, as did risk and benefit. These relationships certainly deserve more attention with the context of risk information seeking behaviors.

Our analysis suggested that all but one of PRISM's original predicted direct relationships with seeking intent were supported (worry, perceived knowledge sufficiency threshold, seeking-related subjective norms, and perceived seeking control), as was the additional relationship between hope and seeking intent. The single unsupported direct relationship was related to attitude toward seeking, which is usually a solid predictor of seeking intent in PRISM research (Ho et al., 2014; Hovick et al., 2014; Willoughby & Myrick, 2016). However, in this study we added benefits and positive emotion, which may have removed some of the variance in seeking intent that is accounted for by attitude toward seeking. More work is needed to explore that relationship. There was one other PRISM study that did not find a significant relationship between attitude and seeking intent – the topic was the 2016 U.S. presidential election (Kahlor et al., 2018). In that study, the measure of emotion was more complex than other PRISM studies, accounting for afraid, anxious, scared, angry, mad and irritated. It is possible that as PRISM studies begin integrating more complex assessments of emotion, attitude toward seeking will need to be revisited as a contributing concept.

The unsupported indirect relationships in this study were still more surprising. Perhaps most surprising were the significant but *negative* relationships that emerged between seeking-related subjective norms and knowledge and perceived knowledge sufficiency threshold. Counter to our predictions, the more normative pressure people felt to seek information, the less self-reported knowledge they had and the less knowledge they felt they needed. This was unexpected, but may be the result of the evaluation of both risks *and* benefits in our measures. We cannot tease apart if there is a disconnect between the type of information respondents felt pressure to seek (benefit vs. risk) and the type of information they had or needed (benefit vs. risk). We want to note that these items were our way of balancing the challenge of keeping the survey length reasonable for respondents, while still capturing all of the PRISM variables plus benefit perceptions and related affect (as well as additional data needed by the larger interdisciplinary research team to which we belonged). It was a compromise to write the questions as we did. As a result, our data was not nuanced enough to allows us to tease apart relationships that are unique to risk perception or benefit perception.

Central within the PRISM theoretical framework is perceived knowledge insufficiency, which serves as both a predictor of seeking intent and a mediator of the relationship between seeking intent and other key variables. The theoretical construct of perceived knowledge insufficiency refers to the gap that exists (or doesn't exist) between the knowledge one perceives he or she has and the knowledge he or she desires (perceived knowledge sufficiency threshold). As expected, in the context of CCS, this gap – individuals' perceived need for information about CCS risks and benefits – contributed significantly and positively to their intent to seek out additional information. Although this relationship may appear somewhat intuitive, there is a tendency among scientists and experts to share information with the public without substantive consideration given to the specific information needs or perceptions of that public (Simis, Madden, Cacciatore, & Yeo, 2016).

Our results suggest that two factors influence perceived information need in this context, attitude toward seeking and worry. That is, perceived information need is higher (and therefore motivation is higher) among those who have positive attitudes towards seeking information related to CCS (i.e. they believe that seeking is helpful, beneficial and wise), and worry about the risks associated with CCS. However, it is notable that the relationship between worry and perceived knowledge sufficiency threshold was relatively weak. This weak relationship may be the result of the public's low awareness of CCS – when awareness levels are low, people are not likely to have strong emotional responses to the risk. Prior research suggests that a lack of awareness about an environmental issue contributes to "emotional non-involvement," which can undermine attempts to engage an audience with an issue (Kollmuss & Agyeman, 2002).

Although our positive emotion – hope – did not work through information need/sufficiency as predicted, it did link strongly to benefit perceptions and weakly to seeking intent. Furthermore, the benefit-hope model performed better than the risk-worry model based on model comparison statistics. If nothing else, this suggests that risk communicators and theorists should explore positive emotion and perceived benefits of new technologies in earnest. Our results indicate that the public considers the benefits alongside the risks when they think about technologies such as CCS. This should be no surprise given that technologies such as CCS are developed to solve problems or mitigate existing environmental risks. Indeed, another study suggested that people living in energy-intensive communities are more in tune with potential benefits of CCS than they are with the risks (Krause, Carley, Warren, Rupp, & Graham, 2014).

It is clear from the results that the desire to seek out more information about the risks and benefits associated with CCS are, in part, motivated by emotional responses to the technology (positive and negative). This suggests that communicators should acknowledge the emotional aspects of technology perceptions in their messages. This approach also is consistent with an approach of cognitive psychology that suggests that "emotions constitute potent, pervasive, predictable, sometimes harmful and sometimes beneficial drivers of decision making" (Lerner, Li, Valdesolo, & Kassam, 2015, p. 799). Interestingly, although both worry and hope had a positive relationship with seeking intent, only worry was positively related to perceived knowledge insufficiency. Compared to hope, worry is more of a cognitive emotion that keeps a person alert to personal harm (Mathews, 1990), and it can affect the amount of attention a person pays to information about a threat. People who feel worried are concerned about a future event, feel uncertain about the outcome (Buhr & Dugas, 2002), has negative expectations and feel anxiety (MacLeod, Williams, & Berkerian, 1991). Therefore, it makes sense that worry will lead to a cognitive evaluation of one's existing knowledge level, which is probably why worry is the most studied emotion within the RISP/PRISM framework.

The two best motivators of information seeking intent were the two theory of planned behavior-influenced variables: seeking-related subjective norms and perceived seeking control. This is not surprising, given the robust performance of these factors in other environmental behaviors (Carfora, Caso, Sparks, & Conner, 2017; Chan & Bishop, 2013; Harland, Staats, & Wilke, 1999; Ho et al., 2015). In the context of CCS, Huijts et al. (2007) proposed a model for public acceptance of sustainable energy technology that relies heavily on these same factors.

Seeking-related subjective norms often emerges as a strong predictor of information seeking intent (Eastin et al., 2015; Ho et al., 2014; Kahlor, 2007, 2010). Our emerging understanding of this relationship is that information seeking can be characterized, at least in part, as a social behavior that is shaped by one's relationships with important others. As a result, communicators might find information engagement enhanced when messages invoke these relationships and expectations. We suggest developing messages that highlight these normative perceptions. Such messages might suggest that CCS is becoming an important topic of conversation for the community and therefore community members are likely to hear it come up in conversation in the near future.

Building on the research presented here, in this novel context, the majority of our respondents either had not encountered information about CCS or were not sure if they had; thus it would be useful to know more about how respondents perceive the information available to them. For example, it would be helpful to know what Griffin et al. (1999) defined as channel beliefs or beliefs about the channels through which one can search for information – especially given the poor performance of attitudes toward seeking in the model. Also, it would be useful to know more about the sources of information about CCS that are currently available to respondents. Another fruitful area for future research would be to compare the model presented here with a version of the technology acceptance model put forth by Huijts et al. (2007). One interesting proposition put forth by that model is that attitudes toward technology plays a pivotal role in technology acceptance and mediate the relationship between perceived risks and benefits and acceptance. The researchers argue that technology acceptance should play a key role in future CCS studies, as "public acceptance of these technologies is crucial for their successful introduction into society" (Huijts et al., 2007, p. 525). It is likely that acceptance plays a role in information seeking behaviors as well, possibly alongside risk and benefit beliefs. Another possibility is that anticipated technology acceptance (or rejection) may be an expected outcome of information seeking and thus an independent variable to explore in PRISM.

Another interesting area for future research is to begin to tease apart the way in which climate change-related risks are perhaps shifting in public perception from impersonal risks to personal risks (Kahlor et al., 2006); if such a shift is occurring, it may impact the way in which people respond to climate mitigation technology such as CCS and the perceived relevance of related information. It also remains unclear whether risk information seeking serves different purposes in personal versus impersonal contexts. For instance, one recent study suggests that when a risk is more impersonal, information seeking seems to satisfy epistemic motivation to contribute to general knowledge. In comparison, when a risk is more personal, such as hurricane Harvey for residents of the greater Houston area, information seeking appears to satisfy social motivation by allowing individuals to provide social support to others (Yang & Zhuang, 2019). Therefore, future research should further explore the role of information seeking in contexts of personal vs. impersonal risks.

5.2. Study limitations

As with all studies, our study also comes with some limitations. First, our exploration of benefit-hope was exploratory, which means that additional research is needed to ensure that the relationships observed in this data set hold across other samples and environmental risk contexts. Furthermore, we assessed many of our model constructs with wording that simultaneously invoked "risks and benefits," rather than teasing apart how people might consider their information seeking related to risks and benefits distinctly. It is possible that they rely on different sources and have different levels of trust in those sources, which may impact their attitudes towards those sources and their perceived level of control related to seeking from those sources. Future research needs to better tease these concepts apart. A further limitation of this study is that it focused on risk information seeking intent rather than behaviors. Researchers have criticized the theory of planned behavior, and similar cognitive–behavioral models, for assuming that intentions are strongly related to behaviors (Webb & Sheeran, 2006). These critiques suggest that the study of actual information seeking in addition to intentions would be fruitful. Another limitation may be our reliance on self-report items, particularly when it comes to self-reported perceptions of one's own knowledge. Self-report measurements tend to suffer from a number of biases, including social desirability bias; that is, respondents might be sensitive to portraying themselves as being naïve or uninformed (Cook & Selltiz, 1964). There are also limits to how well individuals can consciously know or access their preferences or attitudes (Fazio, 1995), thus attitudes or estimates of ones' own knowledge may be inaccessible or skewed. However, before studies can be done that put people in a situation like the one in which they would actually be seeking information, it is important to know their general orientation toward information related to a novel topic, such as is the case with CCS. To deal with this limitation, future research can rely on additional methods of measurement to triangulate with direct self-report data such as implicit attitudinal measures (Krosnick, Judd, & Wittenbrink, 2005).

6. Conclusions

While numerous studies have been conducted in recent years to understand factors related to public awareness of CCS, little is known in terms of what motivational factors could potentially contribute to one's active seeking of information about the emerging tehcnology. The present study proposes a baseline model for exploring how factors such as risk and benefit perceptions, worry and hope, and perceived knowledge work together to influence one's intentions to seek information about CCS. Our inclusion of positive emotion and benefit offer a relatively new avenue for the study of communication about climate mitigation and new technologies, and also reveal that it is time for researchers to revisit the explication of benefit perceptions with the same vigor applied to risk perception in years past.

Note

1. GfK uses a calibration process to correct for biases due to systematic undercoverage associated with the non-probability samples from online panels. The calibrated weights enable representativeness not just with respect to geodemographic distributions, but also a set of attitudinal/behavioral measures including media use and political opinions (GfK, nd).

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