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The role of initial affective impressions in responses to educational communications: The case of carbon capture and sequestration (CCS)

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Abstract

Emerging technologies promise potential benefits at a potential cost. Developers of educational communications aim to improve people's understanding and to facilitate public debate. However, even relatively uninformed recipients may have initial feelings that are difficult to change. We report that people's initial affective impressions about Carbon Capture and Sequestration (CCS), a low-carbon coal-based electricity-generation technology with which most people are unfamiliar, influences how they interpret previously validated education materials. As a result, even individuals who had originally self-identified as uninformed persisted in their initial feelings after reading the educational communication -- though perseverance of feelings about CCS was stronger among recipients who had originally self-identified as relatively informed (Study 1). Moreover, uninformed recipients whose initial feelings were experimentally manipulated by relatively uninformative pro-CCS or anti-CCS arguments persisted in their manipulated feelings after reading the educational communication, due to evaluating the educational communication in line with their manipulated impressions (Study 2). Hence, our results suggest that educational communications will have more impact if they are disseminated before people form strong feelings about the topic under consideration, especially if these are based on little to no factual understanding.

Keywords: Public perceptions of emerging technologies; educational communication; impression formation

The role of initial affective impressions in responses to educational communications: The case of carbon capture and sequestration (CCS)

New technological developments bring the promise of societal benefits while introducing potential risks. Members of a democratic society face public debates about whether or not to support the implementation of specific technologies. Well-meaning educators may aim to facilitate those public debates by informing people's perceptions through educational communications. Here, we refer to "educational communications" when describing materials that have been designed to provide balanced and accurate information, and that have been tested for their ability to improve people's understanding of the topic under consideration (see for example Fischhoff, Brewer, & Downs, 2011; Morgan, Fischhoff, Bostrom, & Atman, 2002).

Yet, it may be difficult to change recipients' feelings about CCS once they have already formed initial impressions, even if they may still have limited knowledge. First impressions are affective in nature, can be formed on the basis of little to no information, guide cognitions and perceptions of risks and benefits, and tend to be difficult to change (Finucane et al., 2000; Zajonc, 1980). Evidence for the perseverance of first impressions comes from three lines of psychological research in which undergraduate participants made hypothetical decisions in carefully controlled experiments. First, research on impression formation has shown a primacy effect, such that people described as intelligent, tall and mean are evaluated more positively than those described as mean, tall, and intelligent (Asch, 1961; for exceptions see Hogarth & Einhorn, 1992). Second, feelings that are evoked by positive or negative performance feedback tend to linger, even after it is disclosed that the feedback has been fabricated (Anderson et al., 1980). Third, psychological experiments have found that false impressions about hypothetical products

are difficult to change, because participants feel that the original claims are more likely to ring true than the refutations (Johar, 1996; Johar & Simmons, 2000).

Several studies have reported that ill-founded first impressions are especially hard to change among individuals who perceive that they know more, even though people often think that they know more than they actually do (Keren, 1991). Perceptions of knowledge may increase with repeated exposure to ambiguous statements (Ares, Boehm, & Xu, 1991), and thinking more about a one-sided argument (Petty & Cacioppo, 1986; Koriat, Lichtenstein, & Fischhoff, 1980). People who perceive themselves as more knowledgeable about an issue become less open to advice (Gino & Moore, 2007), find it harder to consider alternative points of view (Koehler, 1991), and become more likely to interpret new information as confirming what they think they know (Klayman, 1995; Kunda, 1990; Nickerson, 1998).

Most of the studies cited above have used controlled experiments about fabricated issues, so as to ensure that participants had not yet developed any initial impressions. Few studies have tested whether the reported findings generalize to real-world settings. It has been shown that people who distrust a technology tend to interpret new information about it more negatively (Cvetovich, Siegrist, Murray, & Tragesser, 2002; Poortinga & Pidgeon, 2004). Proponents of nuclear power interpret near-accidents as evidence of successful safety strategies, while opponents view them as evidence of risk (Plous, 1991). Individuals who worry about a risk may feel alarmed when reading information that experts deem to be neutral or positive (Levy, Weinstein, Kidney, Scheld, & Guarnaccia, 2008). Finally, people who had initially voted for Nixon persisted in their positive feelings for him after Watergate, while those who had not voted for Nixon did make negative adjustments to their prior impressions (Carretta & Moreland, 1982).

Naturally, one limitation of these real-world studies is that participants had prior access to outside information, leaving it unclear whether or not the impressions in which they persisted were well-informed. Newly emerging technologies provide the appropriate real-world context, because they are typically not well known by members of the general public, and the few people with some familiarity remain relatively uninformed (see for example Fleishman, Bruine de Bruin, & Morgan, 2010).

Application to the case of Carbon Capture and Sequestration (CCS)

CCS is a relatively new technology that aims to mitigate climate change by capturing carbon dioxide from coal-fired power plants and sequestering it deep underground instead of allowing it to be released into the atmosphere. CCS proponents have suggested that the electricity sector may achieve policy goals to cut carbon dioxide emissions through the aggressive deployment of low-carbon strategies including energy efficiency, natural gas, wind, nuclear, as well as coal plants with CCS. Opponents of CCS have voiced concerns about environmental damage, leaks, and small earthquakes (Huijts, Midden, & Meijnders, 2007; James, Richels, Blanford, & Gehl, 2007; Pacala & Socolow, 2004; Shackley et al., 2009).

To date, public perception studies find that most people are unfamiliar with CCS, and that those who have heard of it are still relatively uninformed (Huijts et al. 2007; Palmgren et al., 2004; Shackley, McLachlan, & Gough, 2005; Sharp, Jaccard, & Keith, 2009; Wallquist et al., 2009, 2010). Outreach activities to the general public remain largely non-existent (Ashworth et al., 2010; Shackley et al., 2007). One exception includes the educational communication that was developed by a team at Carnegie Mellon University with input from a diverse team of experts and members of the general public (Fleishman & Bruine de Bruin, in press). It has been

tested for its ability to effectively inform participants (Fleishman et al., 2010). In the present work, we provided these validated educational communications to residents of Wyoming and nearby states with coal-fired power plants, who may soon face decisions about whether or not to accept CCS in their area (Wong-Parodi et al., 2011).

Research questions

Following recommendations that studies of the perseverance of initial impressions should focus on real-world topics (Carreta & Moreland, 1982), we generated specific hypotheses from laboratory research to learn more about how people respond to a validated educational communication about CCS. In Study 1, we tested whether people's responses to educational materials about CCS were associated with prior impressions about CCS (Hypothesis 1), and whether that relationship was stronger in individuals with more perceived knowledge (Hypothesis 2). In Study 2, we tested whether, among self-identified uninformed participants, exposure to one-sided pro-CCS (vs. anti-CCS) arguments would lead to more positive post-argument feelings about CCS (Hypothesis 3) and subsequently more positive post-education feelings about CCS (Hypothesis 4), with manipulated post-argument feelings about CCS persisting in subsequent post-education feelings about CCS (Hypothesis 5). The one-sided arguments were provided with little to no factual information, so that any effect on subsequent feelings about CCS would lack a solid foundation in CCS knowledge.

Additionally, we also explored potential mediators of the relationship between initial feelings (that were pre-existing in Study 1 or newly manipulated in Study 2) and post-education feelings, including interpretation of communication content, and ratings of trust and quality, as well as knowledge about communication content and confidence in that knowledge. These

measures were adapted from communication studies (Fischhoff et al., 2011; Lipkus, 2007) and play a role in responses to corrective advertising, advice taking (Gardner & Berry, 1995; Harvey & Fischer, 1997; Johar, 1996; Johar & Simmons, 2000; Yaniv, 2004; Yaniv & Kleinberger, 2000) and public perceptions of CCS (Palmgren et al., 2004; Huijts et al., 2007; Walquist, Visschers, and Siegrist, 2010).

Study 1

Method

Participants

Participants were recruited through online advertisements entitled "Energy policy survey for residents of Montana, North Dakota, South Dakota, Wyoming, Colorado, Utah, Kansas, and Nebraska only." We recruited from these states because they may soon face decisions about CCS sites (Wong-Parodi et al., 2011). Online advertisements appeared at Amazon's Mechanical Turk, an online market place that is increasingly used for recruiting survey participants (Buhrmester, Kwang, & Gosling, 2011). Participants were offered $1 for completing our survey, which is within the range of subject fees for advertised studies.

Study 1 and Study 2 participants were recruited at the same time, which allowed us to engage in one large recruitment effort and to prevent participants from enrolling in both studies. At baseline, all 571 answered "how much do you know about CCS?" on a scale ranging from 1 (=nothing) to 7 (=a lot).[1] The 88 who self-rated their knowledge above the midpoint of 4 were enrolled into Study 1. The low number reflects the widespread lack of public CCS awareness (Huijts et al., 2007; Palmgren et al., 2004; Shackley et al., 2005; Sharp et al., 2009; Wallquist et al., 2009, 2010). The remaining individuals (n=483) were randomly assigned to Study 1 (n=163)

or Study 2 (n=320). Hence, the combined total number of participants in Study 1 was 251. Average age of the Study 1 participants was 31.15 (SD=11.78), with 40% female, 24% nonwhite, and 47% having a college degree.

Procedure and measures

Baseline assessment. Following previous work (Fleishman et al., 2010), participants received a brief introduction about the study and CCS, noting that "as you read more about it, we will ask for your views." Specifically, participants read "The U.S. Congress may decide to limit the carbon dioxide (CO_2) released by new power plants. As a result, [your state] would have to reduce the CO_2 released by some of its future power plants. Imagine that [your state] is going to build a new coal power plant. The plant can be either with or without CO_2 capture and sequestration (CCS). Imagine that the Governor has asked you to serve on a Citizen's Panel to give your advice."

Next, the baseline assessment of *feelings about CCS* asked "how do you feel about CCS?" with a scale from 1 (=very negative) to 7 (=very positive), which was taken from previous work (Fleishman et al., 2010; Huijts et al., 2007; Wallquist et al., 2009, 2010).[1] The baseline question about perceived knowledge about CCS asked "how much do you know about CCS?" with a scale from 1 (=nothing) to 7 (=a lot), which was also adapted from previous work (Huijts et al., 2007).[2] These single-item measures were chosen to reduce survey length, repetition, and respondent burden, while noting that findings based on single-item measures tend to replicate findings based on multi-item measures (Bergkvist & Rossiter, 2007; Wanous, Reichers, & Hudy, 1997).

Educational communication. Participants received an educational communication about CCS that was adapted from publicly available materials (Figure 1) which in a validation study were shown to effectively inform recipients about CCS (Fleishman & Bruine de Bruin, in press; Fleishman et al., 2010). Content covered twelve CCS attributes, starting with a section on CO_2 release that explained "a coal power plant releases CO_2 into the air" and "adding CCS to a coal power plant prevents much of the CO_2 from being released into the air." Subsequent sections covered current use, availability, benefits, land use and ecology, lifespan, limits of use, safety, noise, pollution and other waste, price, and reliability.[3]

Post-education assessment. After reading the educational communication, *feelings about CCS* were assessed again using the same question as at baseline, which showed consistency with related post-education questions about preferences for CCS.[1] Participants rated their *interpretation* of the educational content about the twelve CCS attributes (e.g., CO_2 release, current use, availability, benefits, land use and ecology, lifespan, limits of use, safety, noise, pollution and other waste, price and reliability), on a scale from 1 (=very negative) to 7 (=very positive), adapting a procedure used previously (Palmgren et al., 2004; Wallquist et al., 2010; Sharp et al., 2009). Cronbach's alpha across the twelve items was .92, thus showing sufficient internal consistency to allow the computation of an averaged summary measure.

Questions about *trust and quality* in the educational communication asked "do you trust the information about coal plants with CCS?" and "do you think the information about coal plants is of low or high quality?" with a scale ranging from 1 (=very low) to 7 (=very high), as adapted from a recent study (Bruine de Bruin et al., in press). Cronbach's alpha across the two items was .82, allowing the computation of a summary measure by computing the overall mean.

Following a standard confidence assessment procedure (Keren, 1991), *knowledge* about the educational communication's content was measured with 10 true/false questions. Participants indicated their *confidence* in their answer to each question, on a scale from 50% (=just guessing) to 100% (=absolutely sure). This procedure is designed to allow a systematic comparison of knowledge, which is reflected in the overall percent of correct responses across items, and confidence, which is expressed as the mean confidence rating across items (Keren, 1991). Overall, we found moderate consistency across participants' responses to the ten knowledge items (α=.61), and good consistency across the confidence ratings they gave for those ten responses (α=.81), which replicate previous findings (Pallier et al., 2002; Stankov & Crawford, 1996). We computed an averaged summary measure for knowledge and for confidence in knowledge.

Results

Initial analyses.

Table 1 shows the descriptive statistics for the assessed measures, as well as the results of our initial analyses. For the variables that were assessed on 1-7 rating scales, one-sided *t*-tests examined whether the means in Table 1 were significantly different from the midpoint of 4. Results indicated that, at baseline, participants' feelings about CCS were slightly positive, while their perceived knowledge was relatively low, which replicates findings of previous CCS studies (Huijts et al., 2007; Palmgren et al., 2004; Shackley et al., 2005; Sharp et al., 2009; Wallquist et al., 2009, 2010). After reading the educational communication, participants' feelings about CCS remained slightly positive.[4] Tests of Study 1 hypotheses are reported below.

The role of prior feelings in forming post-education feelings (Hypothesis 1).

We found support for Hypothesis 1, which predicted that responses to educational materials about CCS would be informed by prior feelings about CCS. Table 1 shows a significant correlation between post-education feelings about CCS and baseline feelings about CCS. Table 2 shows that this relationship holds in a linear regression that controlled for demographic variables (Model 1).

Moderation of the relationship between prior and post-education feelings (Hypothesis 2).

We found support for Hypothesis 2, which predicted that the association between prior feelings about CCS and responses to educational materials about CCS would be stronger in recipients with more prior self-rated knowledge, thus showing significant moderation. The linear regression in Model 2 had the same predictors as Model 1 (Table 2) but additionally included the interaction between self-rated baseline knowledge and baseline feelings about CCS while controlling for main effects and demographic variables, thus slightly improving predictive ability ΔR^2=.05, $F(2, 239)$=8.11, p<.001. As expected, we found a significant interaction, which showed that self-rated knowledge moderated the relationship between baseline and immediate post-education feelings about CCS perceptions (Table 2). To further examine the interaction, we repeated Model 1 for those who self-rated their baseline CCS knowledge above (vs. at or below) the scale midpoint (=4). We found a stronger relationship between baseline CCS perceptions feelings about CCS and immediate post-education feelings about CCS perceptions among those with high self-rated baseline knowledge (β =.57, p<.001) than those with lower self-rated baseline knowledge (β=.21, p<.01).

Mediators of the relationship between baseline and post-education feelings.

Table 1 shows significant positive correlations of baseline feelings about CCS and of post-education feelings about CCS with potential mediator variables, including interpretation of education content, rated trust and quality of education, post-education knowledge, and confidence in knowledge. To examine which of these variables drove the perseverance of initial feelings about CCS after exposure to the educational communication, we compared the linear regression predicting feelings about CCS as reported after the educational communication from baseline feelings about CCS, while including demographic controls (Model 1), with another linear regression that also included the potential mediator variables including post-education assessments of interpretation of content, trust, perceived quality of the materials, knowledge, and confidence in knowledge (Model 3). The latter showed improved predictive ability, ΔR^2=.58, $F(4, 237)$=129.74, p<.001. Moreover, the positive relationship of post-education feelings about CCS with baseline feelings about CCS (Model 1) was no longer significant after controlling for the potential mediator variables, of which interpretation of education content and rated trust and quality were positively associated with post-education feelings about CCS (Model 3). A multi-mediation analysis that included the potential mediator variables and demographic controls (Preacher & Hayes, 2008) did indeed find that interpretations of the education's content (95% *CI*=.19, .40) and ratings of trust and quality (95% *CI*=.02, .09) significantly mediated the positive relationship of baseline feelings about CCS with post-education feelings about CCS. Hence, participants persisted in baseline CCS perceptions because they interpreted and evaluated the educational communication in light of their initial impressions.

We also found that the interaction effect between baseline feelings about CCS and baseline perceived CCS knowledge on post-education feelings about CCS (Model 2) was no

longer significant after controlling for the potential mediator variables (Model 4), ΔR^2=.53, F(4, 235)=120.22, p<.001. However, a multi-mediation analysis that included the potential mediator variables and demographic controls (Preacher & Hayes, 2008) found no significant mediation of the interaction effect, suggesting that the mediation pattern reported above was independent of perceived CCS knowledge at baseline. Hence, these findings suggest that, independent of how much baseline knowledge participants perceived to have, they may have persisted in their baseline feelings about CCS even after reading the educational communication because they interpreted and evaluated the educational communication in light of their initial impressions.

Discussion

In Study 1, we shared educational communications that were designed to inform public perceptions of CCS (Fleishman et al., 2010) with participants from states where CCS is likely to be deployed. Our findings add three insights to the literature. First, pre-existing feelings in this sample predicted feelings recorded after reading the educational materials, with positive baseline feelings about CCS yielding positive post-education feelings about CCS. Hence, persistence of initial impressions is not limited to hypothetical topics considered in the psychological laboratory, and occurs even when people receive a genuine educational communication about an existing real-world topic. Second, perseverance of initial impressions is found even among participants who thought they were relatively uninformed, although it was stronger among recipients who perceived themselves as relatively knowledgeable. Third, perseverance of initial impressions occurred because participants evaluated the educational communication in light of their pre-existing feelings about CCS, thus allowing them to maintain those feelings after the reading educational communication.

The educational communication we used had previously been found to effectively inform recipients' understanding about CCS (Fleishman et al., 2010; Fleishman & Bruine de Bruin, in press). Nevertheless, our findings suggest that these educational materials may be interpreted differently by recipients who have already formed relatively positive or negative first impressions. These first impressions were likely based on incomplete information, because most people remain largely uninformed about CCS, with the few who have heard about the technology commonly showing gaps and misconceptions in their CCS knowledge (Huijts et al., 2007; Palmgren et al., 2004; Shackley et al., 2005; Sharp et al., 2009; Wallquist et al., 2009, 2010). Indeed, the large majority of our participants rated themselves as relatively uninformed – despite people's general tendency to think that they know more than they actually do (Keren, 1991). Yet, as noted, those who perceived themselves as relatively more informed about CCS showed a stronger tendency to stick with their prior impressions after reading educational communications about CCS.

Because those who self-identify as uninformed are more likely to be swayed from their initial impressions (Yaniv, 2004; Ross & Ward, 1995; Gino & Moore, 2007; Gunther et al., 2009; Richardson et al., 2008; Banas & Rains, 2010), Study 2 examined whether people would persevere in relatively uninformed impressions after being manipulated through one-sided arguments. We followed the design of laboratory studies of belief persistence, in terms of randomly assigning participants who self-identified as relatively uninformed about CCS to one-sided pro-CCS or anti-CCS arguments. We then tested whether exposure to one-sided pro-CCS (vs. anti-CCS) arguments would manipulate post-argument feelings about CCS (Hypothesis 3) as well as the subsequent feelings about CCS after reading the educational communication, as

recorded over time (Hypothesis 4), with manipulated post-argument feelings about CCS reverberating in post-education perceptions of CCS (Hypotheses 5).

Study 2

Method

Participants

Following the same recruitment procedures as Study 1, Study 2 included 320 participants from Wyoming, Montana, North Dakota, South Dakota, Colorado, Utah, and Kansas, and Nebraska. These participants were unique to Study 2 and did not participate in Study 1. Volunteers were eligible for Study 2 if they rated themselves as relatively uninformed about CCS.[2] Thus, as in previous research, informed participants were omitted from Study 2, because their existing convictions about CCS are less likely to be influenced (Yaniv, 2004; Ross & Ward, 1995; Gino & Moore, 2007; Gunther et al., 2009; Richardson et al., 2008; Banas & Rains, 2010). The average age of Study 2 participants was 31.26 (*SD* =10.77), with 51% female, 23% nonwhite, and 44% having a college degree.

Procedure and measures.

The procedure and measures for Study 2 were the same as those for Study 1, with a few exceptions. Unlike Study 1 participants, Study 2 participants received one-sided arguments after reporting initial baseline feelings about CCS (1=very negative; 7=very positive), but before receiving the pre-communication assessment or the educational communication. They were randomly assigned to a one-sided argument with pro-CCS or anti-CCS content, which focused on the one topic they selected as most important: nature, the economy, or state independence.[5]

We used simple arguments that provided little to no factual information, which were designed by Wyoming residents to appeal to people like them (Wong-Parodi et al., 2011). Respectively, our pro-CCS arguments about nature, the economy, and state independence stated: (a) "CCS will not harm nature and will not change your state's landscape," (b) "CCS will create construction jobs," and (c) "CCS means that your state is building new technology before the U.S. government tells it what to do." Anti-CCS arguments on these topics stated: (a) "CCS will harm nature and will change your state's landscape," (b) "CCS will not create construction jobs," and (c) "CCS means that your state is building new technology because the U.S. government tells it what to do." Participants were subsequently asked to elaborate on the specific argument they read by writing one or two sentences, which has been shown to increase processing of the one-sided argument and confidence in its content (Banas & Rains, 2010; Roggeveen & Johar, 2002). Participants indicated their post-argument feelings about CCS on a scale from 1 (=very negative) to 7 (=very positive).

Subsequently, participants followed the procedure described for Study 1. They received the educational communication and the post-education assessment, which used the same measures. [6] As in Study 1, we found internal consistency for the 12 items assessing interpretations of the educational communication's content (α=.92), and for the 2 items assessing their ratings of the materials in terms of trust and quality (α=.76). Again, as in Study 1, better internal consistency was found for confidence in post-education knowledge (α=.82) than for actual post-education knowledge (α=.61).

Results

Initial analyses.

As in Study 1, a one-sided *t*-test found that baseline feelings about CCS as reported across participants were slightly positive, with a one-sided *t*-test showing that the mean rating was significantly above the scale midpoint of 4 (M=4.51, SD=1.24), $t(319)=7.31$, $p<.001$, thus falling in the range of previous public perception studies, which have reported ratings that vary from slightly negative to slightly positive (Huijts et al., 2007; Palmgren et al., 2004; Shackley et al., 2005; Sharp et al., 2009; Wallquist et al., 2009, 2010). Because the baseline assessment occurred before participants received the one-sided argument, baseline feelings about CCS should show no significant difference between participants who were to receive the pro-CCS argument and those who were to receive the anti-CCS argument, as is indeed the case (Table 3). Tests of Study 2 hypotheses appear below.

Effect of exposure to one-sided arguments on feelings about CCS (Hypothesis 3).

We found support for Hypothesis 3, such that exposure to the one-sided arguments created a significant group difference in post-argument feelings about CCS. That is, after reading the one-sided argument (but before seeing the educational communication) recipients of the pro-CCS argument were significantly more positive about CCS than recipients of the anti-CCS argument (Table 3).

Effect of exposure to one-sided arguments on post-education feelings about CCS (Hypothesis 4).

We found support for Hypothesis 4, which predicted that the effect of exposure to one-sided pro-CCS (vs. anti-CCS) arguments would still be seen in feelings about CCS as recorded

after reading the educational materials. Indeed, recipients of the pro-CCS argument reported significantly more positive post-education feelings about CCS than recipients of the anti-CCS argument (Table 3). This relationship held in a linear regression that took into account baseline feelings about CCS and demographic variables (Model 1; Table 4). Specifically, recipients of the one-sided pro-CCS (vs. anti-CCS) argument had more positive post-education feelings about CCS, as did those who had stronger positive feelings about CCS at baseline (Model 1; Table 4).

The role of manipulated feelings in forming post-education feelings (Hypothesis 5).

We found support for Hypothesis 5, which predicted that post-education feelings about CCS would be associated with post-argument feelings about CCS. Table 3 shows that post-education feelings about CCS were indeed significantly correlated with post-argument feelings about CCS. This relationship held in a regression model that also took into account whether participants received the pro-CCS (vs. anti-CCS) argument, baseline feelings about CCS and demographic variables (Model 2; Table 4). Adding post-argument feelings slightly improved the predictive ability of the model, (Model 2 vs. Model 1; Table 4) ΔR^2=.09), $F(1, 128)$=11=4.61, p<.001, but reduced the effect of the one-sided arguments on post-education feelings about CCS, thus showing significant mediation (95% CI=.14, .58). Hence, the one-sided arguments manipulated post-argument feelings about CCS which then informed post-education feelings about CCS. The association of baseline feelings about CCS with post-education feelings about CCS was also reduced after adding post-argument feelings about CCS (Model 2), showing significant mediation (95% CI=.06, .24). This result suggests that baseline feelings about CCS informed post-argument feelings about CCS, which in turn informed post-education feelings about CCS, thus showing a lingering effect throughout the course of the study.

Mediators of the relationship between manipulated post-argument and post-education feelings.

Independent-sample *t*-tests compared the group means and found that recipients of the pro-CCS (vs. anti-CCS) argument had significantly more positive interpretations of the educational content and more confidence in their post-education knowledge, despite showing no differences in their trust of the educational communication or their post-education knowledge (Table 3). Hence, although this study was not designed to test the ability of the educational communication to meet its goal of informing recipients about CCS, we do find that people with different feelings about CCS end up with similar levels of knowledge about CCS after reading the educational communication.

Perhaps more importantly, both manipulated post-argument feelings about CCS and post-education feelings about CCS showed significant correlations with potential mediator variables that were assessed in between, including interpretation of education content, rated trust and quality of the educational materials, and post-education knowledge (Table 3). To examine what drove the perseverance of manipulated feelings about CCS after exposure to the educational communication, we compared a linear regression predicting post-education feelings about CCS from post-argument feelings about CCS while taking into account the valence of the one-sided argument, baseline feelings about CCS, and demographic variables (Model 2), with a linear regression that additionally included participants' interpretation of education content, ratings of trust and quality, as well as knowledge and confidence (Model 3). The latter had improved ability to predict post-education feelings about ΔR^2=.44, $F(4, 301)$=90.71, p<.001. It showed a reduced relationship of post-education feelings about CCS with post-argument feelings about CCS, as well as significant positive relationships with the interpretation of communication

content and trust (Model 3). A multi-mediation analysis (Preacher & Hayes, 2008) found that interpretations of communication content (95% *CI*=.21, .38) and ratings of trust and quality associated with the educational communication (95% *CI*=.01, .08) both mediated the positive relationship of post-argument and post-education feelings about CCS as reported after reading the educational communication. As in Study 1, these results indicate that participants who felt positively about CCS before reading the educational communication interpreted and evaluated it more positively, which helped them to maintain their initially positive feelings about CCS after reading the educational communication.

Discussion

As in Study 1, we provided educational communications that were designed by educators to inform public perceptions of CCS (Fleishman & Bruine de Bruin, in press; Fleishman et al., 2010) to participants from states where CCS is likely to be deployed. Participants who self-identified as uninformed were randomly assigned to one-sided arguments with pro-CCS or anti-CCS content which provided little to no factual information about the technology. As expected, these one-sided arguments successfully manipulated participants' feelings about CCS, causing group differences in feelings about CCS that did not exist upon participants' entry into the study but that nevertheless persisted even after reading a genuine educational communication. Hence, Study 2 applies the laboratory findings about the persistence of manipulated feelings (Anderson, Lepper, & Ross, 1980; Ross, Lepper, & Hubbard, 1975) to a real-world context, and additionally shows that such persistence remains even after people receive educational communications.

Indeed, participants who had been manipulated to have positive (vs. negative) feelings about CCS ended up having more positive (vs. negative) feelings about CCS after reading the

educational communication, due to interpreting the educational communication's content and trusting the educational communication more. These findings occurred even though our participants ended up with similar knowledge levels after reading the educational communication, independent of whether they had been manipulated to have positive or negative feelings about CCS. Hence, educational communications may improve recipients' understanding without changing their potentially ill-founded feelings about the topic under consideration.

General discussion

Educational communications aim to inform public debate about emerging technologies and associated policies. These well-intended communication efforts, including our own, may fail if recipients already have formed initial impressions that are hard to change. Psychological laboratory studies have suggested that people may persevere in initial impressions that are based on limited information (Anderson, Lepper, & Ross, 1980; Johar, 1996; Johar & Simmons, 2000; Ross, Lepper, & Hubbard, 1975). We found that these laboratory findings apply when people learn about a real-world topic, with initial impressions lingering in responses to educational communications. These results held when initial impressions were pre-existing (in Study 1) or manipulated by one-sided messages (Study 2). In both studies, perseverance of initial impressions seemed to occur because participants evaluated the content of the educational communication in light of their initial impressions, thus allowing them to maintain those impressions after the educational communication.

Our two studies have several limitations and should therefore be interpreted with caution. First, our participants were paid to read the educational communication, which may have exposed them to content that they might not have sought on their own. Indeed, people tend to

selectively seek information that confirms their initial impressions (Nickerson, 1998). Second, our participants volunteered to complete in a survey about "energy policy" and may therefore not be representative of their states' or the US population. Third, the one-sided arguments in Study 2 were designed to appeal to residents from states where CCS might be implemented and although their effects were persistent they were relatively small. Fourth, because our studies were not meant to evaluate the effectiveness of the educational materials, our studies did not include a no-education control group, which makes it impossible to determine how much (if at all) the observed persistence in initial impressions of CCS was reduced by exposure to the educational communication.

Nevertheless, our findings appear to have practical implications for developers of educational communications on various topics. That is, educational communications would likely be more effective if they were developed before people form persistent initial impressions that are based on little to no information. Indeed, laboratory research suggests that once initial impressions have formed they become difficult to change, even after it becomes clear that they were based on fabricated information (Anderson, Lepper, & Ross, 1980; Johar, 1996; Johar & Simmons, 2000; Ross, Lepper, & Hubbard, 1975). However, the development of educational communications about CCS has been postponed because CCS is not yet fully developed for market-based deployment (Ashworth et al., 2010; Shackley et al., 2009). Similar hesitance to develop communications has been seen in the context of other technologies, potentially leading to the suspicion that facts were deliberately hidden from the public (Fischhoff, 1995). Combined with our findings, this suggests that it might be better to develop educational materials about emerging technologies earlier rather than later.

The mental models approach provides a systematic methodology for developing educational communications to inform people's decisions (Morgan et al., 2002). It recognizes that educational communications need to be designed with an understanding of the intended audience, focusing on decision-relevant facts people are missing but need and want from experts with varying points of view (Bruine de Bruin & Bostrom, in press). The mental models approach has been used to develop educational materials about CCS and alternative low-carbon technologies, which was used in the present experiments and is available online (Fleishman & Bruine de Bruin, in press; Fleishman et al., 2010). It has also been applied to topics such as smart meters, nanotechnology or chemicals in the work place (e.g., Cousin & Siegrist, 2010; Krishnamurti et al., 2012; Niewöhner, Cox, Gerrard, & Pigeon, 2004).

The dissemination of accurate educational materials will be most effective if it occurs before the development of public debate, which may also help to build perceptions of trust and quality (Fischhoff, 1995). Yet, it is unclear that making educational materials available in timely manner will (or should) promote public support of each emerging technology or prevent conflicts in public debates, but it may help to avoid that disagreements are based on misunderstandings.

Footnotes

[1] The measure of feelings about CCS was relatively reliable. At the post-education assessment, Cronbach's alpha was .78 across the standardized scores for responses across four related questions, with the first pertaining to feelings about CCS. The second presented a ranking task taken from previous CCS research in which participants expressed their relative preferences of CCS as compared to six other low-carbon electricity generation options (Fleishman et al., 2010; Palmgren et al., 2004). The third asked

participants whether they would prefer that their state build a coal power plant with or without CCS. In the fourth, they gave advice to their governor about whether to build a coal plant with or without CCS. Inter-item correlations showed that post-education feelings about CCS were positively correlated with relative preferences of CCS compared to other low-carbon technologies (r=.35, p<.001), with preferences for a coal plant with CCS rather than without (r=.59, p<.001), and with advice to the governor to build a coal plant with CCS rather than without (r=.57, p<.001).

[2] We had three reasons for asking for perceived knowledge rather than measuring actual knowledge. First, research in other domains has shown that perceived knowledge is associated with actual knowledge, even though correlations are of course imperfect (Fagerlin et al., 2007; Zikmund-Fisher et al., 2007). Second, self-report questions of knowledge are much less frustrating to participants than tests of actual knowledge, thus reducing attrition rates (Zikmund-Fisher et al., 2007). Third, giving people knowledge tests artificially improves their knowledge and increases how much they learn from any subsequently presented information (Foediger & Karpicke, 2006).

[3] The original materials covered ten low-carbon technologies including CCS, using one page for each technology. Technology descriptions were at the 6th-8th grade reading level. For each technology, the associated page systematically described the same set of features, which were identified as relevant in pilot interviews with experts and members of the general public. Special attention was given to fix common knowledge gaps and misconceptions that emerged in previous interview and survey research (Palmgren et al., 2004; Wallquist et al., 2009, 2010). The final version was tested for readability in think-aloud interviews with members of the general public (who also recommended simplified

wording), and for accuracy with diverse experts in low-carbon electricity generation. A detailed description of materials development is given by Fleishman and colleagues (in press). A validation study showed that the materials reduced the prevalence of common misunderstandings, as measured on a true/false knowledge test (Fleishman et al., 2010).

[4] Although this study was not designed to replicate a previous validation of the educational materials (Fleishman et al., 2010), the effectiveness of the educational materials in terms of informing participants is suggested by independent-sample *t*-tests showing that recipients who perceived being relatively knowledgeable at baseline (seen in a self-rating above the scale midpoint of 4) and recipients who perceived being relatively uninformed at baseline (seen in a self-rating at or below the scale midpoint) ended up with similar levels of post-education knowledge and confidence after reading the educational communication ($p>.05$). (See footnote 2 for our reasons for measuring perceived knowledge at baseline.)

[5] A total of 40.9% selected nature, 52.5% the economy, and 6.6% state independence. Overall, separate analyses on the first two groups suggest that the overall conclusions drawn in this paper hold for each. The third group was too small to warrant separate analyses.

[6] As in Study 1, the measure of feelings about CCS was relatively reliable. Cronbach's alpha across the standardized scores for a set of four items that included post-education feelings about CCS was .84 (see footnote 1). Inter-item correlations showed that post-education feelings about CCS were positively correlated with relative preferences of CCS compared to other low-carbon technologies ($r=.54$, $p<.001$), with preferences for a coal plant with CCS rather than without ($r=.53$, $p<.001$), and with advice to the governor to build a coal plant with CCS rather than without ($r=.53$, $p<.001$).

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Table 1: Descriptive statistics for Study 1.

Variable (response scale)	Mean (SD)	Pearson correlations with feelings about CCS	
		Baseline	Post-education
Baseline feelings about CCS (1-7) [a]	4.68 (1.46)	-	.39***
Baseline perceived CCS knowledge (1-7) [a]	3.62 (1.66)	.17**	-.07
Interpretation of education content (1-7) [a]	4.93 (1.09)	.39***	.83***
Rated trust and quality of education (1-7) [a]	4.81 (1.35)	.24***	.60***
Post-education knowledge (0-100%) [a]	74.66 (19.86)	.12	.17**
Post-education confidence in knowledge (0-100%) [b]	81.30 (9.61)	.19**	.21***
Post-education feelings about CCS (1-7) [b]	4.84 (1.53)	.39***	-

Note. Variables are presented in order of assessment. [a] For all variables assessed on 1-7 scales, the reported mean is significantly different from the scale midpoint of 4 (one-sample *t*-tests, $p<.001$). [b] For all variables assessed on 0-100% scales, reported means are significantly above 50% or guessing (one-sample *t*-tests, $p<.001$) and significantly different from each other (paired-sample *t*-test, $p<.001$). $^{***}p<.001$, $^{**}p<.01$, $^{*}p<.05$

Table 2: Regression models (β) predicting feelings about CCS after reading the educational communication (Study 1).

	Model 1	Model 2	Model 3	Model 4
Baseline feelings about CCS	.39***	.34***	.08*	.08
Baseline perceived CCS knowledge	-	-.15*	-	-.05
Interaction baseline knowledge x feelings[a]	-	.20**	-	.06
Interpretation of education content	-	-	.73***	.71***
Rated trust and quality of education	-	-	.17***	.17***
Post-education knowledge	-	-	.00	-.02
Post-education confidence in knowledge	-	-	-.03	-.02
R^2	.16	.21	.74	.74
Model ANOVA	$F(5, 241)=$ 9.10***	$F(7, 239)=$ 9.18***	$F(9,237)=$ 73.46***	$F(11, 235)=$ 61.21***

Note. All models controlled for demographic variables. [a]The interaction term in Model 2 was mean-centered to avoid multi-collinearity (Jaccard & Turisi, 2003). ***p<.001, **p<.01, *p<.05

Table 3: Descriptive statistics for Study 2.

Variable (response scale)	Mean (SD) by one-sided argument condition		Pearson correlations with feelings about CCS		
	Pro-CCS	Anti-CCS	Base-line	Post-argument	Post-education
Baseline feelings about CCS (1-7)	4.52 (1.32)	4.50 (1.16)	-	.48***	.36***
Post-argument feelings about CCS (1-7)	4.83*** (1.30)	3.50 (1.41)	.48***	-	.37***
Interpretation of education content (1-7)	4.81* (1.10)	4.55 (1.09)	.39***	.42***	.78***
Rated trust and quality of education (1-7)	4.66 (1.28)	4.51 (1.20)	.32***	.29***	.55***
Post-education knowledge (0-100%)	77.90 (19.01)	74.85 (19.73)	.21***	.13*	.12*
Post-education confidence in knowledge (0-100%)	81.35* (9.66)	79.18 (9.50)	.26***	.15**	.08
Post-education feelings about CCS (0-100%)	4.65* (1.55)	4.29 (1.46)	.36***	.37***	-

Note. Variables are presented in order of assessment. Independent-sample *t*-tests compared group means, with the significantly higher mean being flagged (***p<.001, **p<.01, *p<.05)

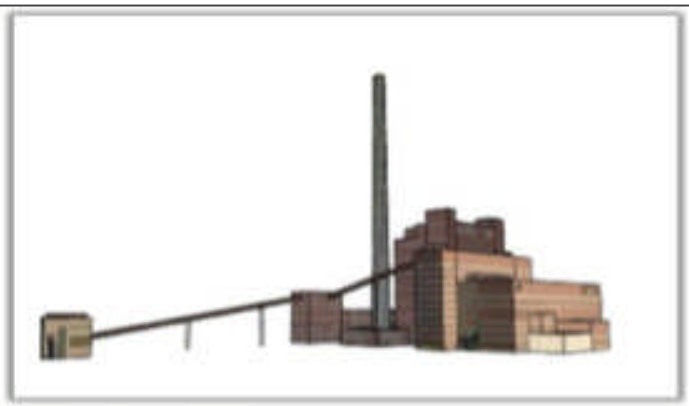
Table 4: Regression models predicting feelings about CCS after reading the educational communication (Study 2).

	Model 1	Model 2	Model 3
Pro-CCS (vs. anti-CCS) argument	.10*	.01	.03
Baseline feelings about CCS	.37***	.26***	.06
Post-argument feelings about CCS	-	.23**	.00
Interpretation of education content	-	-	.68***
Rated trust and quality	-	-	.15***
Knowledge about content	-	-	-.05
Confidence in knowledge	-	-	-.06
R^2	.16	.20	.64
Model ANOVA	$F(6, 306)=10.10^{***}$	$F(7, 305)=10.56^{***}$	$F(11, 301)=47.61^{***}$

Note: All models controlled for demographic variables. $^{***}p<.001$, $^{**}p<.01$, $^{*}p<.05$

Figure 1. Example of educational communication content (adapted from Fleishman et al., 2010).

How a coal power plant works: Coal plants burn coal to make steam. The steam is used as fuel in a type of engine, called a "turbine." This turbine runs a generator to make electricity. When coal is burned, CO_2 is released by the plant. This CO_2 escapes into the air because no CO2 capture and storage (CCS) equipment is added to the plant.



How a coal power plant with CCS works: This is the coal plant described on the previous screen but additional equipment is added for CO_2 capture and storage (CCS). This equipment traps CO_2 before it escapes into the air. First, the CO_2 is turned into a liquid. Then a pipeline takes it from the plant and puts it permanently deep underground (about 2,500 feet). This is shown in the picture to the right. Testing will be done ahead of ahead of time to make sure the CO_2 will stay underground. Over many years, the CO_2 will change from a liquid into a solid.