

Private Well Testing in Peri-Urban African-American Communities Lacking Access to Regulated Municipal Drinking Water: A Mental Models Approach to Risk Communication

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Majority African-American neighborhoods on the edges of North Carolina municipalities are less likely than white peri-urban neighborhoods to be served by a community system regulated under the Safe Drinking Water Act. These households rely on unregulated private wells, which are at much higher risk of contamination than neighboring community water supplies. Yet, risk awareness of consuming well water is low, and no prior research has tested risk communication interventions for these communities. We present a randomized-controlled trial of an oversized postcard to promote water testing among this audience. The postcard design followed the mental models approach to risk communication. To our knowledge, this is the first U.S. randomized-controlled trial of a mailed communication to promote water testing in any audience and one of few trials of the mental models approach. We evaluated the postcard's effects on self-reported water testing with and without a free water test offer (vs. no-intervention control) via a survey mailed one month after the interventions. The combined communication and free test doubled the odds of self-reported water testing, compared to the control group ($p = 0.046$). It increased the odds of testing by 65%, compared to the free test alone. Recall of receiving a postcard about water testing increased the odds of self-reported testing twelve-fold ($p < 0.001$). Although these results suggest that targeted risk information delivered by mail can promote water testing when paired with a free test, the mechanism remains unclear. Additional research on beliefs influencing perceptions about well water may yield interventions that are even more effective.

KEY WORDS: Drinking water; human health risk communication; mental models; private wells; racial disparities

1. INTRODUCTION

Unlike U.S. households with connections to regulated community water supplies, the 13% of U.S. households drawing their water from private wells (Dieter et al., 2018) must be stewards of their own water quality. Private wells are not protected by the

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Safe Drinking Water Act, and as a result there are no federal or state mandates or support for routine monitoring of private well water quality (Bowen *et al.*, 2019; Fox, Nachman, Anderson, Lam, & Resnick, 2016; Zheng & Flanagan, 2017). Rates of water quality testing among households with private wells are low (Fox *et al.*, 2016; MacDonald Gibson & Pieper, 2017b). As a result, many are exposed to contaminated water without being aware of it (Fox *et al.*, 2016; MacDonald Gibson & Pieper, 2017a; Stillo, Bruine de Bruin, Zimmer, Gibson, & MacDonald Gibson, 2019). The risk of private well water contamination is relatively high. For example, a nationwide study by the U.S. Geological Survey found that 23% of private wells were contaminated above standards that are allowable in regulated community water supplies under the Safe Drinking Water Act (DeSimone & Hamilton, 2009).

A 2016 literature review on effective outreach to private well owners recommends direct mailings and tailoring communications to the information needs of specific audiences (Morris *et al.* 2016). Yet, information on how to design effective outreach materials to promote well water testing in different audiences is limited (Colley, Kane, & Gibson, 2019). This article reports on a study that used a systematic approach (known as the “mental models” method) to design and test a risk communication intervention to promote testing of private well water.

1.1. A Priority Audience

The priority audience for this work was majority African-American communities close to cities and towns, but without access to a regulated community drinking water supply. There are many private well users living in African-American communities at the edges of cities and towns that lack access to nearby water lines (Leker & MacDonald Gibson 2018; MacDonald Gibson, DeFelice, Sebastian, & Leker, 2014; Heaney *et al.* 2013; Wilson *et al.* 2008). There have been a number of documented cases where race has played a role in who was determined to be living within the boundaries of the town and its services, a phenomenon sometimes called racial underbounding (Aiken, 1987; Anderson, 2008; Johnson, Parnell, Joyner, Christman, & Marsh, 2004; Joyner & Christman, 2005; Joyner & Parnell, 2013; Lockhart, Wood, & MacDonald Gibson, 2020; Marsh, Parnell, & Joyner, 2010). Previous work by our research group showed that in Wake County, North Carolina (NC), majority African-American census blocks in

peri-urban areas are more likely to be without municipal water service than similarly situated, majority white blocks (MacDonald Gibson *et al.*, 2014). In these excluded neighborhoods, residents rely on private wells for their water, even though they may be surrounded by areas served by a municipal system (Lockhart *et al.*, 2020; MacDonald Gibson *et al.*, 2014; Stillo, MacDonald Gibson, & Gibson, 2017). Similar patterns have been documented throughout North Carolina and other states (Anderson, 2008; Durst 2014; Leker & MacDonald Gibson 2018).

Prior research indicates that people using private wells for drinking water in these underserved peri-urban neighborhoods are more likely to have bacterial and lead contamination in their drinking water than nearby households on municipal water (Stillo & MacDonald Gibson, 2018; Stillo *et al.*, 2017). These increased exposures have been linked to increased risks of acute gastrointestinal illness (Stillo *et al.*, 2017) and elevated blood lead levels in children (MacDonald Gibson, Fisher, Clonch, MacDonald, & Cook, 2020). Arsenic also is frequently detected in private well water in the region, putting people potentially at risk for illnesses ranging from skin diseases to bladder and lung cancer (Kim, Miranda, Tootoo, Bradley, & Gelfand, 2011; National Research Council, 2001; Sanders *et al.*, 2012).

Promoting laboratory testing for common contaminants can be a first step toward increasing awareness of the risks of contaminated drinking water in these communities. For example, a study of private well owners in Wisconsin in an area with high groundwater arsenic found that providing water test results along with safety standards for arsenic in drinking water motivated participants to take protective actions to prevent exposure and to support policies to decrease arsenic in groundwater, as long as their sensory perceptions of the water’s quality did not override test results indicating the water was unsafe (Severtson, Baumann, & Brown, 2006). The NC Division of Public Health recommends that private well owners test their water every year for bacteria, every two years for inorganic contaminants (such as arsenic, lead, and nitrates/nitrites), and every five years for organic chemicals (such as pesticides and volatile organic compounds) (North Carolina Division of Public Health, n.d.). However, compliance with these recommendations is very low. Only 28% of participants in a previously published survey of our priority audience (African-American communities at the edges of cities and towns) reported they

had tested their well water within the past two years (Stillo et al., 2019).

1.2. The Mental Models Approach to Risk Communication

In this study, we use the mental models approach to risk communication (Morgan, Bostrom, Fischhoff, & Atman, 2002) to design an intervention to increase private well water quality testing in peri-urban neighborhoods without water service. This approach gathers data on beliefs and knowledge of the target population, compares them to expert knowledge, and designs the risk communication to include the most prevalent knowledge gaps and misconceptions that are also the most decision-relevant ones (Morgan et al., 2002). It was designed to counter one of the most common pitfalls of efforts by scientists and other experts to communicate risk information to the general public: the reliance on expert beliefs about what people should know, rather than on empirical evidence about what people need to know to make decisions that are more protective of their health and welfare (Bruine de Bruin & Bostrom, 2013). A recent mixed-methods study of risk communication materials available to prevent private well water contamination in the Republic of Ireland noted the lack of empirically based communications about private well water as a major gap worldwide; one communication expert interviewed for the study noted, “In terms of a theoretical component, I’m not totally convinced that the risk communication material ... has been informed by an in-depth appreciation of risk theories ... or any kind of theory that’s based on understanding what triggers a perception” (Mooney, O’Dwyer, & Hynds, 2020).

Since its development in the 1990s, the mental models approach has been used to understand how people make decisions about a wide variety of health, environmental, and technological risks—from sexually transmitted diseases to climate change and cell phone towers (Boase, White, Gaze, & Redshaw, 2017; Bruine de Bruin & Bostrom, 2013; Morgan et al., 2002). However, no prior work has used it to promote testing or other activities needed to manage private well water quality. A recent literature review identified only five randomized-controlled trials of the mental models method (Boase et al., 2017). Of these, only two (both related to sexual health protection practices) measured the intervention’s effects on behavior, self-reported or intended behavior, with the others assessing only effects on beliefs (Downs

et al., 2004; Vogt & Schaefer, 2012). Thus, this article contributes not only to knowledge of how to improve adherence to health-based guidelines for testing of private wells at the household level but also to the much broader literature on the mental models approach for risk communication.

An important principle of the mental models approach is to focus the communication just on the knowledge and beliefs participants seem to be missing but are relevant to decision making (Bruine de Bruin & Bostrom, 2013; Morgan et al., 2002). Communication design follows a series of steps involving interviews with experts to understand what the audience *should* know (step 1), semi-structured interviews with and written surveys of the priority audience to identify what they already know and what they misunderstand (step 2), communication design and pilot testing (step 3), and assessment of communication effectiveness (step 4). During the design phase (step 3), the communication is improved through feedback from subject experts, to improve accuracy, and members of the target audience, to improve usability. The mental models approach also calls for the communication to be tested for effects on understanding and decision making (step 4) in a randomized-controlled trial (Bruine de Bruin & Bostrom, 2013; Morgan et al., 2002), although as we noted very few such trials have been carried out.

Steps 1 and 2 of this application of the mental models approach have been reported previously in the work of Fizer, De Bruin, Stillo, and Gibson (2018) and Stillo et al. (2019), which identified an expert model of well water risks and surveyed members of the priority audience to identify information gaps and misunderstandings. Here we present the results from steps 3 and 4: design and testing of the risk communication.

1.3. Identification of Key Communication Concepts

Our priority population for promoting well water testing included residents of majority African-American census blocks near cities and towns but without municipal water service. Information on connection to municipal water systems was available for Wake County, NC, the second most populous in NC and seat of the state capital. Such households in Wake County were identified by overlaying a map of municipal zoning boundaries with tax parcel data on water access and with census demographic data identifying blocks that had at least 50% African

American residents (MacDonald Gibson *et al.*, 2014).

In 2017, Fizer *et al.* interviewed 19 private well owners in the target neighborhoods in Wake County about their views on well water and health, then compared their responses to an expert model of how a water well user can be protected from potential contaminants (Fizer *et al.*, 2018). They identified several misconceptions and knowledge gaps of potential importance, including incomplete knowledge of how to get water tested, possible routes and health effects of contamination, misconceptions that contaminants can be detected by the senses (appearance, taste, and smell of the water), and concerns about costs.

Following up on Fizer *et al.* (2018), Stillo *et al.* developed and administered a survey to assess the prevalence of those misconceptions and knowledge gaps and their relationship to decisions to test well water quality among this audience (Stillo *et al.*, 2019). The survey was sent to 934 addresses in these areas, and 115 recipients responded. Although the response rate was relatively low, more than half of respondents (54.4%) were African American, and self-reported incomes were similar to median household incomes in the targeted census blocks (\$62,500 vs. \$59,100). Principal components analysis identified three key sets of beliefs that were associated with well water testing within the past 2 years: (1) an inappropriate reliance on sensory perceptions to assess water quality, (2) lack of knowledge and urgency about well water testing, and (3) perceived cost barriers to well water testing (Stillo *et al.*, 2019). Table S1 summarizes the survey questions that were associated with these belief sets. These results from survey respondents in Wake County provided the basis for designing the risk communication reported here.

1.4. Identification of Relevant Communications Promoting Well Testing

There is a shortage of information on evidence-based approaches for communicating with U.S. residents about well water testing generally (beyond our priority audience). A recent systematic literature search of peer-reviewed, scholarly journals identified only two studies evaluating the effects of risk communications on well water testing in the United States or Canada (Colley *et al.*, 2019). One of the two studies tested the influences on private well water testing in Quebec, Canada, of a mass media campaign alone or in combination with a community intervention consisting of targeted mailings, distribu-

tion of flyers throughout the community, and inclusion of water testing information with property tax bills (Renaud, Gagnon, Michaud, & Boivin, 2011). The mass media intervention alone did not significantly increase water testing, but the combined intervention increased the odds of testing by 4.79 in intervention communities, compared to in controls. The second study evaluated the influence of a combined free water testing and risk communication campaign on private well testing in New Hampshire (Paul, Rigrod, Wingate, & Borsuk, 2015). The campaign increased the number of well water samples sent to the state laboratory compared with preintervention years. However, the study design did not include controls and was not randomized, so conclusions about the significance and magnitude of the intervention's effects could not be drawn. Neither study included the details of the risk information materials they distributed or how those materials were developed, making it difficult to assess their potential to address the needs of private well owners in other locations.

For our intended audience more specifically, an evaluation of existing risk communication materials currently used by health departments and non-government organizations can be found in Supporting Information (section S1). The communication pieces reviewed in that evaluation aimed to encourage well water testing in regions that would include the communities of primary interest in this research. None of them addressed all of the beliefs about water testing summarized in Table S1.

1.5. The Current Study

The main purpose of this study was to use the mental models approach to design and test a risk communication to promote testing of private well water, as self-reported by participants from African American neighborhoods lacking community water service. A second purpose was to evaluate the influence of additionally offering a free test to alleviate cost concerns, alone or combined with the risk communication. Overall, we sought to answer three research questions:

- (1) Does providing risk information, a free water test offer, or a combination of both motivate testing of water quality, as self-reported by private well owners?
- (2) Does providing risk information, a free water test offer, or a combination of both influence knowledge and a sense of urgency about

Table I. Messaging in the Risk Communication Postcard Corresponding to Beliefs about Water Testing

Category of Beliefs and Associated Survey Questions	Messages Included in the Postcard
Belief set 1: Sensory perception misconception	
Water looks, smells, and tastes fine, so there is no need to test	You cannot see lead in well water You cannot smell arsenic in well water You cannot taste bacteria in well water
No need to test, because water looks, smells, and tastes clean	You cannot see lead in well water You cannot smell arsenic in well water You cannot taste bacteria in well water
No need to test, because I've been using the water for years without problems	Not addressed directly [highlight correlated with sensory misperceptions]
Belief set 2: Lack of knowledge and urgency for testing	
Plan to test but haven't gotten around to it.	Time to test your well! It's time!
No time to test	It's Easy!
Don't know where to test	Test through your local health department or a state-certified lab
Don't know how to test	Call [phone number provided] or Visit [web link]
Don't know what to test for	NC Division of Public Health recommended testing schedule
Wouldn't know what to do if failed test	Have a free consultation with an Environmental Health Specialist about your options, if any of the tests show a concern.
Belief set 3: Cost barriers	
Can't afford to test my water	Many counties offer discounted tests. [Statement was removed from final communication because cost concerns were addressed with free test offer]
Can't afford to fix my well water if bacterial contaminants are found	Some water treatment options are not expensive. [Statement was removed from final communication because cost concerns were addressed with free test offer.]
Can't afford to fix my well water if chemical contaminants are found	
Would install a water filter if I could afford it	
Would prefer city water if it were free	Not addressed [highly correlated with other statements concerning costs]
Well water is free	

water testing; the misconception that contaminants can be detected through taste, appearance, or smell; and/or concerns about water testing costs?

- (3) Is sending private well testing information by mail an effective means of reaching private well owners—that is, do recipients remember receiving the information?

2. METHODS

2.1. Method for Communication Design

To match the information needs of our audience, we used the outcomes of our prior mental models research (Fizer et al., 2018; Stillo et al., 2019) to design a new communication for promoting well water testing. A large (6" × 11"), two-sided, full-color postcard matched preferences indicated in a secondary analysis of data from our previous survey, as reported in

detail in the supplemental material (Fig. S1). Logo, contact information and website pointed to both the University of North Carolina–Chapel Hill (UNC) and the NC Division of Public Health as sources of the communication. These were each rated by over 80% of the previous survey respondents as trusted organizations for well water testing (see Fig. S2). It was particularly important to indicate a reputable source, as we were aware of mailings in the area from water treatment companies and others that were not focused on public health goals.

For our new postcard, messages were developed that focused exclusively on the three sets of beliefs associated with well water testing in our target population: reliance on sensory perceptions, lack of urgency and knowledge about testing, and perceived cost barriers. Table I summarizes the statements included on the postcard to address each set of beliefs. We sought to address these beliefs concisely, without burying the information in lengthy text explanations.



Fig 1. Final, revised postcard, front and back.

The misconception that one can rely on the senses to know whether there is a problem (belief set 1 from the Stillo *et al.*'s (2017) survey results) was addressed with three phrases on the address side of the postcard. For brevity, we chose to mention just three contaminants, each with one of the senses that people sometimes rely on: "You cannot see lead in well water. You cannot smell arsenic in well water. You cannot taste bacteria in well water." These contaminants were selected because they are among the most common in private well water in the Piedmont region (Kim *et al.*, 2011; Pieper, Krometis, Gallagher, Benham, & Edwards, 2015; Stillo & MacDonald Gibson, 2018; Stillo *et al.*, 2017). Belief set 2 comprised questions about logistical knowledge of well testing (where and how to test, what to test for, and what to do afterwards) and questions indicating a sense of urgency, or a lack thereof (e.g., "I plan to test my water, but haven't gotten around to it yet"). The headline phrases, "Time to test your well!" (address side) and "It's Easy!" (reverse side) were emphasized to encourage action (Fig. 1). Concerns about the costs of testing and water treatment (the third belief sets) were addressed by pointing out the availability of discounted testing in some counties and of low-cost treatment options."

A graphic designer created the layout and added arrows between short instructions and the necessary information to take next steps: a phone number and a website for starting the testing process. A concise table, seen in the bottom panel of Fig. 1, gave the recommended testing schedule for quick reference and to counter "I don't know what to test my well water for." Additionally, we used colors and images that would cue readers to the content of the postcards. Such elements included a faucet, drips and blue color. The postcard used clear, everyday language and logical organization, as recommended by the literature (Morgan *et al.*, 2002; Neuhauser and Paul, 2011). Statements were grouped by topic; recommended steps towards testing were given in sequential order.

To craft messages in familiar language, we consulted the transcripts from the mental models interviews of members of our target population (interview analysis in Fizer *et al.*, 2018). The phrase, "Be confident your water quality is good" came from statements that several interview participants made about why they tested their water or why they would test. For example, a participant who reported testing their water once a year said, "I feel fairly confident about the quality of my water just because I'm responsible

for taking and having it tested to make sure it meets my drinking qualifications.” A Flesch-Kincaid readability analysis estimated the draft postcard to be at a 6.7 grade level.

In-person “think aloud” interviews were conducted with five members of the target population to look for potential misunderstandings when reading our communication. Individual interviews allow for an in-depth exploration of participant responses, even with a small number of pilot participants (Morgan et al., 2002). Participants for the think-aloud interviews were recruited from those who had responded to our previous mental models survey (Stillo et al., 2019) and indicated a willingness to be contacted further. Contact attempts were made until we had completed five interviews. Participants were offered a \$15 gift card as an incentive and expression of our appreciation for their participation.

A pair of researchers met with each participant in a public or semi-public setting (coffee shop or participant’s office). Participants were given 10 seconds to view the postcard and then asked what they had noticed from just a first look. To mimic one aspect of the real conditions in which our audience would encounter our communication piece, we alternated which side of the postcard was facing up when presented to participants, since either side could be facing up when someone picks up the mail. After the first look, participants were asked to think aloud while they read the full postcard. We specifically mentioned that any comments were fine, even if they seemed irrelevant, and that the participant would not hurt our feelings with any comments about the postcard.

Interviews were recorded, and all comments were evaluated by two researchers to identify: (1) Did participants easily recognize the topic of the postcard? (2) Were the first impressions and key take-aways about our main messages? (3) Was the source of the postcard easily identifiable and recognizable? (4) Did participants say anything that indicated a misunderstanding of one of our messages? (5) Was anything off-putting or evoking a response that would cause someone to discount or push aside the communication?

When asked for first impressions, interviewees pointed to, “Time to test your well,” the phone number, the UNC logo, and the faucet. After more time reading, additional comments confirmed that key information stood out. No major misunderstandings were identified. Revisions were based on any concerns that came up in pilot testing related to the

above questions. In particular, if concerns about any of those areas were brought up by more than one person, we found a way to address them. Both nonverbal reactions (like long pauses) and comments indicated that the back side seemed a bit “busy” or “complicated.” We revised this side (see differences between final version in Fig. 1 and preliminary version in the supporting information, section S3) by removing the two orange information bubbles about the availability of discounted tests and about the existence of inexpensive water treatment methods, as well as the cue to look up the county health department contact.

The other concern expressed by interviewees was whether the process would actually be easy once they made that first phone call. Participants were concerned about getting a lengthy menu of options, a voicemail, or getting transferred from person to person without results. To address this concern, we changed the phone number on the card from the general main number of the NC Division of Public Health to the direct line of a state employee who regularly communicates with well owners and who was familiar with our project.

Early and final drafts were reviewed by two experts on household drinking water well issues at the NC Division of Public Health, who are responsible for communicating with well owners. They confirmed that the presented facts were correct and needed no changes.

The final postcard included messages addressing two of the three decision-relevant sets of beliefs, including reliance on sensory perceptions and lack of urgency and knowledge about testing. To address the perceived cost barriers, we opted to offer a free test as one of the study conditions in the randomized-controlled trial of this communication piece, as described in the next section.

2.2. Method for Randomized-Controlled Trial

The randomized controlled trial was a 2 × 2 design comparing the risk communication, free water test offer, and their combination to a no-intervention control condition. Respectively, the three interventions consisted of the risk communication postcard, a postcard offering a free water test but not including risk communication information, and a postcard including the risk messages *and* a free test offer. All of these interventions are reproduced in the supporting information (section S4). Those in the no-intervention condition did not receive a postcard.

The interventions were mailed on June 11, 2018. Follow-up surveys asking about well water knowledge, beliefs, and self-reported testing were sent one month later. This research was approved by the Institutional Review Board of the University of North Carolina, Chapel Hill (IRB #18-1434).

2.2.1. Sample

Interventions and follow-up surveys (mailed one month after the interventions) were sent to residents relying on private well water in two different NC counties: Wake County (the location of the previously described formative research on which the communication is designed) and Gaston County. The mailing lists for the two counties were combined, and households were randomly assigned to one of the four conditions (control group, free test only, risk communication only, or combined intervention).

Different processes were used to generate the mailing list for each county due to differences in data availability. For Wake County, we followed the procedure described in previous research involving this population (MacDonald Gibson *et al.*, 2014; Stillo *et al.*, 2019). This procedure was based on analysis of Wake County Department of Tax Administration data indicating whether or not each house was connected to a regulated community water supply, along with U.S. Census data on racial composition of census blocks. Unlike in Wake County, Gaston County property tax records do not include information about household water source. Therefore, to generate a participant list, we obtained addresses of households that had applied for private well permits from the Gaston County Department of Health, initially received and verified by the University of North Carolina at Charlotte (Owusu, Lan, Zheng, Tang, & Delmelle, 2017). The permits were organized by census tract, and census tracts were ordered by percentage of the population identified as African American, with the highest proportions at the top of the list. The first 947 households located in peri-urban areas (as defined in our prior research) were included on the mailing list (MacDonald Gibson *et al.*, 2014).

Of the 2,173 follow-up surveys, 237 (11%) were returned to sender due to vacant lots or other unknown reasons. Among the remaining 1,936 households, 193 (10%) returned their surveys. Of these, 29 (15%) were omitted because the respondent answered “no” to having a private well; another two (1%) were omitted because they did not answer the question about whether they had tested their well

water during the previous month. Our analyses were based on the remaining 162 surveys (84% of the returned surveys).

To check for nonresponse bias, we compared demographic characteristics of the census blocks containing the 1,936 houses to which surveys were successfully delivered and the 162 households returning useable surveys (Table S4). There were no significant statistical differences in race, gender, or income characteristics between the census blocks where we mailed our interventions and those where respondents to our follow-up surveys live (Table S4). We also compared census block demographic information to self-reported demographic information of survey respondents. (Household-scale comparisons for mailed surveys were not possible, because we lacked household-level demographic information for our recruitment mailing list.) In Wake County, significantly fewer survey respondents self-identified as Black than in the census blocks to which surveys were mailed, while the opposite was true in Gaston County (though the difference was not significant in Gaston County (Table S4). In both counties, female respondents were overrepresented, compared to populations in the census blocks to which surveys were mailed (Table S4). Self-reported incomes of survey respondents were lower than median household incomes of blocks to which surveys were mailed in Wake County, but the opposite was true of Gaston County (Table S4). Self-reported race, gender, and income were controlled for in regression models if they had a significant influence on the outcome measure in bivariate models (*i.e.*, $p < 0.05$), consistent with recommended criteria for variable selection (Hosmer & Lemeshow, 2000). In cases where self-reported race was retained as an independent variable, self-reported income also was included to separate the roles of race and socioeconomic status (VanderWeele & Robinson, 2014). Interactions between self-reported race and the interventions also were tested but were not significant for any of the outcomes.

It should be noted that due to limitations on data for identifying private well locations, the Gaston County mailing list turned out not to be representative of the priority audience for this research (majority African American communities at the edges of cities and towns). The Gaston County list was generated from private well permits and tract-level demographics. Many older wells do not have permits on record (MacDonald Gibson & Pieper, 2017b), and tract-level demographics did not adequately

Table II. Outcome Measures for Randomized-Controlled Trial

Outcome	Survey Question	Response Options
Self-report of getting a water test	“Has your well been tested since June 11 [the date the interventions were mailed]?”	Yes, no, or not sure (not sure grouped with “no” for analysis)
Knowledge and beliefs about well water testing	Mean scores across questions in each knowledge and belief category in Table I (see Table S5 for summary statistics by question)	For each question, five-point Likert scale ranging from 0 (“completely disagree”) to 4 (“completely agree”)
Recall of receiving a postcard about water testing	“Do you remember receiving a postcard asking you to test your water?”	Yes or no

capture demographic variation at a smaller (e.g., census block) scale. This was an unavoidable limitation of our study and reflected the lack of uniform state or national databases on drinking water sources at the household scale (Fox et al., 2016).

The number of returned surveys ($n = 162$) was sufficient for 80% power to detect a small- to medium-sized main effect (Cohen’s $h = 0.39$) of the two interventions (risk information vs. no risk information, or free test vs. no free test) at a significance level of 0.05. The design had medium capability ($h = 0.55$) to detect an interaction effect between the interventions.

2.2.2. Outcome Variables

We measured the influence of the interventions on three outcomes: self-reports of whether respondents tested their well water, what they know and believe about well water and water testing, and whether they remember receiving information about water testing. Table II summarizes the questions used to determine these outcomes.

2.2.3. Data Analysis

Research question 1—influence of interventions on self-reports of getting a water test: To assess whether the risk communication or free test offer influenced self-reported water testing behavior, logistic regression models were fitted to the data set using responses to the question “Has your well been tested since June 11?” as the dependent variable. Independent variables were whether the respondent had or had not been mailed a risk communication or free test offer, an interaction term for these two interventions, and whether respondents recalled receiving a post card about well water testing. A control variable was added for county of residence, since this differed by intervention group. Bivariate analyses were con-

ducted to assess the role of race, income, and gender on water testing, but none were significant. Interaction terms between these variables and the interventions also were assessed but were not significant. All regressions were conducted using the “glm” package in *R*. Model fit was tested using the Hosmer-Lemeshow test implemented with the “hoslem.test” function in the “ResourceSelection” package.

Research question 2—influence of the interventions on knowledge and beliefs about well water testing: The role of the interventions on the three belief sets in Table I was assessed using multivariate regression, with participants’ average score on the relevant question set as the dependent variable. Independent variables were again whether the respondent had been mailed a risk communication or free test offer, the interaction of these two, and whether they recalled getting a post card about water testing. Controls were added for demographic variables that were significant in bivariate models as explained above. Interactions of the interventions with race were considered and included if significant. Regressions were conducted using the “lm” package in *R*.

Research question 3—effectiveness of mailed postcards for reaching private well owners: This question was assessed using the same logistic regression model as was used to answer Research Question 1. The significance and magnitude of the effect of sending information by mail was assessed using the coefficient on the answer to “Do you remember receiving a postcard asking you to test your water? (Yes or No).”

3. RESULTS

3.1. Demographic Characteristics of the Four Experimental Groups

Among respondents, 36% identified as Black, 53% as White, and 11% as Other (Table III). Most

Table III. Demographics and Recall of Receiving Water Testing Information by Intervention Group

Demographic Variable	Intervention Group				Total (n = 162, 100%)	p*
	Control (n = 44, 27.2%)	Free Water Test Postcard (n = 38, 23.5%)	Risk Communication Postcard (n = 35, 21.6%)	Risk Communication with Free Test Postcard (n = 45, 27.8%)		
Race						0.569
Black, n (%)	17 (38.6%)	13 (33.2%)	11 (31.4%)	17 (37.8%)	58 (35.8%)	
White	22 (50.0%)	19 (50.0%)	23 (65.7%)	22 (48.9%)	86 (53.1%)	
Other	5 (11.4%)	6 (15.8%)	1 (2.9%)	6 (13.3%)	18 (11.1%)	
Sex						0.581
Male	14 (31.8%)	15 (42.9%)	11 (31.4%)	12 (27.3%)	52 (32.9%)	
Female	30 (68.2%)	20 (57.1%)	24 (68.6%)	31 (70.5%)	105 (66.5%)	
Unspecified	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2.3%)	1 (0.6%)	
Income, \$1000s, mean (SD)	62.442 (46.852)	63.429 (42.626)	61.406 (45.799)	68.462 (43.840)	63.027 (43.504)	0.908
Highest Level of Education						0.559
< High school	2 (3.5%)	1 (2.7%)	1 (2.9%)	0 (0.0%)	4 (2.5%)	
High school	7 (15.9%)	6 (16.2%)	10 (28.6%)	13 (31.0%)	36 (22.8%)	
Any college	29 (65.9%)	22 (59.5%)	20 (57.1%)	25 (59.5%)	96 (60.8%)	
Graduate degree	6 (13.6%)	8 (21.6%)	4 (11.4%)	4 (9.5%)	22 (13.9%)	
Age of well, years, mean (SD)	30.200 (25.432)	31.000 (16.384)	23.906 (13.128)	26.477 (15.091)	27.841 (18.440)	0.364
County						0.042
Wake	20 (45.5%)	29 (76.3%)	21 (60.0%)	28 (62.2%)	98 (60.5%)	
Gaston	24 (53.5%)	9 (23.7%)	14 (40.0%)	17 (37.8%)	64 (39.5%)	
Recall receiving water testing information by mail, n (%)						0.264
Yes	14 (31.8%)	20 (52.6%)	14 (41.2%)	21 (46.7%)	69 (42.9%)	
No	30 (68.2%)	18 (47.4%)	20 (58.8%)	24 (53.3%)	92 (57.1%)	

* p refers to significance levels as computed in one-way ANOVA tests.

(67%) were female, and most (74%) had attended college or had a graduate degree. Household income varied widely, with a mean of \$64,027 (*SD* = \$44,5604) and a range of less than \$15,000 to greater than \$175,000. Demographic characteristics did not differ significantly by intervention group, with the exception of county of residence (Table III). The similarity of demographic characteristics across the four study groups suggests that the process of randomizing participants across interventions was effective. However, these results also indicate that our respondents did not fully reflect the demographic group we had hoped to reach, since less than 50% were African American. As a result, we tested for the role African American race (vs. all other races) played in all outcomes of interest in this study and controlled for race together with income when the associations were significant.

3.2. Does Providing a Free Test, Risk Information, or Both Increase Self-Reported Water Testing?

Overall, 17% of participants (27 of 162) answered “yes” to the question about whether they had tested their well water in the time period after we mailed the interventions (Table IV). Surprisingly, neither the free test offer nor the risk information significantly influenced well water testing when provided alone, as shown by *p* values on the coefficients for the main effects of these interventions in the logistic regression model in Table V. However, those who received both interventions—the free test with risk information on a single post card—were significantly more likely to self-report testing their water than those in the control group or single-intervention groups, as shown by the *p* value (0.046) on the coefficient for the interaction of these two interventions in Table V. The combined intervention increased the

Table IV. Respondents who Self-Reported Testing their Water Within the Postintervention Period

	Intervention Group				Total (n = 162)
	Control (n = 44)	Free Water Test Postcard (n = 38)	Risk Communication Post Card (n = 35)	Risk Communication with Free Test Postcard (n = 45)	
Self-reported testing well water	6 (13.6%)	8 (21.1%)	1 (2.87%)	12 (26.7%)	27 (16.7%)
Self-reported not testing well water	38 (86.4%)	30 (78.9%)	34 (97.1%)	33 (73.3%)	135 (83.3%)

Table V. Logistic Regression Model for Testing Whether a Combination of Risk Information and Free Test Offer Influences Water Testing*

Variable	OR (95% CI)	p
Baseline**	0.0375 (0.00786–0.133)	<0.001
Intervention		
Free water test postcard	1.16 (0.317–4.37)	0.82
Risk communication postcard	0.128 (0.00634–0.870)	0.071
Risk communication with free test postcard	13.0 (1.36–308)	0.046
Remember receiving a postcard about well water testing	12.1 (4.16–44.9)	<0.001
Demographic Variables		
Gaston County (vs. Wake)	1.31 (0.475–3.59)	0.60

*Model fit as indicated by the Hosmer-Lemeshow test was significant (chi-sq(df = 3) = 1.75, p = 0.625, that is, the null hypothesis that the model fits is not rejected).

**Refers to exponentiated constant from logistic regression model. Regression coefficients significant at p < 0.05 are indicated in bold.

odds of self-reported water testing by 1.93, compared to not receiving any intervention (computed from the odds ratios in Table V: 1.16 × 0.128 × 13.0 = 1.93). Compared to offering only a free test, adding mental models risk information to the test offer increased the odds of self-reported water testing by 1.66 (0.128 × 13.0 = 1.66).

3.3. Does Providing a Free Test, Risk Information, or Both Influence Knowledge and Beliefs About Water Testing?

3.3.1. Effects on Lack of Knowledge and Urgency About Water Testing

Overall, most participants lacked knowledge about how to test water and did not prioritize it. Among the participants, 62% scored greater than 2 on this set of questions, indicating they tended to “agree” with their lack of knowledge and low priority given to water testing. The mean across all groups was 2.31 and was significantly above the scale midpoint of 2.00 ($t(159) = 3.86, p < 0.001$).

According to our “mental models” research on water testing (Table S1), the interventions should have decreased scores on the “Lack of Knowledge and Urgency” questions. Decreased scores on this measure would have indicated that the interventions increased participants’ knowledge and sense of urgency about water testing. When each intervention was offered on its own, the desired effect was achieved as shown by the regression model in Table VI, although these effects did not reach statistical significance ($\beta = -0.309, p = 0.18$, for the free test and $\beta = -0.422, p = 0.069$, for risk information). However, combining these interventions significantly offset the benefits. As Table VI shows, the combined intervention increased scores on questions about knowledge and urgency ($\beta = 0.676, p = 0.039$), compared to offering either risk information or a free test on its own. Fig. 2 illustrates this effect. Those receiving just one intervention scored lower on questions about lack of knowledge and urgency than the control group, which was the desired effect. However, combining the risk communication and free test offset these benefits: those getting both interventions scored similarly to those in the control group.

Table VI. Regression Models for Influence of Interventions on Categories of Beliefs about Water Testing

Variable	Coefficient (95% CI)	<i>p</i>
1. Did the interventions decrease participants sense of not knowing how to get a test and not having time for it?		
<i>Intervention</i>		
No intervention (baseline)*	2.33 (1.88–2.79)	<0.001
Free water test postcard	–0.309 (–0.769–0.150)	0.18
Risk communication postcard	–0.422 (–0.877–0.0330)	0.069
Risk communication with free test postcard	0.676 (0.0347–1.32)	0.039
<i>Remember receiving a postcard about well water testing</i>	–0.162 (–0.485–0.162)	0.33
<i>Demographic Variables</i>		
Gaston County (vs. Wake County)	0.212 (–0.123–0.546)	0.21
African American race (vs. any other race)	0.322 (–0.013–0.658)	0.060
Income (units = \$100,000)	0.0396 (–0.334–0.413)	0.83
2. Did the interventions decrease concern about the costs of water testing?		
<i>Intervention</i>		
No intervention (baseline)*	2.40 (1.99–2.80)	<0.001
Free water test postcard	–0.283 (–0.6986–0.12)	0.17
Risk communication postcard	–0.308 (–0.709–0.0923)	0.13
Risk communication with free test postcard	0.573 (0.010–1.14)	0.046
<i>Remember receiving a postcard about well water testing</i>	–0.00316 (–0.287–0.281)	0.98
<i>Demographic Variables</i>		
Gaston County (vs. Wake)	0.039 (–0.255–0.333)	0.80
African American race (vs. any other race)	0.631 (0.336–0.926)	<0.001
Income (\$100,000)	–0.241 (–0.570–0.0877)	0.15
3. Did the interventions decrease the belief that contaminants can be detected via sensory perceptions?		
<i>Intervention</i>		
No intervention (baseline)*	1.65 (1.05–2.25)	<0.001
Free water test postcard	–0.148 (–0.748–0.451)	0.63
Risk communication postcard	0.220 (–0.381–0.822)	0.47
Risk communication with free test postcard	0.157 (–0.696–1.01)	0.72
<i>Remember receiving a postcard about well water testing</i>	–0.194 (–0.623–0.235)	0.37
<i>Demographic Variables</i>		
Gaston (vs. Wake)	–0.138 (–0.576–0.301)	0.54
African American race (vs. any other race)	–0.642 (–1.09 to –0.195)	0.0052
Income (\$100,000)	0.218 (–0.265 to 0.700)	0.37

*“Baseline” refers to regression model constant terms. Regression coefficients significant at $p < 0.05$ are indicated in bold.

3.3.2. Effects on Concern About the Costs of Water Testing

Participants tended to agree that they were concerned about costs associated with testing and maintaining their water. Overall, 62% scored greater than 2 on this category of beliefs, indicating they agreed they were concerned about costs. The mean score, 2.35, was significantly above the scale mid-point ($t(158) = 4.72, p < 0.001$).

The interventions’ effects on concerns about costs were parallel to those on the “Lack of Knowledge and Urgency” category. As the regression model in Table VI shows, when offered one at a time, both interventions decreased concern about costs,

though these effects did not reach statistical significance. However, combining the interventions offset these effects ($\beta = -0.2039, p = 0.17$, for the free test and $\beta = -0.308, p = 0.13$, for risk information). Fig. 3 shows this unexpected interaction effect.

There was a highly significant difference in scores on the “Cost Barrier” category of beliefs by race. African Americans were significantly more concerned about costs than participants of other races (Table VI, $\beta = 0.631, p < 0.001$). On average, African Americans scored 32% higher on the “Cost Barrier” questions than those of other race/ethnic groups.

In our prior surveys of the target population (Stillo et al., 2019), the likelihood of self-reporting

Fig 2. Participants who received either the free test offer alone or the risk information alone scored slightly lower on questions indicating lack of knowledge and urgency about water testing, compared to the control group. However, combining the interventions counteracted these benefits. Participants who got both interventions felt less confident about and motivated to test their water than those who got only one intervention and had similar scores to those receiving no intervention. NOTE: Bars show mean scores by group; error bars are 95% confidence intervals.

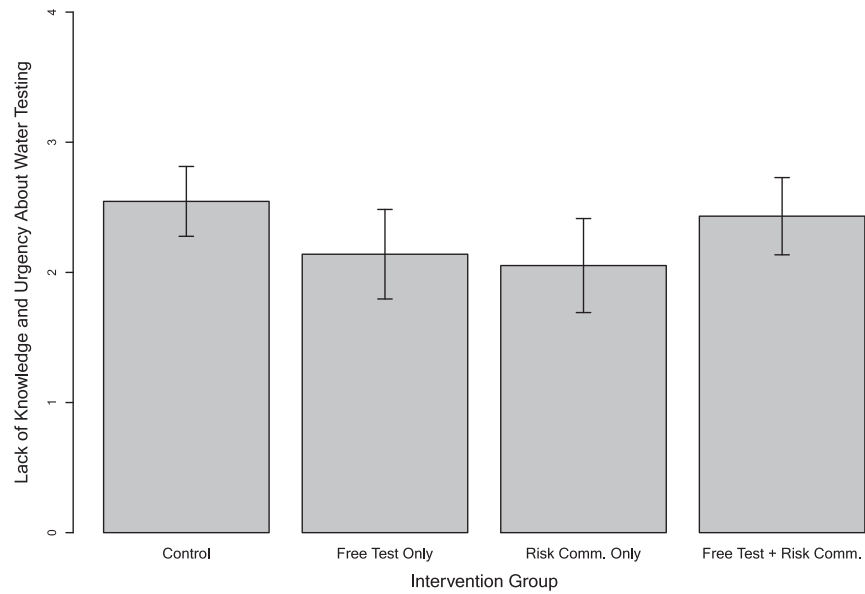
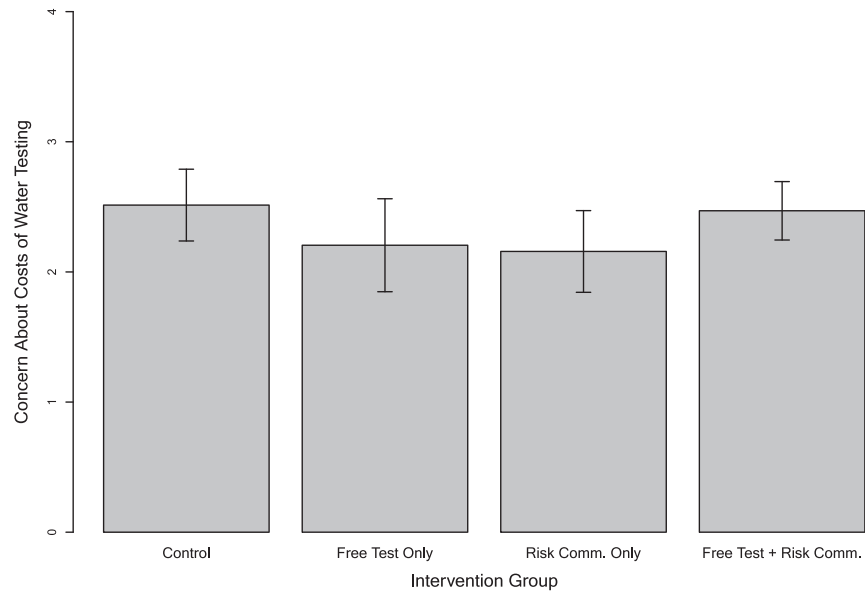


Fig 3. Participants who received either the free test offer alone or the risk information alone perceived lower cost barriers to water testing than the control group. However, combining the interventions counteracted these benefits. Those who got both interventions perceived higher cost barriers to water testing and had similar scores to those receiving no intervention. NOTE: Bars show mean scores by group; error bars are 95% confidence intervals.



a water test decreased significantly as scores on the “Cost Barrier” questions increased. However, in this study, perceptions of a cost barrier did not influence self-reports of getting a water test, as shown in the logistic regression model relating water testing to “Cost Barrier” in Table S8 ($\beta = -0.0438$, OR = 0.957, $p = 0.87$, for the coefficient on “Cost Barrier”), even when controlling for income and intervention group. The reasons for this difference are unknown. We would have expected respondents who perceived costs as a greater barrier to water testing

to be less likely to test their water than others, but this was not the case. On the other hand, as was the case in our prior research, scores on “Cost Barrier” questions increased significantly as “Lack of Knowledge and Urgency” increased. That is, the less people knew about water testing, the more worried they were about costs. This result is shown in the regression model of “Cost Barrier” as a function of “Lack of Knowledge and Urgency” in Table S7 ($\beta = 0.367$, $p < 0.001$, for the effect of “Lack of Knowledge and Urgency” on “Cost Barrier”).

3.3.3. *Effects on the Misperception That Contaminants Can Be Detected Through Taste, Smell, or Sight*

Most participants disagreed that contaminants could be detected through taste, odor, or appearance. The mean score on questions related to this category of beliefs, 1.50, was significantly below the scale midpoint ($t(158) = 4.86, p < 0.001$). However, 35% of participants had an average score above 2, indicating they agreed at least somewhat that contaminants can be “sensed.” In addition, 23% held strongly to this misperception, with scores of 3 or more.

The interventions had no significant influence on these misperceptions about detecting contaminants with the senses. This was true whether the interventions were provided alone or in combination. Neither the main effects nor the interaction term for the interventions were significant in the regression model predicting agreement with the idea of detecting contaminants with the senses, as shown in Table VI.

There was a highly significant difference by race in the tendency toward this misperception. African Americans were significantly ($p < 0.001$) less likely to erroneously believe they could taste, smell, or see contaminants in water than those of other races. Overall, they scored 43% lower than participants of other races on questions measuring this misperception.

Sensory perceptions significantly influenced decisions to get a water test in our prior survey (Stillo et al., 2019). Those who believed more strongly that they could see, smell, or taste contaminants were significantly less likely to self-report getting a water test than those with lower scores on this category of beliefs. The same was true in this sample (Table S9, $\beta = -0.416, OR = 0.659, p = 0.050$), and the interventions did not influence this pathway in the decision model.

3.4. **Are Mailed Postcards Effective for Reaching Private Well Owners?**

Overall, 43% of respondents recalled receiving a postcard about well water testing. Surprisingly, this percentage did not differ significantly by intervention group (Table III, bottom rows, $p = 0.264$). Even in the control group, nearly one-third of participants recalled getting a postcard about water testing. This finding may reflect that our interventions were one of multiple active campaigns to promote well water testing in these communities.

Whether participants remembered receiving a postcard about water testing was the single most important predictor of well water testing behavior among all variables considered in this research. The odds that participants tested their water after our interventions were mailed increased by a factor of 12.1 ($p < 0.001$) among those who remembered seeing a water testing postcard, compared to those who did not (Table V).

Recall of receiving information about water testing by mail did not alter preexisting categories of knowledge and beliefs about well water testing. This lack of impact is shown by the insignificant coefficients on “remember receiving a postcard about well water testing” in all of the regression models in Table VI. This result suggests that the currently circulating information about water testing, including the risk communication we designed, is not effectively countering key cognitive barriers to well water testing identified in our prior surveys and also that there may be additional barriers we have overlooked.

4. DISCUSSION

We sought to determine the influence of a postcard to promote testing of private wells on water testing behavior when offered with or without a free water test. We used the mental models approach to risk communication to design the postcard’s content to counteract cognitive barriers to water testing. We found that neither risk information nor a free water test alone increased the likelihood that participants self-reported getting a water test. However, the combination of these interventions—a postcard including risk information with a free test offer—increased the odds of self-reported water testing by nearly a factor of two, as shown in the logistic regression results in Table V. This was true when controlling for whether participants recalled receiving water testing information. The increased self-reports of testing suggests that this paired intervention—mental models risk information plus a free test—could be useful in areas where public health departments and others wish to actively encourage those relying on private wells to test their water.

We also sought to assess the influence of mental models risk information and free water tests on cognitive barriers to water testing. The effects of the combined intervention on these cognitive barriers were not what we expected, as shown in the regression models in Table VI and the plots in Figs. 2–3. Specifically, the individual interventions altered

beliefs in the expected directions, which should have increased water testing, but the combined intervention offset these benefits, even though it was effective in promoting water testing while the individual interventions were not. This result suggests that (1) the risk communication content needs to be modified to better address the knowledge and beliefs in Table I, (2) this belief set is incomplete, or (3) both these conditions are true. It is also possible that offering the free test with the risk communication might have raised concerns about costs and about not knowing how to get a test because respondents in this intervention group did not have to pay for or figure out how to get a test.

One potential problem with our communication as designed is that it did not cover all of the components of beliefs about water testing captured in our prior research. As Table I shows, the postcard did not address concerns about affordability of solutions (like a water treatment system) if a well is contaminated, which was one of the measures included in the “Cost Barrier” category of beliefs. It also did not address the misperception that there is no need to test if one has been drinking the water for a long time period without noticing obvious health problems, part of the “Sensory Perceptions” variable. Adding these concepts to the information presented may improve the effectiveness of the postcard, but this would need to be tested in future research.

It is also possible that the three key beliefs we identified in our initial mental models research (Table I) was incomplete. A new study of private well owners in the Republic of Ireland showed that three factors not included in our model were associated with maintenance of private wells: perceived level of contamination risk, worry about that risk, and sense of control over water quality (Schuitema, Hooks, & Mcdermott, 2020). Our previous mental models survey of the target population found that perception of health risks from water contamination was not associated with water testing behavior (Stillo et al., 2019), so our postcard did not include information to amplify risk perceptions. The study in Ireland found that risk perception interacted with a sense of control over water quality: those who perceived the risk was high but who also felt a strong sense of control over their water were more likely to maintain and test their wells. They also were less worried about the risks, perhaps as a result of their increased water system maintenance. On the other hand, increased worry about risks—in the absence of a sense of control—served as a disincentive to

water system maintenance. The study authors concluded that communications to promote private well testing should therefore focus on “reducing unrealistic feelings of control and increasing worry levels” (Schuitema et al., 2020). Additional mental models surveys of the target population should test the effects of risk perceptions, worry about risks, and sense of control, along with their interactions, in this community to refine the belief sets in Table I.

Another important finding of this research is that recall of receiving a postcard about water testing was the single most important predictor of self-reported water testing. Those who remembered getting a water testing postcard were 12 times as likely as those who did not to report getting a water test. This result suggests that mailed postcards may be a highly effective means of reaching private well owners. It is consistent with our formative surveys, in which participants ranked mailed postcards as their preferred format for receiving water testing information, followed by inserts in county tax bills and door hangers (Fig. S1). Although this result is promising, most of those in the intervention groups did not recall receiving our postcards. Repeated mailings may be needed to achieve the desired behavior change.

Importantly, there were significant differences by race in concerns about the costs of water testing and misperceptions about detecting contaminants with the senses. Those who self-identified as African American were more concerned about costs but less likely to rely on taste, sight and smell to decide about water testing. However, there was no differential effect of the interventions on water testing by race. This suggests that our results may be generalizable beyond the originally intended audience for these communications (residents of majority African American communities).

4.1. Comparison to Prior Studies of Interventions to Promote Well Water Testing

A recent systematic review found only two prior studies evaluating the influence of risk communication interventions on water testing in developed nations (Colley et al., 2019). Like our study, these found that multi-faceted outreach programs can promote testing of private well water quality (Paul et al., 2015; Renaud et al., 2011). However, these previous studies did not detail the frameworks or methods they used to design their risk information. They also did not describe the information content of their communication materials.

Additional studies have evaluated the influence of risk communication and/or free test interventions on knowledge about how to maintain well water quality. A recent systematic review identified 9 such studies in developed nations (Mooney, McDowell, O'Dwyer, & Hynds, 2020). A meta-analysis across all these studies found a mean improvement of 48% ($SD = 38\%$) on questions assessing knowledge about private well water and water testing. Some of these studies assessed the influence of either risk communications or water testing campaigns alone, while others assessed both. In studies including only risk communication, the average knowledge increase across studies was 41%. Our results showed the risk communication decreased participants' concern that they did not know how to test their water or prioritize testing by about 20% (knowledge score 2.05 in the risk communication only group versus 2.55 in the control group), but this effect was not statistically significant ($p = 0.069$). This suggests the need to revisit the information content of the risk communication to ensure it addresses all of the key aspects of this belief category. Additional in-person, think-aloud interviews with members of the target audience could inform this effort.

4.2. Comparison to Prior Studies of Mental Models Risk Communications

A systematic review by Boase et al. in 2017 identified five prior randomized-controlled trials of the mental models approach for risk communication (Boase et al., 2017). Of these, only one—aimed at behavior to prevent sexually transmitted diseases in adolescents (Downs et al., 2004)—assessed behavior change and outcomes. Girls who viewed a video with risk information that was designed according to the mental models approach were significantly more likely to pursue safe sex behavior and significantly less likely to test positive for Chlamydia and self-report a sexually transmitted disease in the months following the intervention than a control group. Another study—focused on oral contraceptive use in young women—found a significant increase in intention to use combined oral contraceptives after reading the intervention, although this effect diminished after three months (Vogt & Schaefer, 2012). All five prior studies assessed influences on decision-relevant knowledge. According to Boase et al., knowledge significantly increased above that of controls in three of the five studies and was equal to knowledge among controls in the other two (Boase et al., 2017). Our

findings add to the evidence about the potential for risk information designed according to the mental models approach to change risky behaviors. In our study, information alone was not enough to change behavior but was effective when paired with an economic incentive (the free water test). However, our findings also suggest that our implementation of the mental models approach may need further work to design a communication that is more effective in countering cognitive barriers to behavior change.

4.3. Limitations

One important limitation of this study was the relatively low rate of response to our postintervention survey (10%). This limited response may reflect the increasing difficulty in generating responses to mail-out surveys (Groves, 2006), especially in African American populations (Gallagher & Fowler, 2005; Scharf et al., 2010). In addition, it is possible that some did not respond because they did not have a private well. Nonetheless, demographic characteristics did not significantly influence the effects of the interventions of this study on water testing, suggesting that the overall approach and results may apply not only to the priority audience for this research but also to different audiences of households with private wells.

An additional limitation was potential confounding of our results due to respondents receiving mailers about water testing from other organizations, such as private water treatment system vendors and the county government. Uneven distribution of these other mailers across the study population meant that some participants received multiple mailings about water testing, while others received only ours, and that some in the control group also received water test information in the mail. We addressed this potential confounding by including a variable representing participant recall of receiving a postcard about water testing.

A related limitation is that many of those in our treatment groups (risk communication only, free test only, or risk communication plus free test) did not remember receiving a postcard about water testing. Of the participants, 41, 53, and 47% of those in the risk communication only, free test only, and risk communication plus free test groups recalled receiving water testing information in the mail. In future studies, this limitation should be addressed through repeated mailing of the water testing postcard, but resources available in this study were not sufficient to do so.

Another limitation was that although the mental models risk information effectively increased water testing when combined with a free test—and also resulted in more people responding to the free test offer—it did not operate by changing the beliefs about water testing in Table I. It did not significantly increase knowledge about water testing, decrease concern about costs, or counter misperceptions about being able to detect contaminants via the senses. Future qualitative interviews with a larger sample from the target audience (more than the five recruited for pilot testing the communication) might reveal why the communication and free test were not effective in changing these beliefs and also perhaps why this intervention promoted water testing despite this unexpected result.

The study was also limited by relying on self-reported water testing (except among those who received the free test offer). Those self-reports may not always reflect whether participants actually got their water tested. Ideally, future research should consider tracking actual water testing, after randomly assigning participants to different interventions (versus control), although this would be complicated by the many public and private vendors of water testing services.

5. CONCLUSIONS

Multiple government agencies and nonprofit organizations have developed risk communication materials to promote private well water testing, but the vast majority are deployed without testing their effectiveness in changing behavior. Our results suggest that these materials can be effective in promoting water testing when participants remember receiving them. The results also suggest that pairing risk information with a free test offer is more effective than information or a free test offer alone. In this study, those who got our mental models risk communication postcard with the free test offer were twice as likely to test their water as others when controlling for whether participants remembered receiving other water testing information in the mail. However, additional work is needed to better inform the design of information content of future water testing campaigns. Although we followed the mental models approach, the risk information did not significantly alter the beliefs associated with water testing in our prior mental models survey. Additional studies are needed to assess whether there are additional cognitive barriers to water testing (such as a false perception of con-

trol) and to evaluate alternative types of information content. In addition, follow-up research is needed to find more effective ways to reach the particular target audience of this research, majority African American communities relying on private well water. Outreach to this population—and to households relying on private wells more generally—could be facilitated by creating a national (or at least state-level) database of locations of private wells. The current lack of such database is a major limitation to targeting interventions to decrease risks associated with contamination of private well water.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Supplementary material