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Measuring public knowledge, attitudes, and behaviors related to radon to inform cancer control activities and practices

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Abstract

Radon exposure is the second leading risk factor for lung cancer among smokers and the leading risk factor among non-smokers. Radon concentrated in lower levels of homes/buildings can be reduced if found, thus lowering lung cancer risk. The objective of this study was to measure radon knowledge in diverse populations, with varying radon-related laws, to inform radon-related cancer control practices and activities. A survey was mailed to 3000 homebuyers who purchased single-family homes; 995 responses (33%) were received. Overall, 86% of respondents heard of radon-related health issues. Real estate agents (69%) or home inspectors (65%) were the most common sources of information. Respondents were more likely to test their home for radon if they reported previously hearing of radon-related health issues or understanding of how radon-related health issues affect the home-buying process. Respondents in states with notification policies were twice as likely as those without policies to have heard about radon-related health issues (OR 2.01, 95% CI: 1.27–3.17). This study provides useful information for cancer control activities including that education is positively associated with home testing for radon. It also suggests partnering with real estate agents to further radon education and testing efforts to reduce radon exposure and lung cancer risk.

Keywords

cancer; environmental carcinogens; lung cancer; radon; realtors; survey

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1 | INTRODUCTION

Lung cancer is the leading cause of cancer death in the United States, and smoking is the strongest risk factor for lung cancer.¹ Exposure to radon is estimated to be the second leading risk factor for lung cancer, causing approximately 21 000 cases per year, and is the leading risk factor among non-smokers.^{2–4} Pooled studies in the United States, Europe, and China have found that radon is an independent risk factor for lung cancer, regardless of smoking status.^{5–7} Radon is a colorless, odorless radioactive gas decay product that occurs naturally as an intermediate step in the normal radioactive decay chains. Radon can become concentrated in the lower levels of homes or buildings. The U.S. Surgeon General recommends that every home be tested for radon.^{8,9} Radon detected in homes can be mitigated, and health risks related to radon can be reduced.¹⁰ However, the health-related risks of radon as an indoor environmental hazard may not be completely understood by the general population.¹¹ Even among homeowners who may be concerned about the health-related risks of radon, only a fraction may actually test their home for radon.^{12,13} Homeowners with greater knowledge about health effects of radon, or whom perceive a higher risk of exposure to radon,^{14,15} may be more concerned and seek out additional information about radon.¹² To support progress in achieving this in the United States, the Centers for Disease Control and Prevention (CDC) and multiple other agencies support the Federal and National Radon Action Plans to improve radon control.¹⁶ CDC also administers the National Comprehensive Cancer Control Program (NCCCP) which funds 65 states, tribes, and territories, to form diverse cancer coalitions to maximize efforts to prevent and control cancer within their population.¹⁷ Cancer coalitions are composed of cancer practitioners from local government, academic, non-profit, and volunteer organizations who write and implement activities that address the cancer burden within their population in a formal, publicly available cancer plan.¹⁸ Since 2011, the NCCCP has increased awareness of radon as a cancer risk factor. In 2017, a majority of NCCCP grantees (65%) included radon-related activities in their cancer plans and were educating their populations about existing radon-related policies and resources available to help improve health and reduce lung cancer risk.¹⁹

To inform continuing cancer control efforts and activities in radon, we sought to assess radon-related knowledge, attitudes, and behaviors among homebuyers in different states. Homebuyers were chosen as the sample population because radon is mainly contained within homes and several states have existing policies related to radon during home buying. We surveyed individuals in states with existing radon policies and in those without existing radon policies in an attempt to better understand current knowledge.

2 | METHODS

This study was reviewed and approved by the CDC Human Subjects Review Board (protocol #6491) and the U.S. Office of Management and Budget (OMB #0920–1051). All participating states deferred to the CDC human subjects review board approval.

2.1 | Data sources

To ensure a sample size with adequate power to detect significant differences, eligibility was limited to homebuyers in states that had cities with more than 750 single-family home sales in the twelve months prior to recruitment. To assess radon attitudes among a diverse sample of individuals, states with differing radon policies were considered for inclusion. Ten states had existing *radon notification* policies that required the buyers, sellers, and real estate agents involved in the purchase of single-family homes to receive an informational brochure about radon and sign a separate sheet of paper acknowledging that the property had or had not been tested for radon, and 23 states had existing *professional certification* policies that required radon mitigation professionals to be licensed by a state agency.²⁰ After considering eligibility criteria, four states were selected for the study (Illinois [IL], Minnesota [MN], North Carolina [NC], and Ohio [OH]). At the time of the study, IL and MN had existing radon notification policies, and IL and OH had existing state-managed radon professional licensure requirements. NC had no existing radon-related policies at the time of the study. City and/or county tax assessor offices within or near each study site (ie, individual county/city selected within each state) were contacted to obtain publicly available information about the property address, buyer address, home type (eg, single-family, condominium, farm), and sale price of homes sold in the 12 months prior to survey distribution. Sales of home types that were not considered “single-family” homes according to the local tax assessor criteria, properties where the buyer was listed as something other than a person (eg, “corporation,” or “Limited Liability Corporation”), or properties where the owner address was different from the property address (ie, possible vacation homes and rental property) were excluded.

2.2 | Data collection

A paper-based survey was developed to ascertain respondent demographic information (ie, age category, sex, race, ethnicity, and educational level) as well as their knowledge, attitudes, and practices for radon. The survey consisted of 27 individual questions (some with multiple parts) in various formats (ie, open ended, yes/no, multiple choice, Likert scale response categories). Skip patterns were used to tailor relevant questions to participants, and also to minimize the time and effort required for individual completion. Cognitive testing of the survey was conducted by participants recruited from two of the study sites (NC and MN) to ensure the survey was clear and that no questions required additional explanation or rewording. This was completed using the “concurrent think-aloud” method²¹ to elicit real-time feedback and emotional responses to understand participants’ thoughts as they work through the survey. Following cognitive testing and revisions to the survey, 750 addresses from each state were randomly selected from publicly available home sales lists and contacted for participation, using the information obtained from county tax assessor office. Within-household sampling was not conducted. Between July 2015 and January 2016, potential participants were mailed a pre-survey postcard with a link to an online response portal. Over the course of the study, up to three survey mailings were sent to participants. Responses were monitored for the number of hardcopy surveys received following the first mailing. The first mailing was sent to all participants via the U.S. Postal Service. Four weeks following the first mailing, the next two mailings were sent to individual addresses who had not responded to a previous mailing. The second and third mailings were sent via Federal

Express, requiring delivery to the door and signature of receipt to improve response rates.²¹ Respondents were offered a \$15 incentive for their participation.

2.3 | Data management and analysis

All data received from surveys returned by mail were manually entered and merged into a single Microsoft Excel© dataset in preparation for analysis. Surveys returned without any information were excluded ($n = 1$). Data from 20% of surveys returned were doubleentered for data quality purposes, and it was determined that less than 1% data entry had discrepancies requiring correction. While we did not intend to ascertain identifiable information as part of the survey, all survey data were reviewed and de-identified to remove any such information. Basic demographic information and state of residence (study site) of the respondent was retained in the database. Furthermore, all hardcopy surveys were kept locked in a filing cabinet following data entry, and the resulting database and analytic dataset were maintained on a secure server that could only be accessed by the study investigators.

For analysis purposes, participants were aggregated into groups of states with radon notification policies (IL and MN [yes] vs NC and OH [no]) and states with stated managed professional certification policies (IL and OH [yes] vs NC and MN [no]) for descriptive analyses. Simple and multiple logistic regression modeling was conducted to assess the association between these state policy groupings and three primary outcomes (knowledge of radon-related health issues, whether their understanding about radon-influenced home-buying decisions, and whether the home they purchased was tested for radon). The multiple regression controlled for potential confounding from demographic factors (sex, race, ethnicity, age, and education) based upon significant differences observed between these strata, the exposures, and outcomes of interest. All analyses were completed using SAS 9.3 (Cary, NC), and statistical significance was regarded as a two-sided P -value $< .05$.

3 | RESULTS

The overall response rate was 33% ($n = 995$) and response rates varied significantly ($P < .001$) by state: 39% in NC and MN; 33% in IL, and 21% in OH. Among responses received, the percent received from each mailing were 48% (first mailing), 27% (second mailing), and 25% (third mailing). Comparison of respondent demographic information to the U.S. Census bureau indicated that a higher proportion of respondents were white non-Hispanic, had college degrees, and younger than those of a weighted average of homebuyers overall (results not shown). The demographic characteristics of survey respondents are listed in Table 1. Men made up 52% of the sample, and the predominant race/ethnicity reported was non-Hispanic white (83%). Most of the respondent population reported either having a college degree (64%) or some college education (15%). More than half of respondents (53%) were aged 25–44 years, and the median age was 40. A majority (92%) of homes purchased were previously owned (ie, not new construction) and 20% had some sort of homeowners association (results not shown). Homebuyers from states with radon notification policies differed significantly in regard to age, but did not differ significantly from those without policies in regard to sex, race, ethnicity, or educational level. States with professional certification policies differed significantly in regard to race and education, but

did not differ compared to those that did not have professional certification policies in regard to age, sex, or ethnicity.

Overall, most survey respondent homebuyers (86%) reported previously hearing of health issues related to radon, and awareness was similar regardless of existing state policies (Table 2). Respondents who said they had heard of radon reported real estate agents (69%) and home inspectors (65%) as the most common sources of information. Most reported sources of radon-related health information did not vary significantly by policy type for the majority of sources ($P > .05$). There were two exceptions to this: respondents in states with notification policies were more likely to report receiving radon-related health information via television ($P = .05$, rounded up), and respondents in states with professional certification were more likely to report receiving the radon information from a radon professional ($P < .001$). A total of 58% of respondents said they had their home tested for radon, and testing was similar regardless of existing state policies. Real estate agents were most often listed as the source of the home-testing recommendation (38%), with home inspectors, and family members/friend/respondents themselves also being commonly listed as recommendation sources (21%). Respondents who discussed radon with a real estate agent were significantly more likely to test for radon (74% vs 42%) $P < .0001$.

Overall, a majority of respondents had discussed radon with their real estate agent (60%) or signed paperwork related to radon testing (51%) during the home-buying process (Table 3). Respondents in states with notification policies were significantly more likely to report discussing radon with their real estate agent (64% vs 56%, $P = .007$), signing radon-related testing paperwork (61% vs 39%, $P < .001$), or receiving a brochure during the inspection or closing (50% vs 31%, $P < .001$) compared with those in states without notification policies (Table 3). Less than half (41%) of respondents said that their understanding of radon-related health issues impacted their home-buying process, and this did not vary in states with and without radon notification policies (42% vs 41%, $P = .87$). Respondents within professional certification states were significantly less likely (36% vs 46%, $P = .002$) to report their understanding of radon-related health issues affected their home-buying process compared with respondents not in professional certification states. Among those reporting that radon affected their decisions during the home-buying process ($n = 409$), the predominant response was that radon information helped them decide the action needed ($n = 237$, 58%) followed by helping to make the decision to buy the home ($n = 122$, 30%) (results not shown). Among those whose knowledge of radon health effects did not affect their decisions during the home-buying process ($n = 580$), the predominant response was that they knew about radon but it did not affect whether they bought the house ($n = 381$, 66%) followed by did not know about radon ($n = 45$, 8%) (results not shown).

In adjusted models, having previously heard of radon-related health issues (Odds Ratio (OR) = 2.43, 95% Confidence Interval (CI): 1.47–4.01) and responding that understanding of radon-related health issues affected the home-buying process (OR=3.90, 95% CI: 2.73–5.56) were significantly associated with having the home tested for radon (Table 4). The existence of a state radon-related policy was not a significant determining factor of whether the home was tested for radon. Significantly more respondents had heard of radon-related health issues in states that had a notification policy (OR 2.01, 95% CI: 1.27–3.17), and significantly

fewer respondents said their understanding of radon influenced the home-buying process in states with professional certification policies (OR=0.69, 95% CI: 0.5–0.94; Table 5).

4 | DISCUSSION

This study is the first large multistate comparison of knowledge, attitudes, and behaviors related to radon. The results highlight a number of novel findings; particularly, those related to the predominant sources of radon information being realtors and the degree to which understanding of radon-related health issues impact the radon home testing and the home-buying process. Additionally, we found that regardless of state radon policies, homebuyers who reported hearing of radon-related health issues and homebuyers who reported their understanding impacted the home-buying process were 2 to 4 times more likely to test their home for radon.

Our results related to real estate agents being the predominant source of information are consistent with the literature. In 2016, 88% of homebuyers purchased their home through a real estate agent and 79% of homebuyers report that their real estate agents were a “very useful” source of information.²² In addition, one previous study found realtors were considered a trustworthy source of information regarding carbon monoxide detectors among homeowners.²³ Together, our study and previously published ones highlight the role of real estate agents in identifying and addressing health issues in homes, and demonstrate the unique role they can play in cancer control. Regardless of current state radon policies, real estate agents may be valuable partners for NCCCCP grantees in their radon efforts, they may help better communicate home-related health issues to home buyers and sellers, and help to bring about outcomes to decrease lung cancer risk, such as radon mitigation in homes.²⁴ In this study, homebuyers who talked to their real estate agents about radon were significantly more likely to test for radon; these results were similar for persons in states with and without radon notification policies. NCCCCP grantees can establish more formal connections with real estate agents in their state by asking them to serve on the local cancer coalition or specific workgroups devoted to reducing environmental cancer risks. In states with radon certification and/or notification policies, NCCCCP grantees can also reach out to real estate agents through targeted educational campaigns describing radon’s association with cancer risk, and work with them to ensure existing policies surrounding radon disclosure and notification are implemented. In states with and without radon notification or certification policies, NCCCCP grantees may share information on radon testing and mitigation in the construction of new homes, and radon mitigation of existing homes for populations that may have a greater need (eg, lower income families, multi-unit housing).¹⁹

Much of the radon-related work in the NCCCCP is geared toward increasing education and knowledge about radon as a risk for lung cancer. Education could include describing current Environmental Health Protection Agency (EPA) recommendations to test all homes before sold, incorporation of radon-resistant new construction codes, information about state practices (notification and professional certification), notification of radon testing for renters of homes, and steps required to mitigate elevated levels of radon. Our results showing those who had heard of radon were significantly more likely to get their homes tested. Living in states with notification policies may have indirectly increased the likelihood that respondents

had heard of the radon-related health effects. These findings support the continuation of radon education by NCCCCP grantees. Additionally, there is a need for the NCCCCP to continue to fulfill this role, given our findings that knowledge of radon-related health risks did have a significant effect on radon testing in homes. Collaborative community engagement on radon exposure has the potential to increase awareness, testing, mitigation, and policy.²⁴ A state's comprehensive cancer control plan can align with priorities, goals, and activities of cancer coalitions with the practices that reduce radon exposure and the risk of radon-induced lung cancer. Approximately, one-third of NCCCCP grantees cancer plans have no mention of radon, and grantees without this information could include radon in cancer plans to better identify and address radon exposure in the United States.¹⁹ NCCCCP grantees that do not currently have radon-related activities in their cancer plans can bolster lung cancer prevention efforts (particularly for non-smokers) by working with local partners (eg, real estate agents, builders, radon professionals, state radon program) that have existing knowledge of radon reduction efforts. NCCCCP grantees with existing state radon policies could also incorporate support of these objectives into their cancer plans to promote radon reduction work in-progress.

The main limitation of this study is that our response rate of 33% was lower than that reported for mail survey response rates (50%).²⁵ This indicates the results of this study may not be representative of the population and thus the generalizability is limited. Also, while respondents from only four states were included, they were diverse with respect to geography (three coming from two divisions of the Midwest U.S. Census region and one from the South region), and existing policies related to radon that may have impacted respondent knowledge. Self-reported data may also be subject to social desirability or recall bias. Finally, this study did not assess actual measured concentrations of radon. Even with these limitations, our findings allowed us to gain valuable insight in this area and inform future programmatic cancer control activities. Future studies could expand on these results through local surveys and communication with new homebuyers to include populations under-represented in this study (eg, non-white, less educated, older homebuyers) and expand to other geographic areas (eg, other states, metropolitan and nonmetropolitan counties) with varying radon policies for homebuyers.

5 | CONCLUSIONS

More than 150 000 men and women in the United States die from lung cancer each year. Increasing knowledge about radon as a major risk factor for lung cancer, especially among non-smokers, may result in increased radon testing, mitigation, and ultimately reduction in lung cancer deaths. Future NCCCCP programmatic efforts in this area, in particular, outreach to real estate agents to assist with radon education, are important in ensuring radon knowledge is increased.

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Practical Implications

- The most common source of radon testing information among homebuyers was realtors and home inspectors. Regardless of state radon policies, homebuyers who reported hearing of radon-related health issues were more likely to test their home for radon. Increasing knowledge about radon as a major risk factor for lung cancer, especially among non-smokers, may result in increased radon testing, mitigation, and ultimately reduction in lung cancer deaths.

TABLE 1

Demographic characteristics of survey respondents by state policy type (N = 995)

| | Total (N = 995) | Notification policy states | | | Certification policy states | | |
|-----------------------------------|-----------------|----------------------------|--------------|----------|-----------------------------|--------------|-------------|
| | | Yes (n = 542) | No (n = 454) | χ^2 | Yes (n = 410) | No (n = 586) | χ^{2a} |
| | % ^b | % | % | P | % | % | P |
| Sex | | | | | | | |
| Female | 47 | 48 | 46 | .56 | 47 | 47 | .98 |
| Male | 52 | 51 | 53 | | 52 | 52 | |
| Race/Ethnicity | | | | | | | |
| White, non-Hispanic | 83 | 84 | 81 | .26 | 83 | 83 | .01 |
| Black, non-Hispanic | 2 | 2 | 2 | | 4 | 1 | |
| Asian, non-Hispanic | 2 | 3 | 1 | | 2 | 2 | |
| Other ^c , non-Hispanic | 1 | 1 | < 1 | | 1 | < 1 | |
| Multiple | 2 | 1 | 2 | | 2 | 1 | |
| Hispanic/Latino | 2 | 2 | 2 | .17 | 2 | 2 | .65 |
| Education | | | | | | | |
| High School | 5 | 5 | 17 | .46 | 7 | 3 | .008 |
| Some College | 15 | 17 | 5 | | 18 | 14 | |
| College | 64 | 63 | 14 | | 60 | 66 | |
| Age (years) | | | | | | | |
| <25 | 2 | 1 | 2 | <.001 | 2 | 2 | .22 |
| 25–44 | 53 | 59 | 45 | | 56 | 50 | |
| 45–64 | 29 | 26 | 32 | | 25 | 31 | |
| 65+ | 13 | 10 | 16 | | 13 | 12 | |
| Median \pm SE | 40 \pm 0.45 | | | | | | |
| State | | | | | | | |
| Illinois | 25 | 46 | 0 | | 61 | 0 | |
| Minnesota | 29 | 54 | 0 | | 0 | 50 | |
| North Carolina | 29 | 0 | 65 | | 0 | 50 | |
| Ohio | 16 | 0 | 36 | | 39 | 0 | |

^aFor cell counts with less than five expected responses, Fisher's exact test was calculated. Statistical significance was regarded as a two-sided *P*-value <.05.

^bNot all percentages total to 100% due to rounding to whole numbers.

^cAmerican Indian, Alaskan Native, Native Hawaiian, Pacific Islander.

TABLE 2

Knowledge and awareness of radon and sources of radon-related information by state policy type (N = 995)

| | Total (N = 995) | Notification policy states | | | Certification policy states | | |
|--|-----------------|----------------------------|--------------|----------|-----------------------------|--------------|-------------|
| | | Yes (n = 542) | No (n = 454) | χ^2 | Yes (n = 410) | No (n = 586) | χ^{2a} |
| | | % | % | <i>P</i> | % | % | <i>P</i> |
| Heard of health issues related to radon | 86 | 88 | 85 | .19 | 86 | 87 | .64 |
| Sources of radon-related health information ^b | | | | | | | |
| Television | 30 | 33 | 27 | .05 | 32 | 29 | .36 |
| Family Member, friend, neighbor, coworker | 41 | 43 | 38 | .12 | 39 | 43 | .23 |
| Real estate agent | 69 | 70 | 66 | .24 | 66 | 70 | .15 |
| Home inspector | 65 | 64 | 67 | .39 | 64 | 66 | .58 |
| Contractor (home repair/remodeling) | 10 | 11 | 10 | .68 | 8 | 11 | .12 |
| Professional radon testing company | 24 | 27 | 21 | .07 | 32 | 19 | <.001 |
| Other | 17 | 15 | 19 | .08 | 17 | 16 | .89 |
| Had house tested for radon | 58 | 61 | 56 | .30 | 59 | 58 | .80 |
| Who first recommended radon testing ^c | | | | | | | |
| Sellers tested prior to purchase | 10 | 12 | 8 | .10 | 13 | 8 | .05 |
| Myself, family member, friend | 21 | 20 | 23 | .30 | 20 | 22 | .47 |
| Real estate agent | 38 | 36 | 41 | .23 | 40 | 37 | .47 |
| Home inspector | 21 | 22 | 19 | .35 | 13 | 26 | <.001 |
| Radon professional (other than home inspector) | 4 | 5 | 3 | .39 | 7 | 2 | .002 |
| Other | 3 | 4 | 3 | .56 | 5 | 2 | .14 |

^aFor cell counts with less than five expected responses, Fisher's exact test was calculated. Statistical significance was regarded as a two-sided *P*-value <.05.

^bAmong persons who reported "yes" to having heard about health issues related to radon (n = 860). Percentages do not total to 100% due to respondents ability to report multiple sources of information.

^cAmong persons who reported "yes" that their home was tested for radon (n = 580).

TABLE 3Attitudes and behaviors related to radon during the home-buying process^a, by state policy type

| | Total (N = 995) | Notification Policy States | | | Certification Policy States | | |
|---|-----------------|----------------------------|--------------|----------|-----------------------------|--------------|-----------------------|
| | | Yes (n = 542) | No (n = 454) | χ^2 | Yes (n = 410) | No (n = 586) | χ^2 ^b |
| | % | % | % | <i>P</i> | % | % | <i>P</i> |
| Real estate agent discussed radon with homebuyer | 60 | 64 | 56 | .007 | 61 | 60 | .87 |
| Paperwork signed by buyer/seller related to radon testing | 51 | 61 | 39 | <.001 | 60 | 46 | <.001 |
| Buyer received radon brochure during inspection/closing | 41 | 50 | 31 | <.001 | 43 | 40 | .15 |
| Understanding of radon health issues impacted home-buying process | 41 | 42 | 41 | .87 | 36 | 46 | .002 |

^aAll survey respondents were homebuyers in the last 12 mo prior to survey administration.^bStatistical significance was regarded as a two-sided *P*-value <.05

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TABLE 4Multiple regression models^a assessing outcomes of radon knowledge^b

| Home tested for radon | | | |
|--|-----------|---------------|----------|
| | OR | 95% CI | P |
| Understanding influenced home-buying process | | | |
| No | 1.00 | | |
| Yes | 3.99 | 2.79–5.70 | .001 |
| Heard of health issues related to radon | | | |
| No | 1.00 | | |
| Yes | 2.43 | 1.47–4.01 | <.001 |
| Certification policy state | | | |
| No | 1.00 | | |
| Yes | 1.24 | 0.89–1.73 | .21 |
| Notification policy state | | | |
| No | 1.00 | | |
| Yes | 1.11 | 0.80–1.55 | .54 |

^aAdjusted for age, gender, education, race and ethnicity.^bSeparate models were run for each policy grouping (certification or notification) and each associated outcome.

TABLE 5Multiple regression models^a assessing outcomes of radon certification and notification policies^b

| | <u>Heard of health issues related to radon</u> | | | <u>Understanding influenced buying process</u> | | |
|----------------------------|--|---------------|----------|--|---------------|----------|
| | OR | 95% CI | P | OR | 95% CI | P |
| Certification policy state | | | | | | |
| No | 1.00 | | | 1.00 | | |
| Yes | 0.96 | 0.61–1.51 | .90 | 0.69 | 0.50–0.94 | .02 |
| Notification policy state | | | | | | |
| No | 1.00 | | | 1.00 | | |
| Yes | 2.01 | 1.27–3.17 | .003 | 1.03 | 0.70–1.31 | .78 |

^aAdjusted for age, gender, education, race, and ethnicity.^bSeparate models were run for each policy grouping (certification or notification) and each associated outcome.

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