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Clearing the air: A systematic review of mass media campaigns to increase indoor radon testing and remediation

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Abstract: Indoor radon is a natural radioactive gas that enters homes through cracks in the foundations. It is one of the leading causes of lung cancer. Although radon can be detected with an indoor radon test and can be mitigated by means of either ventilation or professional measures, testing and mitigating rates of the at-risk population remain insufficient. The objective of this study is to systematically review the current level of evidence regarding the design and effectiveness of mass media campaigns to address the health risks of indoor radon to homeowners. The results show that informative tone of voices prevailed, other components, such as emotional or social components, were often not included. Furthermore, the focus was mostly on intention and less on behavior itself, and on testing instead of mitigation. Further research is needed to test effective and innovative communication strategies to increase protective behavior concerning indoor radon.

Keywords: radon, lung cancer, mass media, systematic review, communication, health promotion

1 Introduction

Radon is a colorless, odorless and tasteless natural radioactive gas present in the earth's crust. While radon outdoors is not a health risk due to rapid diffusion in the atmosphere, radon can also enter buildings through cracks in the foundations, which poses a serious health risk in certain geological areas. The decomposition effects of radon, hereafter referred to as "radon", are among the leading causes

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of lung cancer among non-smokers since they become trapped in the airways and thus form the main contribution to cancer (Darby et al., 2005; World Health Organization, 2009).

In Europe, indoor radon accounts for 9 % of all lung cancer deaths (Darby et al., 2005). The first step in reducing the risks is identifying the indoor radon levels by carrying out a radon test. When high radon concentrations are found, remediation techniques are necessary (Dowdall, Fenton, and Rafferty, 2016; World Health Organization, 2009). However, despite straightforward testing and mitigation methods, testing and remediation rates remain insufficient (Dowdall et al., 2016; Vogeltanz-Holm and Schwartz, 2018).

In order to convince people to take action, health promotion intervention is crucial and involves three types of complementary interventions. First, regulative measures: policy makers could, for instance, impose radon protective measures in the building permit, as applied in Belgium (Federal Agency for Nuclear Control, 2020). Second, economic policy instruments could provide financial means to people so that they are able to test and remediate: for instance, free tests and/or funding for people with high radon levels to remediate their homes, as applied in Ireland (Environmental Protection Agency, 2019). Finally, communication is crucial to make people aware of the risk and to persuade them to take action (Vedung, 1998).

Literature shows that due to the characteristics of radon, communicating about related health risks is challenging. For instance, the lack of sensory cues of the gas, the lack of casualties known, and the fact that it is a natural gas, decrease the perceived susceptibility of the health issues, and result in an optimistic bias (Cheng, 2016; Fisher and Johnson, 1990; Hevey, 2017). Additionally, behavior related to radon, such as testing and remediating, is not only predicted by risk perception (Weinstein and Sandman, 1992), but also by concern (Weinstein, Sandman, and Roberts, 1990), social influence (Khan and Chreim, 2019; Sandman and Weinstein, 1993), and other determinants. That is why we focus on health communication in general rather than on risk communication specifically.

Regarding radon, the European Commission legally requires all member states to develop and implement a Radon Action Plan (Council Directive 2013/59/EURATOM, of 5 December 2013). One of the components is to develop a communication strategy to increase public awareness about the health risks related to radon. When it comes to increasing awareness, mass media can be an effective approach (Wakefield, Loken, and Hornik, 2010).

In order to inform policy makers and member states about the best communication strategies, Bouder et al. (2019) formulated recommendations regarding radon communication, proposing a need for evidence-based, theory-based, and strategic communication. While they emphasize a need for evidence-based com-

munication, it can be useful to assess the *current* level of evidence. The objective of the paper is, therefore, to systematically review literature about mass media campaigns that address the health risks of residential radon in the general population. Mass media campaigns are defined as "any planned effort that disseminates messages to produce awareness or behavior change among an intended population through channels that reach a broad audience" (Abroms and Maibach, 2008, p. 222). Examples of channels include radio, TV, newspapers, magazines, billboards, films, recordings, books, the Internet, and smart media (Wimmer and Dominick, 2013).

Because of their wide reach, cost-effectiveness, and improved ability to target, mass media are often used in health promotion. Previous studies have shown that mass media campaigns can be effective in increasing awareness and knowledge, and in changing attitudes and beliefs about health. Moreover, scholars showed growing evidence that well-executed mass media campaigns can have small to moderate effects on behavior change (Noar, 2006; Quattrin, Filiputti, and Brusaferro, 2015; Wakefield et al., 2010). To increase the chances of behavior change, mass media campaigns should be complemented with interpersonal communication and environmental change, for instance regulation, economic means, or changes in the community (Flora, Maibach, and Maccoby, 1989); however, the scope of the current paper is mass media only.

An extensive amount of research has examined how to plan a health communication campaign and what components to include. This systematic review started with the Intervention Mapping (IM) approach, developed by Bartholomew et al. (2016) to design health promotion interventions based on theory and evidence and with an emphasis on evaluation at every step to ensure a solid intervention (Noar, 2011; Snyder, 2007). The framework focuses both on the individual and the environmental context of the target population. However, this literature review focuses on the individual only, and more specifically on homeowners, since they are found to be responsible for their own radon levels (Flora et al., 1989; Hevey, 2017). The premise of the IM is to use theory and evidence at every step of the process which starts with the composition of the logic model of the problem. This logic model is based on the PRECEDE model, which looks at the quality of life, the health problem, the behavior and the determinants of the behavior. Proceeding with the logic model of change, it then identifies what change in behavior is needed to prevent or reduce the risks, again informed by theory and evidence. Laying out the logic model of change allows the researcher to establish which applications of which theories can be adopted in the communication intervention, and how theory can inform message design and channel selection. Unique to IM is that different applications of different theories should be combined, since a tailored intervention-approach for each health problem is recommended (Fernandez, Ruiter, Markham, and Kok, 2019).

Instead of focusing on the IM as a whole, we decided to focus on the three main principles of campaign design as laid out by Snyder (2007). More specifically, we will focus on goals, strategy, and research (Snyder, 2007) to find an answer to the question "How can intervention programs promote radon-related healthy behaviors amongst the residential population by changing their personal determinants?".

Firstly, *goals* state the desired outcomes of the campaign, for instance, the reduction of indoor radon, whereas campaign objectives are more specific and focus on behavior itself, such as the performing of a radon test, or on the determinants of this behavior, for instance, awareness or self-efficacy. All related radon behaviors and determinants are considered in this paper. Among these goals, the target audience should be specified (Noar, 2006).

Secondly, *strategy* includes using theories, such as behavioral models, to ensure that the target group is guided through the process of behavior change (Noar, 2006), but also to inform message design and channel selection (Noar, 2011; Randolph and Viswanath, 2004). In this systematic review we will investigate which strategies were adopted and how they were applied regarding message design and channels.

Thirdly, Snyder (2007) indicates that *research* is crucial during the design and implementation of the intervention. On the one hand, process evaluation is necessary to inform the campaign design in terms of target behavior(s), behavioral determinants, and message and channel preferences (Noar, 2011). On the other hand, during the implementation, outcome evaluation will test whether the objectives were met, and process evaluation can be useful in understanding the obtained results (Noar, 2006, 2011). This paper will look into the extent to which the campaigns were evaluated; and whether this allows for conclusions to be drawn on the effectiveness of the campaigns.

2 Methods

The systematic review followed the Cochrane guidelines, proposed by Higgins et al. (2020). This resulted in a predefined protocol that included the search strategy, inclusion and exclusion criteria, and determined the screening process. The protocol included six inclusion criteria to identify (1) English, (2) peer-reviewed publications (3) that report empirical findings (i. e., results from formative research, experiments, and implemented campaigns) (4) about mass media communication interventions (5) targeted at the general population with a focus on homeowners (6) and with the objective of increasing radon-related behavior and its proximal determinants.

Table 1: Search strategy used in 10 databases.

Search category	Search terms
Radon	Radon
	AND
Intervention	promot* OR persua* OR encourag* OR convince OR communicat* OR campaign* OR strateg* OR guid* OR marketing OR "mass media" OR "social media" OR "social marketing" OR program* OR message OR smartphone OR internet OR intervention* OR information* OR educati*
	AND
Objective	awareness OR percept* OR knowledge OR threat OR health OR test* OR mitigat* OR remediat* OR reduce* OR prevent* OR measur* OR retest* OR attitude* OR behaviour* OR behavior*
	AND
Target group	Home OR homeowner* OR residen* OR population OR household* OR domest*

The search strategy was not limited in year of publication nor in country of subject, to ensure a full overview of the available literature, including regions with a lower radon risk. The search terms included radon AND keywords related to communication, AND outcome-related keywords, AND keywords used to define the target group of the campaign. The complete search strategy can be found in Table 1. These search terms were applied in 10 databases (Web of Science, Scopus, Taylor and Francis, Scopus, Wiley, Social Science Abstracts, Sociological Science Abstracts, ERIC, Communication Abstracts, and CMMC) on November 18, 2020. Whenever possible, title, abstract and keyword searches were used. The PRISMA-flowchart as presented in Figure 1 outlines the screening process of the search results (Page et al., 2021).

The search yielded a total of 1,724 results. Duplicates were removed in Endnote, and the remaining results (N = 1,094) were imported into the Rayyan software to review the eligibility (Ouzzani, Hammady, Fedorowicz, and Elmagarmid, 2016). In order to assess inter-rater reliability, a second coder reviewed 20 % of the campaigns. Conflicts were discussed until full consensus was reached.

Screening and eligibility

During the first stage, all remaining results were screened based on title and abstract and this resulted in an agreement rate of 96.41 % and a Cohen's Kappa of .79 (Landis and Koch, 1977). Due to the strong agreement, the sample of 20 % was sufficient to control for inter-rater reliability. Based on the results of the abstract-screening, full-texts were retrieved (N = 72) and eligibility was assessed. Between the two review-

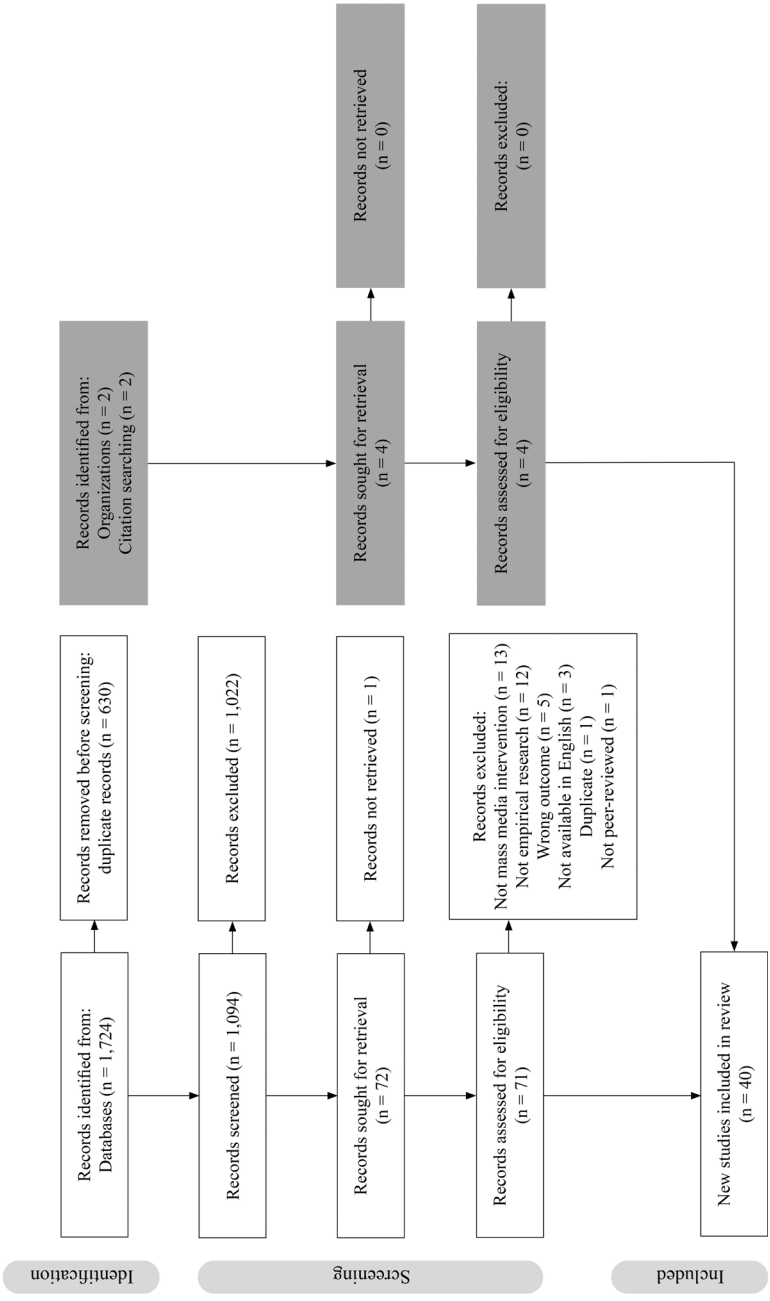

Figure 1: PRISMA 2020 flow diagram for this study.

ers there was an agreement rate of 93.75 %, with a Cohen's kappa of .86, which indicates an almost perfect agreement (Landis and Koch, 1977).

Of the 72 remaining results, 36 were excluded: 13 did not report a specific mass media campaign, 12 did not report empirical results, five did not include radon protective behavior or determinants as outcomes, three were written in languages other than English, one duplicate, one without a full-text available, and one not peer reviewed. Additionally, four records were obtained by searching the reference list of the studies included and through contact with expert authors from the field. This resulted in a final sample of 40 peer-reviewed papers that met all inclusion criteria.

Data extraction

Data were extracted in two phases. Firstly, a preliminary data extraction of the publications (N = 40) included was carried out by the main researcher to identify the different campaigns (N = 27). In the second stage, data were extracted based on an extraction form and an accompanying codebook. The form included questions about the goals (i. e., objectives, determinants), the strategy (i. e., theory, target audience, application, message, channel), and the research (i. e., formative evaluation, process evaluation, study design) (Snyder, 2007). The codebook provided background information, predefined answering categories, and decision flowcharts, which allowed for consistent coding. A second coder extracted data from 20 % of the campaigns. The inter-rater reliability (IRR) was calculated for each coded variable. Percent agreement varied from 83 % to 100 %, with a mean percent agreement of 93 %. Cohen's kappa ranged from .60 to 1.00, with a mean kappa of .85. This indicates a strong agreement between the two coders (Landis and Koch, 1977).

To be able to investigate the communication materials themselves, further searches were carried out. Additionally, all original authors were contacted to ask for copies of the original communication materials, which was for 11 campaigns at least partially the case. The communication materials of these campaigns were studied by coding the communication strategies.

3 Results

The systematic literature review identified 40 articles reporting on 27 distinct mass media campaigns. The majority (N = 22) of the campaigns took place in the United States, four in Europe, and one in Canada. The articles cover a period from 1987

to 2020, with a gap between 2001 and 2010 during which only one study was published; in 2003. The majority (N = 19) of the articles were published between 1991 and 2000.

Goals

All the campaigns aimed at reaching homeowners or residents, either exclusively, or as part of the general population, one study used students to test and evaluate the communication materials, but specified that the ultimate target group would be homeowners (Kim, Brewster, and Schwartz, 2020).

The target behavior of the mass media campaigns in this study focused on requesting information, testing, and mitigation, and sometimes a combination of multiple behaviors.

Intention to test and intention to mitigate were also measured, and while intention is an important predictor of behavior and therefore a determinant (Ajzen, 1988), it was also sometimes used as the dependent variable. For purposes of keeping relevant determinants and behaviors combined, intention is discussed together with the respective behavior.

Firstly, six of the campaigns focused on information requests, for instance, the studies of Burns, Ashbaugh, Paris, and Toombs (1998) and Moir, Bush, Chen, Ford, and Whyte (2012) registered the number of phone calls to a free radon phone number. In contrast, LaTour and Tanner (2003) measured intention to call and Weinstein et al. (1990) intention to request additional information as a self-report question.

Secondly, radon testing was the most targeted behavior. On the one hand, 15 of the campaigns focused on increasing intentions to test. Kim et al. (2020) measured intention to test by registering test kit orders, so did Long and Fenton (2011); others included a self-report question in a survey (Gold et al., 2018; Niemeyer and Keller, 1999). On the other hand, actual testing was measured in 12 campaigns. Registering test kits that were sent back for analysis was the most popular way of measuring radon testing behavior (Bain, Abbott, and Miller, 2016; Doyle, McClelland, Schulze, Elliott, and Russell, 1991).

Both intention to test and testing behavior were measured in six campaigns by registering how many tests were ordered and how many were sent back to the lab for analysis.

Thirdly, increasing mitigation behavior was less often the main objective. Six campaigns measured intention to mitigate, and seven measured actual mitigation behavior. Except for the campaign carried out in Iowa where Bain et al. (2016) registered mitigations by certified mitigators, mitigation behavior was measured using a question in a survey.

In order to increase behavior change, the majority (N = 18) of the campaigns focused on determinants of the behavior. How determinants were related to behavior was in most cases not explained in great detail, nor was the choice of determinants justified. Of the 27 campaigns, four used behavioral models to define these relationships. Hahn, Wiggins, et al. (2019) and Weinstein, Lyon, Sandman, and Cuite (1998) used the Precaution Adoption Process Model as the underpinning of their campaign. The Protection Motivation Theory was explicitly used by LaTour and Tanner (2003) and implicitly by Kim et al. (2020).

The most prevalent determinant assessed, changed and/or evaluated was knowledge, which occurred in almost half (N = 8) of the campaigns that included determinants (N = 18). Golding, Krimsky, and Plough (1992) evaluated knowledge using a knowledge quiz; whilst Adams, Dewey, and Schur (1993) assessed knowledge based on the participant's own perceived knowledge. Besides knowledge, perceived susceptibility and risk perception were frequently included in the campaign (N = 7), as well as attitudes (N = 6). Awareness and self-efficacy were included in five cases. Other determinants, such as concerns, perceived severity, and perceived ease of testing, occurred less frequently.

Strategy

Various communication strategies were applied so as to address multiple determinants, for instance, tailoring of the the campaign to previously measured characteristics was applied. Hahn, Wiggins, et al. (2019) adapted the messages to the participants' stage of action, and Weinstein, Roberts, and Pflugh (1992) to radon levels in the participants' houses. Golding et al. (1992) used a narrative role model storyline, and belief selection – where positive beliefs were strengthened and negative beliefs were weakened – was adopted in the leaflet of the US Environmental Protection Agency and was used in at least four campaigns (Desvousges, Smith, and Rink, 1992; Niemeyer and Keller, 1999; Nissen, Leach, Nissen, Swenson, and Kehn, 2012; Witte et al., 1998).

Other strategies aimed at increasing awareness and risk perceptions. For instance, LaTour and Tanner (2003) applied fear arousal to increase awareness and urgency.

To change attitudes, cultural similarity was used by portraying typical families, showing children, multiple racial backgrounds and multiple types of homes (Bain et al., 2016; Desvousges et al., 1992; LaTour and Tanner, 2003; Niemeyer and Keller, 1999; Nissen et al., 2012; Witte et al., 1998). Another approach made use of anticipated regret whereby a radio commercial asked whether the listener was a responsible homeowner who protected their house and their family (Desvousges et al., 1992).

Despite the use of multiple communication strategies, the overall characteristics of the communication materials were largely similar. First of all, almost all the campaigns adopted an informative, factual tone of voice. Only Golding et al. (1992) also investigated a narrative approach, and only LaTour and Tanner (2003) used explicit emotions (i. e., fear).

Secondly, concerning the mass media channels, it became apparent that leaflets were adopted most often, both as the only channel (Adams et al., 1993) and in combination with other channels such as direct communication (Baechler and Englin, 1989), posters (Hobson, 1992), or as a supporting channel to broadcasting media (Hahn, Rayens, Kercsmar, Robertson, and Adkins, 2014). Newspapers, television (documentary, news stories, public service announcements) and radio were often combined (Burns et al., 1998; Doyle et al., 1991). Digital media, for instance websites, social media and apps were used in a minority of the campaigns (N = 7).

The channel was mostly in line with the strategy. For instance, public service announcements on television are known for stimulating awareness, as was the objective for the video produced by LaTour and Tanner (2003), brochures were indeed used to deliver detailed information, and smartphones or direct communication made use of tailored content (Hahn, Wiggins, et al., 2019; Kim et al., 2020).

Research

Process and effect evaluation of the campaigns were carried out in a variety of ways. Due to the heterogeneous character of the evaluation approaches, the campaigns were classified into four categories. An overview of all the studies per category can be found in the appendix.

The first category (see Table A1) includes mass media campaigns tested as stimuli in (quasi-)experimental controlled studies (N = 9) (i. e., lab studies). The evaluations in this category included a survey as a post-measure. Five also included a survey as a pre-measure. Finally, five also included a control condition. Regarding formative research in this group, two studies pilot-tested their campaign. In this category, seven found significant results regarding changing determinants and four regarding target behavior.

While Niemeyer and Keller (1999) found that brochures could increase intention to test, Gold et al. (2018) showed that brochures with information about the combined risk of radon and smoking could decrease testing intentions among nonsmokers. LaTour and Tanner (2003) concluded that the use of fear in videos could increase the number of information requests about radon, but only for parents, and the study of Hahn, Wiggins, et al. (2019) showed that direct tailored communication increased intention to mitigate.

Since these are controlled campaigns, process evaluation in this category is quite limited, with only Weinstein et al. (1992) and Witte et al. (1998) including questions regarding appreciation and understandability of the communication materials.

In the second category (see Table A2) campaigns (N = 8) were again the stimulus tested in a (quasi-)experimental design, but in a more ecological environment, for instance, by making use of different towns as conditions (Desvousges et al., 1992), or by collaborating with utility services (Smith, Desvousges, Johnson, and Fisher, 1990). Requirements for this category involved either testing different conditions on a larger scale or explicitly mentioning "field study" or "field experiment". Similar to the controlled campaigns, all field campaigns included a post-measure, five included a pre-measure and five had a control condition. In this group, three pilot-tested the campaign beforehand. Weinstein et al. (1990) found that a leaflet with information designed to change the perceived threat and perceived susceptibility increased intention to test significantly. However, Weinstein, Sandman, and Roberts (1991) later tested the effectiveness of personalized letters and phone calls to increase radon testing. The results showed that while perceived severity and perceived susceptibility increased as a result of the campaign, intention to test did not differ significantly from those who did not receive the personalized letter.

The campaign by Golding et al. (1992) did not show significant differences between factual newspaper series and a narrative newspaper series due to a smaller participation rate than expected. Other campaigns did observe increases in intention to test and testing, albeit without being significant (Adams et al., 1993; Hahn, Rayens, Kercsmar, Robertson, and Adkins, 2014). Johnson and Luken (1987) were the only authors that focused on increasing mitigating behavior. While their informative leaflet did seem to increase mitigating rates, significance was not tested.

In the field campaigns, process evaluation gained more importance. In half of the campaigns the appreciation of the campaign was assessed, as well as how it was perceived. One campaign also assessed reach (Hahn, Rayens, Kercsmar, Robertson, and Adkins, 2014).

When looking at the two previous categories combined, it becomes apparent that 10 out of 17 (quasi-)experimental designs were able to contribute potential changes to the communication campaign, as seen in Figure 2. Among these 10 studies risk perception is most often significantly changed by using leaflets (Johnson, Fisher, Smith, and Desvousges, 1988; Weinstein et al., 1990), direct communication (Hahn, Wiggins, et al., 2019; Weinstein et al., 1991), or informative videos (Weinstein et al., 1998). Moreover, risk perception was related to an increase in intention to test (Weinstein et al., 1998; Weinstein et al., 1990; Weinstein et al., 1991), and an increase in intention to mitigate (Hahn, Wiggins, et al., 2019). Self-efficacy was

increased significantly by showing videos (LaTour and Tanner, 2003; Weinstein et al., 1998) or by direct communication about the radon levels (Hahn, Wiggins, et al., 2019); and newspaper ads were successful in increasing knowledge, awareness and attitudes (Desvousges et al., 1992; Golding et al., 1992). Finally, perceived susceptibility was related to increases in intention to test (Gold et al., 2018; Weinstein et al., 1990), and an increase in information requests (LaTour and Tanner, 2003).

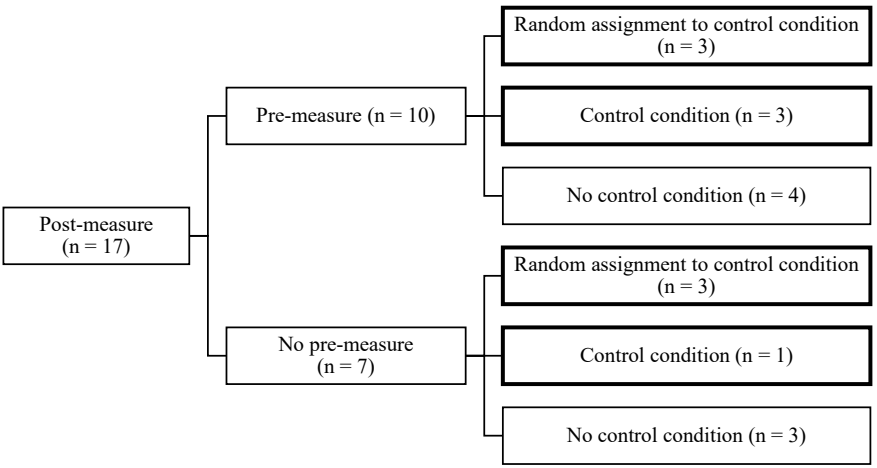

Figure 2: Overview of (quasi-)experimental studies included in systematic review.

The third category (see Table A3) includes campaigns that were implemented nation-wide (N = 4), and during which surveys (Wang et al., 2000) or interviews (Lofstedt, 2019) were conducted with a small sub-sample to evaluate the campaign. In this category, a shift is observed towards targeted behavior, evaluation methods and channels. Process evaluation gained importance and reach and media coverage were therefore more often mentioned as evaluation measures. Channels were more often oriented towards traditional media such as television, radio and newspapers, or a combination of those. Most of them did observe an increase in intention to test and testing. In the television campaign carried out in Washington D.C., intention to test increased, testing behavior decreased in comparison to kits ordered, and there was no significant difference observed in mitigating orders (Doyle et al., 1991). In contrast, a campaign in the United Kingdom where leaflets and posters were distributed, increased mitigating behavior (Hobson, 1992).

The final category (see Table A4) includes six campaigns that did not include empirical studies to evaluate their effectiveness, but adopted direct process and outcome measures such as reach, and direct behavior, for instance, radon test kits

purchased or received by the lab. Long and Fenton (2011) reported the numbers of ordered test kits, while Bain et al. (2016) reported the numbers of completed radon tests.

All of the campaigns in this group reported an increase in media coverage, reach, or both, which can be considered process evaluation measures. The campaigns of Burns et al. (1998) and Moir et al. (2012) also observed an increase in information requests by phone calls and e-mails. A documentary combined with newspaper, radio and internet presence increased radon test kit orders (Long and Fenton, 2011), as did leaflets combined with direct communication and feedback (Baechler and Englin, 1991). While a TV, radio and social media campaign was not effective in increasing testing in Bulgaria (Makedonska, Djounova, and Ivanova, 2018), it was effective in the State of Iowa; moreover, Bain et al. (2016) also saw an increase in remediations performed at homes.

4 Discussion

In the context of the requirements of European Member States to design and implement a communication strategy to increase awareness, this systematic literature review looked at the current level of evidence regarding radon campaigns and tried to answer the question "How can intervention programs promote radon-related healthy behaviors amongst the residential population by changing their personal determinants?". The findings suggest that better adherence to theory to inform all stages of the campaign design is likely to increase the effectiveness of radon communication campaigns.

Looking at the goals, and more specifically, the campaign objectives, it is clear that the main focus is still on testing behavior, rather than remediation behavior; despite the latter being crucial to tackling the health issue. Behavior is generally predicted by determinants, as indicated in behavioral models such as the Health Belief Model, or the Theory of Planned Behavior (Noar, 2011). Literature shows that radon behavior is also predicted by diverse determinants, yet we see that most interventions target only "knowledge". Moreover, in the current interventions, there was limited insight into how determinants predicted or related to behavior, as only four campaigns departed from behavioral models. Not only is radon protective behavior predicted by multiple determinants, people also have to go through numerous steps in order to perform the behavior. For instance, Hevey (2017) distinguished 17 steps starting from receiving information to confirming the effectiveness of remediation works. And while these steps also involve certain determinants, it shows the extensiveness of the behavior.

This shows a first gap in the current research, namely a lack of theoretical foundation in determining the right behavior to address, and the related determinants. Future research and radon campaign designers should develop a logic model of change prior to developing a campaign, as this appears to be crucial in order to increase behavior change. Theory and evidence could help in informing behavioral models, and more importantly, in informing the application of these models, as laid out in the Intervention Mapping approach. Only then will behavior change be facilitated (Bartholomew et al., 2016).

As goals and **strategy** are inextricably linked, we found that, in line with the focus on knowledge, almost all campaigns adopted a facts-based informative tone of voice with little room for emotions and a lot of technical information. This implies an information provision approach, in which people are considered rational beings who will act upon the information provided to them. However, similar to the findings of Poortinga, Bronstering, and Lannon (2011), this is rarely the case. People often experience a bounded rationality, in which their rationality is subject to emotions, biases, and heuristics. For instance, low perceived susceptibility results in an optimistic bias, whereby people believe others are more at risk than themselves, but also agency of the radon risk, the lack of casualties known from radon and the absence of any sensory cues of the gas add to this (Cheng, 2016; Clifford, Hevey, and Menezes, 2012; Fisher and Johnson, 1990; Hevey, 2017).

This finding is in line with the literature that states that merely informing people about a risk is not enough. Slovic, Peters, Finucane, and Macgregor (2005) state that the affect heuristic accentuates the importance of feelings in decision -making about cancer prevention actions.

Moreover, it emphasizes the importance of personal relevance of the communication. A strategy that was found to be effective in multiple cases was tailored communication. Whether tailored to radon levels, gender, smoking status, or having children, a tailored message is paramount to effective communication strategies regarding radon. The results showed that messages were mostly effective for a very specific audience and could even result in the opposite of the desired effect when targeting other audiences (Gold et al., 2018).

This shows a second gap in the literature, namely the lack of personal relevance of communication initiatives. As tailored campaigns show the effectiveness of personalized campaigns, constraints in time and budget might not always allow a tailored campaign. Therefore, there is a need for research on other communication strategies that increase the relevance, and the urgency, of the radon health issue. Addressing the availability heuristic appears to be important in just that (Hevey, 2017). Approaches such as the use of narrative persuasion or nudges could be tested. As well as targeting emotions, such as concern, or even humor (Miller, Bergmeier, Blewitt, O'Connor, and Skouteris, 2021). Additionally, communication

should also address social norms and social influence to decrease the psychological distance of the risk (Hevey, 2017; Khan and Chreim, 2019). Merely informing is not sufficient, so other ways to engage people are needed. Moreover, audience research on homeowners in radon-prone areas should reveal the best ways to reach them, with options such as social networks (both online and offline), and innovative technologies, rather than informative and general leaflets. Furthermore, strategic communication is also about informing and involving stakeholders, such as doctors, building companies, and local representatives. On the one hand, they should be informed so that they can also interact with the public about the campaign. On the other hand, they should be involved in the campaign development as well, in order to prevent a solely top-down approach. Interactive workshops, such as Design Thinking approaches with stakeholders can increase the multi-level knowledge and collaboration on the development of the intervention (Bartholomew et al., 2016).

Regarding **research**, some noteworthy results appeared. When looking at the evaluation of the effectiveness of the campaigns, methodological challenges concerning causality and outcome measures emerge. As shown in the results, only ten campaigns allowed for conclusions to be drawn about the effectiveness of the communication campaigns. Of the other campaigns, the question therefore remains whether the changes in behavior were due to the mass media campaign. These methodological challenges still remain a missed opportunity to build on the acquired knowledge and to increase growth within the field of radon communication (Glasgow, Vogt, and Boles, 1999; Randolph and Viswanath, 2004).

These inadequate evaluation measures show a third gap in the literature. Ideally, evaluation starts at the very first step with formative research, with the communication materials being tested in lab studies, preferably in randomized controlled trials, and is the campaign implemented while taking into account process and outcome evaluation (Bartholomew et al., 2016; Noar, 2009).

Finally, the discrepancy between studies based in the United States and studies based in Europe is noteworthy. One possible explanation is that radon has been part of the public agenda of the United States since 1985 (George, 2015; Mazur, 1987). From that moment on, different states implemented legislation regarding the licensing of mitigation companies, and residential radon testing. While in Europe it was not until 2005 that the importance was proven by showing connections between lung cancer and exposure to radon (Darby et al., 2005). This resulted in the launch of the International Radon Project of the World Health Organization in 2005 (Pantelić et al., 2019), the formulation of guidelines in the WHO Handbook (World Health Organization, 2009), and the inclusion of radon in the renewed European Basic Safety Standards (Council Directive 2013/59/EURATOM, of 5 December 2013). The later action from the European point of view might explain the limited studies based in Europe.

5 Limitations

Just like all studies, this one also has some limitations. A first limitation of this study is the focus on mass media only. Within health promotion there is a need for regulation, economic means, and communication to reinforce behavior change. The focus on mass media targeted at the individual in the current research is limited since within the communication component other formats of communications should be used, such as interpersonal, non-mediated communication and other stakeholders, for instance constructors or local government representatives, should be targeted. A homeowner is not a single actor in this matter, and a strategy that involves not only the multiple aspects of communication, but also environmental factors such as regulation and economic means is recommended, but was not included in the scope of the research. Related to this, the focus of the systematic review was on homeowners and residents, and although they carry some responsibility in testing their homes for radon and remediating them if necessary, the responsibility should not be limited to homeowners only as governments are also accountable. This shared responsibility was not included in this review.

Additionally, not all communication materials were available and could be investigated. Results regarding messages and communication strategies are limited to those who had communication materials available. Furthermore, this systematic review was limited to mass media campaigns that were published in peer-reviewed journals. Other mass media campaigns, that were perhaps not reported scientifically, are not included but could provide a practical perspective about certain communication strategies. Both scientific and implemented evidence about communication campaigns designed to address the risks from radon is needed urgently as countries are required to develop and implement communication campaigns.

6 Conclusion

To conclude, when looking at how mass media campaigns can promote indoor radon testing and remediation amongst the general population, the answer is threefold. First of all, theory is needed to determine the right goals and objectives in terms of target behavior and determinants. Secondly, strategic communication, based on theory, is needed to ensure better chances of success. Moreover, increasing the personal relevance in the communication is crucial. Approaches such as targeting emotions, telling stories, or using tailored communication should be considered when addressing the health issues of radon. Thirdly, concerning research, appropriate evaluation methods are recommended to provide support of the effec-

tiveness of the campaigns so that the evidence base can develop further. This is crucial so that researchers and campaign designers can build on this knowledge, improve their campaigns, increase the testing and remediation rates, and hence reduce lung cancer due to indoor radon.

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