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Do healthy home checklists nudge people to test their home for radon? Evidence from a randomised control trial

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Abstract

Radon degrades indoor air quality and is the leading cause of lung cancer after smoking. We examined if a 'Healthy Home Checklist' nudged households to purchase a radon test online. We used a cluster randomised control trial with 15,043 households across 22 postal route groups in Ottawa. Treated households were mailed postcards with a checklist that framed testing for radon as a routine action to check air quality and keep a healthy home. It also included a vendor website link where people could buy a test kit online. The control group did not receive a postcard. More test kits were purchased in the treated clusters but the take-up was low – only seven tests were purchased in the treated groups and one test in the control. Our result suggests that this nudge was not necessarily cost-effective.

Keywords

radon, air quality, risk communication, nudge, experiment, checklist, friction

JEL classification

C93, D81, D84, D91, I12, Q53, Q58

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1. Introduction

Radon degrades indoor air quality and is the leading cause of lung cancer after smoking (World Health Organization, 2016; Hevey, 2017). Lung cancer risk increases by 16% per 100 Becquerels per meter cubed (Bq/m3) increase in long time average radon concentration (Boardman and Glass, 2015; World Health Organization, 2016). While the WHO recommends a 100-300 Bcq/m3 limit, Health Canada's radon action guideline is 200 Bcq/m3 and the United States has a limit of 148 Bcq/m3.

Radon is present in all homes, so the only way to know exposure levels is to test for it. It is an invisible, odourless, and tasteless gas. It emerges from the naturally-occurring breakdown of uranium (within rocks and soil) into radioactive particles and seeps into homes from the ground up. If a home tests above the recommended level, durable radon mitigation methods are available. For instance, active soil depressurisation techniques can move the gas outdoors by installing a pipe and fan in the foundation, thereby reducing radon levels by 91-99% (Frutos et al., 2011). Yet public demand for tests are too low – 7% of Canadian homes were tested for radon in 2017 and 3% in 2009 (Statistics Canada, 2018).

This paper examines if a 'Healthy Home Checklist' postcard nudges households to purchase a radon test kit. We employed a cluster randomised control trial (RCT) covering 15,043 households across 22 postal route clusters in Ottawa. Households in treated clusters were randomly assigned to receive a postcard, which framed the act of testing your home for radon as a part of a checklist of routine actions to safeguard indoor air quality and keep a healthy home. Two variations of the postcard was tested in two treatment groups. The postcard in treatment A directed people to a vendor website where a test could be directly purchased with one click (low friction). In treatment B, people were directed to a product aggregator website, currently recommended by Health Canada, which offers more product choice, health risk information and at least four clicks to purchase a test (higher friction). So a secondary aim was to explore if testing could be increased by reducing friction in the online choice context. The study was conducted in partnership with Health Canada's National Radon Program.

We are the first to evaluate if a nudge framing radon testing as part of checklist of routine actions to safeguard household air quality increases online test purchases, and if the vendor website matters. We are also not aware of any other controlled experimental evaluations of government initiatives to boost radon test purchases. We found that the nudge increased test purchases but the low-take up – seven tests in the treated groups versus one in the control - suggests this nudge is not a cost-effective strategy in isolation.

The remainder of this article is organized as follows. Section 2 notes the past literature used to motivate this study. Section 3 presents the study context, hypotheses and experimental design. Section 4 presents the results. Section 5 concludes.

2. Related Literature

This paper builds on and relates to several recent papers in environmental economics and risk management, which highlights many reasons why people do not test their homes for radon. First, people may lack awareness of and underestimate radon health risks. Estimates from Canada's Households and the Environment Survey found only 55% of participants had heard of radon, and only 59% of this group was able to correctly identify what it was (Statistics Canada, 2016). Although around 16% of lung cancer deaths in Canada are caused by indoor radon exposure (Chen et al., 2012), past studies found that most people do not know radon causes lung cancer and cannot recall someone getting lung cancer from radon (Hevey, 2017; Vogeltanz-Holm and Schwartz, 2018; Khan and Chreim, 2019). This implies low levels of knowledge about radon health risks may explain low testing levels.

Second, people fail to take action even if they have some awareness. A recent survey found 32% of Ottawa homeowners expressed some concern about radon health risk yet only 12% of them tested their homes for radon (Khan et al., 2019). People also do not feel personally at risk. Past studies have found US residents who were aware about radon and more exposed did not perceive it as an immediate health risk in their own homes (Duckworth et al., 2002;

Ferng and Lawson, 1996). Similarly, radon awareness campaigns (which typically disseminate technical risk information and occasionally free tests) have failed to adequately increase risk perception, and testing and mitigation, even among those who knew that they were at high risk (Weinstein et al., 1988; Field et al., 1993; Poortinga et al., 2011). Poortinga et al. (2011) is a notable exception – their survey revealed a long-term locally directed radon awareness campaign increased testing amongst UK households in higher-risk areas. Past studies, while forming a crucial evidence base, rests on self-reported and non-experimental survey data from small samples. It is difficult, therefore, to distinguish the causal effect of moralsuasion from other confounding factors including social pressure from surveyors and demand effects since people knowingly participated in studies (Weinstein et al., 1988; Field et al., 1993; Poortinga et al., 2011; Larsson, 2015).

Third, people may not test their homes for radon because it is a voluntary action, and there is no prevailing norm to do so and the default is not testing. Current campaigns, including Canada's National Radon Program, primarily relies on moralsuasion by providing radon health risk information to raise awareness, appealing to people to test their homes, and more recently directing people to vendor's websites from whom they can purchase radon test kits online. Yet testing rates remain very low. Low rates highlight the need to improve, expand and evaluate the set of potential interventions that could be used to encourage residents to test their home for radon. An important question, then, is how to stimulate the formation of behavioural norms around radon testing.

A cost-effective approach which has nudged behaviour in diverse domains like energy and water conservation, recycling and littering is to make existing descriptive and injunctive social norms salient in appeals (Thaler and Sunstein, 2008; Ferraro and Price, 2013; Allcott and Rogers, 2014; Farrow et al., 2017; Benartzi et al., 2017). But this approach is less tenable in the current context as the strong prevalent norm - effectively the status quo - is not testing (Sunstein, 2017). So we take a different approach, by linking radon testing to other well-established norms to check household air quality (like installing a smoke detector) through framing the appeal as a 'Healthy Home Checklist'.

Fourth, we also studied whether varying friction in the online choice context impacts the purchase behaviour. Friction typically refers to the increased cost of acquiring and processing more information, including exploring and assessing more product options in a given choice set (Handel and Schwartzstein, 2018). It is an important factor driving purchase behaviour in models of rational inattention (Caplin and Dean, 2015; Handel and Schwartzstein, 2018; Gabaix, 2019), satisficing (Caplin et al., 2011; Simon, 1955) and choice overload (Chernev et al., 2015). Studies have observed that more choice does not necessarily lead to increased purchases of consumer products like jams, chocolates and electronics (Iyengar and Lepper, 2000; Chernev, 2003; Berger et al., 2007) or even better health insurance plans (Bhargava et al., 2017).

This is in contrast to the standard expectation is that more product choice and more information induces stronger preferences (for e.g. by offering option value, experienced utility and choice satisfaction) and increases product choice (Botti and Iyengar, 2006; Patall et al., 2008). Recent meta-analyses highlights mixed results from past studies, including cases where more choices facilitated product sales, the reverse (especially in lab and field studies) and no effects (Chernev et al., 2015; Scheibehenne et al., 2010). Chernev et al., (2015) note results can depend on the decision context, and that high complexity in the choice set and preference uncertainty can deter product choice. Thus, whether an online choice context with more friction deters radon test purchases or not in this setting is an empirical question. To explore this, we test two variations of the postcard. In variation A, people could directly purchase a radon test kit from one vendor with one click (low friction). In variation B, people were directed to a product aggregator website with many test options and radon risk information (high friction).

In summary, our main contribution is to test whether a novel informational nudge, the 'Healthy Home Checklist', encouraged households to purchase a radon test online. We connected the nascent literature between encouraging radon testing and how friction affects product choice by exploring if increased friction in online choice context affects test purchases. In addition, we also attempted to broaden the evidence base about the effectiveness of radon moralsuasion and awareness campaigns, currently drawn primarily from non-experimental surveys, by evaluating the behavioural impact of this nudge through a cluster RCT.

3. Experimental method

2.1. The study context and hypotheses

Health Canada recommends that all residents test their home for radon since this the only way to know the radon levels in a home. Radon test kits typically cost Canadian $30-$60. Purchasing a test is the first step in a more complex sequence of actions, including initiating the kit for 3-12 months in the home, mailing the test kit to a testing lab and then arranging for mitigation if it is deemed necessary.

Health Canada wanted to trial the effect of a nudge delivered through direct mail. Nudges have been shown to be as or more cost-effective as traditional information and incentive-based campaigns (Benartzi et al., 2017). Direct mail is a recommended tactic to reach households who would ultimately need to voluntarily purchase the test (World Health Organization, 2009). In addition, we explored if the website currently recommended by Health Canada for online test purchases – on variation B of the postcard - unintentionally mitigated test sales due to increased friction from factors like more information, product choice and a longer purchase journey through more clicks.

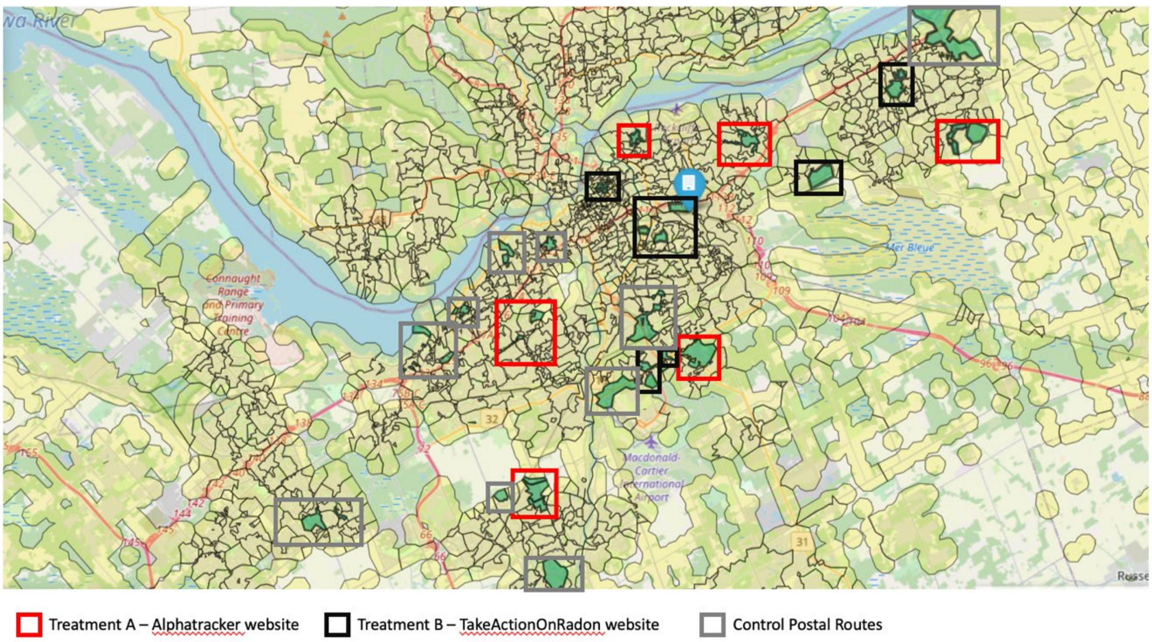
Thus, our primary aim was to evaluate if direct mail appeals via the checklist postcard increased tests purchases. Based on the past literature and current policy (Poortinga et al., 2011; Sunstein, 2014; World Health Organization, 2009), the first hypothesis was that receiving any Healthy Home Checklist postcard in the treated groups increases test purchases compared to the control group which received no postcard.

Our secondary aim was to explore if directing people to a purchase website with lower friction encouraged online test purchases. Based on the mixed findings from the past literature on how friction affects product purchases (Handel and Schwartzstein, 2018; Bhargava et al., 2017; Chernev et al., 2015; Scheibehenne et al., 2010; Iyengar and Lepper, 2000), our second hypothesis is that there is no difference in test purchases if people are directed to a website more friction versus one with less friction.

2.2. Study design

We evaluated the impact of the checklist postcards using a clustered randomised control trial. The clusters were the postal routes in Ottawa from Canada Post's Ad Mail Service, so all households that were part of the same postal route constituted one cluster within the study. We used a cluster-level design because of logistical concerns, since it was not possible to randomise at the household level due to the direct mailer service offered by Canada Post. This study was conducted in Ottawa, Canada during a five-week period between September 2, 2019 and October 6, 2019. It was approved by the ethics committee of the university.

Figure 1: Treatment and control postal route clusters



We determined that a sample of 6 postal routes per treatment arm, with a random sample of 500 households per postal route, was sufficient to obtain 80% power for a 5% level test of a difference of at least 2 percentage points difference in test kit purchases between the two groups (treatment A, treatment B, and control). Thus, 6 postal routes were randomly selected to receive intervention A, 6 to receive intervention B, and 12 to receive no additional intervention in the control group (using a computer-generated random number generator) from a total of 627 postal routes in Ottawa. Figure 1 presents a map of the treated and control clusters. So, 12 clusters belonging to the treatment groups received one of the checklist interventions while 12 clusters in the control group did not receive anything. Study design details are in the Appendix.

2.3. Interventions

The interventions were two variations of the 'Healthy Home Checklist' postcard shown in Figure 2. In treatment A, the Healthy Home Checklist postcard directed people to a vendor website where the radon kit could be directly purchased (low friction). Treatment B was identical except that it directed people to a product aggregator website (higher friction).[1] The postcards were identical in every way barring the vendor website link.

We designed a 'Healthy Home Checklist' to frame testing a home for radon as a normal part of keeping a home healthy. A norm, in this instance, was used to suggest an ideal form of behaviour for keeping a home healthy by undertaking a radon test. As previously noted, there is currently no positive social norm or mandate to testing a home for radon, and around estimated 7% of homes in Canada have tested their home for radon (Statistics Canada, 2018).[2]

To frame and link radon testing to other normal and routine actions to test air quality, we used a checklist format. There were three questions asking the participant if they had a working smoke detector, if they had a working carbon monoxide detector, and if they had tested their home for radon. All three items related to testing air quality in a home and the first two are already widely adopted within Canadian homes. The third item explicitly suggested a new and desirable norm for testing a home for radon and was presented without a 'checked' box to make it more salient as an item that needed to be done or 'checked' off the list (Gawande, 2010; Jackson and Schneider, 2015). Thus, the checklist aimed to remind

[1] Each of the postcards were double-sided, with an English side and a French side to comply with a Health Canada policy (see Appendix Figure A3). The intervention was also designed by leveraging the principles of norms and salience from the MINDSPACE approach, which has also been applied in other environmental contexts (Dolan et al., 2012; Palm-Forster et al., 2019).

[2] Presenting this statistic in the postcard could have resulted in participants being less likely to purchase a test kit if it discouraged them by making salient that the norm is not to test or 'not many people are doing this', which can have a powerful effect on outcomes (Cialdini, 2003).

people of past norms of keeping the home healthy while presenting a choice set of similar but distinct actions to test for air quality in the home (Kahneman and Miller, 1986; Bordalo et al., 2017).

We used checklists they are an under-utilised memory aid which can simplify routine actions into smaller memorable chunks (Gobet et al., 2001; Ariely and Wertenbroch, 2002; Milkman et al., 2011; Ericson, 2017). They can be especially useful when there is an interaction between procrastination and forgetting (Ericson, 2017), which is likely in the context of radon testing; for e.g. people can forget about purchasing the test or procrastinate, even if they previously intended to purchase it. More broadly, checklists have proven to be effective at providing explicit instructions in other worker, health and safety contexts (Haynes et al., 2009; Gawande, 2010; Jackson and Schneider, 2015). Yet few studies have explored their potential to address environmental health risks.

Apart from the checklist, a message on the left side of the postcard directly addressed the reader and used a health frame to increase salience and personal relevance: "Our home health is critical for our personal health. The air in your home should contribute to your health". We avoided technical, impersonal radon risk information as well as fear-inducing language as past work has found both these approaches to radon communication have been less effective (Golding et al., 1992; Dragojevic et al., 2014; Hevey, 2017). Instead, the postcard suggests that having your home tested for radon is a normal part of keeping your home healthy and as a result, keeping yourself healthy.

In addition to the norm of keeping a healthy home, we aimed to link messages in the postcard to personal norms of keeping healthy. Previous work suggests that normative strategies are more effective when they align personal and social norms (Thøgersen, 2002, 2006; Gifford and Nilsson, 2014; Dietz and Whitley, 2018). In this way, the message was intended to reinforce desired personal and social norm for maintaining a healthy home in lieu of existing social norms to test for indoor air pollution.

Lastly we include a message stating "Purchase a radon test kit at weblink.ca" since providing information on how to get a test is more effective than simply stating health risks (Weinstein et al., 1988; Poortinga et al., 2011; Larsson, 2015). The weblink was the only distinction between the two variations of the postcard, so the difference between treatments A and B was relatively subtle.

In treatment A, the weblink directed people to the vendor Alpha Tracker's website (alphatracker.ca). This vendor was chosen as it was the only vendor website at the time of the study to enable a purchase with one click at the time of the experiment and who agreed to participate when contacted. If the weblink was entered into a web browser, participant was taken straight to a webpage where people could directly purchase a test kit (see Figure 3). Only one click was required to add the radon test kit to the online shopping cart from the website implying lower friction cost, less information and only one choice with a clear description of the product.

In treatment B, the weblink took people to the "Take Action on Radon" website (takeactiononradon.ca), which aggregates all available online radon test vendors in Canada (including alphatracker.ca, the vendor from treatment A). We chose this product aggregator website since Health Canada currently directs people to it in their radon communication and moralsuasion efforts. If entered into a web browser, people were taken to an informational landing page, where, if users selected the "Buy your radon kit" button they were taken to a list of vendors. If they clicked a vendor, they were taken away from this website to the vendors webpage. For example, if they clicked "Order Online" via the Alpha Tracker option, they were directed to alphatracker.ca, where they could then purchase a test kit directly from the vendor. Thus, in treatment B, a minimum of four clicks were required to add a radon test kit to the online shopping cart. The second website, therefore, had more information and product choice across many vendors, and people were taken off this website to a private vendor's website for the actual sale, therefore higher friction costs.

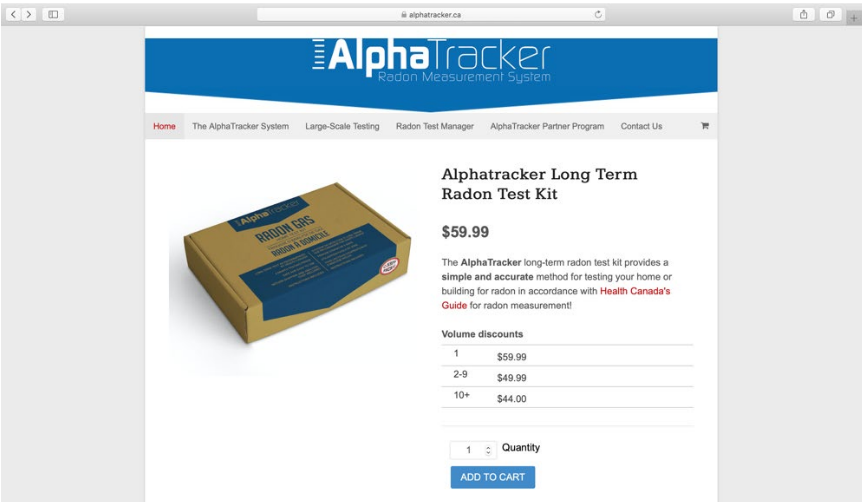
Figure 2: Behavioural Interventions I: Healthy Home Checklist postcard

Treatment A

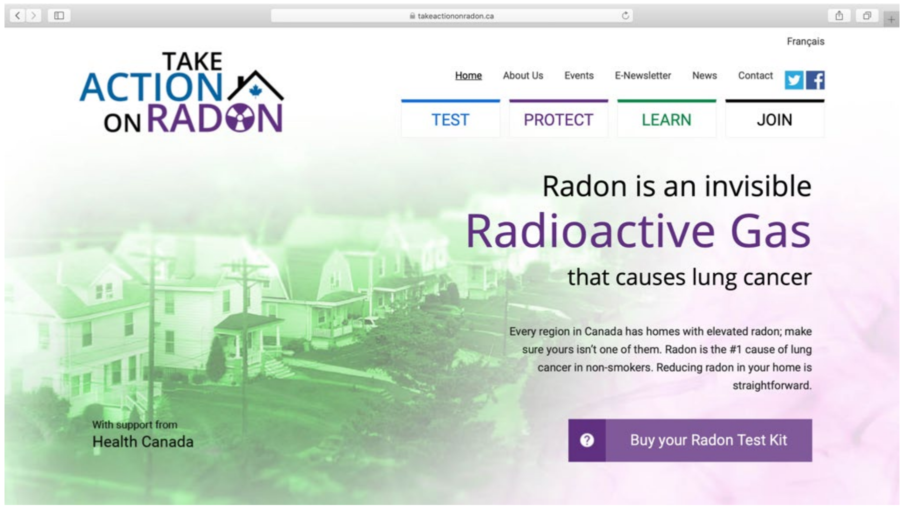
Treatment B

Figure 3: Behavioural Interventions II: Landing pages of radon test vendor websites

Treatment A



Treatment B



Both variations of the postcard was identical barring this weblink, so any differences between treatments A and B would emerge once people visited the website. However, apart from more friction, there are differences in the design of the webpage itself which we could not fully control for. For example the price at $59.99 was immediately salient on alphatracker.ca since the test could be purchased with one click. Another possibility is that people may have perceived takeactiononradon.ca to have more credibility because “supported by Health Canada” (in red font) was stated on the landing page. We attempted to mitigate these differences through our experimental design by ensuring that both groups had the same message at the bottom of the postcard stating “Project Supported by Health Canada”, to increase confidence and credibility in both treatments. Moreover, Alpha Tracker’s landing page also stated that the kit was “designed in in accordance with Health Canada's Guide for radon measurement” (also in red font). However it is possible that these factors – apart from differences in friction – may still impact online purchase behaviour and should be kept in mind while interpreting the results.

2.4. Data

The postal routes were obtained from Canada Post’s Ad Mail service. Canada Post provides only the number of households in each postal route but not any other socio-demographic data. The number of radon tests and purchase postal code were obtained from the test vendors. To obtain the number of tests purchased per postal route, the purchase postal code for each kit sold online by each vendor during the study period was linked to the postal route. The study only tracked purchases through either alphatracker.ca and takeactiononradon.ca. takeactiononradon.ca aggregates all 26 radon vendors in Canada, and all of them were requested to participate in the study. Of these, 19 vendors agreed to participate and share data with us. The 7 vendors who we did not hear from were removed from the website for the duration of the study.

2.5. Estimation strategy

We used intention to treat analysis, that is, the assumption was that all households receiving the checklist postcard remained in the treatment group to which they were initially assigned for the study duration. All the analyses was conducted at the cluster-level since household-level data in each postal route was not available. The dependent variable was the number of test kits purchased in each cluster.

We began our analysis by cross-tabulating cluster-level test purchases by control and treatment groups. To detect if differences between the groups was statistically significant, we used non-parametric Wilcoxon tests since it does not require the assumption of normality of cluster-level outcomes (Leyrat et al., 2018).

We also conducted a cluster-level regression analysis because Wilcoxon tests only provide the p-value and no estimate of the treatment effect. We followed Leyrat et al. (2018) recommendation to use a weighted Ordinary Least Squares (OLS) regression model to detect treatment effects, since we have a small-to-medium number of unevenly-sized clusters. Each cluster is weighted by sample size, which is the number of households. This method allowed us to account for variations in number of households in each cluster.

4. Results

4.1. Treatment effect

Table 1 provides the descriptive statistics at the cluster-level. The final sample contained 22 clusters, of which 12 received one of the checklist interventions (6 clusters in each treatment group) while 10 received no postcard. Two control postal routes were excluded since they contained no residential addresses (they were marked as agricultural or business zones).[3] There was balance in the total number of homes between the control group and treatment A, and between the two treatment groups, but treatment group B had fewer homes than the control.

Disappointingly, very few tests were purchased in the control and treatment clusters (see Table 1). At least one test kit was purchased in one control cluster, three in treatment A and four in treatment B. The fraction of tests purchased to the total homes in each cluster was,

[3] The results are qualitatively similar if all 24 clusters are included and these results are omitted for brevity.

therefore, very low: 0.0002% in the control group, and 0.0006% and 0.0016% in treatment A and B respectively.[4]

Table 1: Experimental design, descriptive statistics and balance tests

Experimental group	Description	#Homes	#Postal routes	#Tests
Control (C)	No postcard	8,115	10	1
Treatment A (A)	Postcard A	4,015	6	3
Treatment B (B)	Postcard B	2,913	6	4
Treatment A+B (A+B)	Postcards A+B	6,928	12	7
All groups		15,043	22	8
Balance tests (p-values)	C vs. A	0.664		0.083
	C vs. B	0.051		0.073
	A vs. B	0.2		0.789
	C vs. A+B	0.1469		0.0474

Notes: p-values are from non-parametric two-sample Wilcoxon rank-sum (Mann-Whitney) tests.

The differences in the number of tests purchased were statistically significant between the control and each of the treatment groups using two-sample Wilcoxon rank-sum tests. The difference between control and treatment A was significant at the 10% level ($|z| = 1.732$, p-value = 0.083), and the difference with treatment B was also significant at the 10% level ($|z| = 1.790$, p-value = 0.073). The difference between treatment A and B was not statistically significant ($|z| = 0.267$, p-value = 0.789). The difference between the control and combined treatment group (treatments A+B) was significant at the 5% level ($|z| = 1.982$, p-value = 0.045).

Table 2 presents the results of the weighted OLS regression model where cluster-level observation is weighted by the number of households in each cluster. In model (1) the explanatory variables are dummy variable for treatment A and B. The treatment A coefficient is positive and significant at the 5% level (p-value = 0.021 and 95% Confidence Interval [0.099 - 1.0713]). Wald tests of the parameters suggest, however, that there is no difference between Treatment A and B coefficients (F = 0.04, p-value = 0.845). Thus, we pool together

[4] In the control group, the one test kit was purchased on 13-Sep-2019. In treatment A, three test kits were purchased on 16-Sep-2019, 08-Sep-2019 and 09-Sep-2019. In treatment B, four test kits were purchased on 02-Oct-2019, 04-Oct-2019, 02-Oct-2019 and 21-Sep-2019.

observations in treatments A and B to create a combined control group (Treatment A+B) in model (2). The coefficient on the combined control group is positive and significant at the 5% (p-value = 0.016, 95% Confidence Interval [0.132 - 1.124]). This suggests that relative to the control group, 1.87 more tests were purchased in the combined treatment group at the cluster-level.

In summary, that the difference the control and combined treatment group is significantly different from zero suggests that postcards, may have nudged kit purchases, is in support to Hypothesis 1. That the difference between the two treatments were not significantly different from zero, lends support to Hypothesis 2. However, the low uptake across treatment clusters suggests that this nudge was not very effective at boosting test kit purchases overall.

Table 2: Weighted OLS regression model: Treatment effect

Weighted OLS regression model: Variables	(1) tests	(2) tests
Treatment A	1.796**	
	(0.417)	
Treatment B	1.987	
	(0.930)	
Treatment A+B		1.874**
		(0.446)
Constant	1.076	1.076
	(0.083)	(0.081)
Observations	22	22
R-squared	0.297	0.294
Adjusted R-squared	0.223	0.258
F	4.069	6.977
Prob > F	0.034	0.016

Notes: Robust standard errors in parentheses. ** p<0.05. Cluster weights are the number of households per cluster.

4.2. Limitations

This study has some important limitations. The effect of the postcards were in the expected direction and statistically significant, and the final sample consisted of a large number of households. However, the study may have been underpowered and failed to detect the true effect and there is a risk of false positives (Leyrat et al., 2018). Moreover, there may be some contamination between the treatment and control groups if participants in the control group talked to participants in the treatment group about receiving the postcard. This may have been more likely if the control and treatment clusters were adjacent to each other. Figure 1 shows that clusters were often close together but not always adjacent. That said, we cannot completely eliminate the risk that there may have still been contamination.

There may also be some measurement error in the outcome variable of the number of tests purchased, since the study only tracked purchases through the nineteen vendors who were on the websites for the study duration. We removed the other seven vendors who did not agree to participate for the study duration. However, participants in all groups could have still purchased tests at other online locations or in-person at a local home improvement store and may have been more likely to do so in the treatment groups.[5]

We could look only at the joint effect of increasing friction due to multiple elements like increased information and number of choices in treatment B. More specifically, we cannot differentiate between specific sources of friction (e.g. more information versus longer purchase journey through more clicks and webpages versus increasing the choice set via more vendors). The role of friction could also not be fully isolated from other differences between the two websites. In particular, the salience of Health Canada's support on the landing page on takeactionradon.ca, may have induced greater trust (and in turn purchases) in treatment B, although alphatracker.ca mentioned they were in accordance Health Canada's guidelines. To address this, we explicitly stated Health Canada's support in both postcards. It was not possible to re-design vendor webpages during the trial and we did not have another vendor website which enabled a direct purchase with one click. Although isolating the sources of friction and role of trust in vendors are important avenues for future work, we believe identifying the combined effect of frictions and information relative to a low friction single choice setting is still useful since we evaluated if an existing 'allocation policy' - whose aim

[5] While we cannot confirm this, we cannot rule out this possibility either since there was a spike in Google web search trends for the word radon from Ontario (and Ottawa) during September and October 2019 (see Appendix Figure A4). We have also contacted the vendors to see if there was any difference in test kit purchases after the experiment (to explore if the effects were durable), but we have not been able to get this data.

was to direct people to take the specific action of testing for radon – could be improved (Handel and Schwartzstein, 2018).

Finally, this study only looked at radon test kit purchases, so it is difficult to determine whether households followed through with the remaining steps required to complete the radon mitigation, if it was required. Based on prior work, it is possible that the gap between radon testing and mitigation is large (Johnson and Luken, 1987; Weinstein et al., 1988; Field et al., 1993). We could not follow up with those who purchased a test kit to determine if they completed the test or who already had a test. Moreover, Health Canada wanted people to first test their home for radon so that they know whether or not they need to protect their homes.

5. Conclusions

This study aimed to evaluate an attempt to nudge residents to purchase a radon test kit, the first step to address health risks from radon. Specifically, we designed and mailed a 'Healthy Home Checklist' postcard which framed radon testing as a part of routine actions to safeguard indoor air quality and directed households to a website where they could buy tests online. We also checked if varying the website – and the underlying amount of choice, information and thereby friction - had any effect. As far as we are aware, this is the first study to evaluate a novel nudge to increase radon test kit purchases online using a cluster RCT. We thereby widen the past literature, which has primarily focused on awareness and moralsuasion campaigns using surveys, about how to increase radon testing.

We found that the checklist postcard increased online test purchases compared to the control group which received no postcard. However the low take-up – only 7 tests in the combined treated group versus 1 in the control – suggests that this nudge is not sufficient to boost testing. This result is in line with past studies highlighting the many challenge of increasing radon testing and mitigation behaviour using informational approaches (Field et al., 1993; Poortinga et al., 2011). It is also in line with other studies noting that unsolicited nudges can result in low uptake in other environmental domains like energy audits (Fowlie et al., 2015).

This intervention, like other nudges, can be considered relatively inexpensive since costs arise primarily from printing and directly mailing the postcard. But costs need to be contextualised in terms of whether the intervention changed behaviour. Based on the results of this trial, the average cost to Health Canada for encouraging a household to purchase a radon test kit was Canadian $416.41 (i.e. cost of total cost of intervention/number of tests purchased in the treatment groups). This is significantly higher than the cost of purchasing a radon test kit online which typically ranges from Canadian $30 to $60. That said, there may have been additional benefits from this study, like increased awareness and radon risk perception, which we cannot measure.

Alternative approaches that combine incentives, risk information and nudges may be fruitful to test. Incentive-based schemes may be especially useful since stated preference studies typically find a low willingness to pay for radon testing and mitigation (Smith and Desvousges, 1990; Akerman et al., 1991). Interviews with homeowners also suggest costs are a barrier to testing (Larsson, 2015; Khan and Chreim, 2019). However, as noted by Fowlie et al (2015), non-monetary factors (for e.g. perceived time and effort to install the radon test) may also act as a barrier to increasing test purchases and testing.

In addition, future studies can explore if responses to the treatment are heterogeneous based on radon risk to inform better programme targeting (Poortinga et al., 2011; Brown et al., 2017). It may be that those living in high radon risk areas are more likely to respond to the checklist postcard than those in non-high-risk areas, if they are more aware of radon, perceive higher health risks or had prior intentions to test but then forgot. In related work, Pinchbeck et al (2020) found a significant negative relationship between changes in published radon risk levels and residential property prices of affected properties in the UK; they found that higher socio-economic groups mitigate exposure by moving away from radon affected areas, which in turn can attract poorer residents via lower prices. Apart from suggesting radon exposure can be mitigated through the housing market, these findings also highlight that intervention effects may be heterogeneous based on both household (e.g. socio-economic status) characteristics and radon risk. However, the only way to know radon risk exposure by location is to test for it. Currently, there is significant uncertainty in radon risk exposure since localised levels of testing (including in Ottawa) are often unreliable especially at the household level

(Statistics Canada, 2018). Given this, Health Canada recommends that existing data on radon risk should not be used as a tool to determine radon risk potential or whether or not to test a home for radon. The only way to know if a home has an elevated level of radon is to test, regardless of location.

Finally, directing people to a website with more information, more product choice and more clicks to purchase was not less effective, suggesting that more friction on the purchase website did not deter purchases in this context. Why was there no difference? One possible explanation is that the forced choice of the single product offered by a private vendor in treatment A at $59.99 may have led to discomfort if people were uncertain of alternative test options leading them to delay or avoid a decision (Dhar and Simonson, 2003). Another reason could be that those interested in purchasing the kit benefitted from the greater information and choice available - despite higher friction relative to the control group - since health risks from radon, range of alternative tests and their costs are less well known (Chernev, 2003). Whether purchases could have been increased by offering a limited range of choices (rather than just one versus many choices) or varying other elements of friction costs like the number of clicks, are possible avenues for future research as well, apart from trialling other behavioural policy approaches.

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Appendix

Figure A 1: Radon Testing Process in Canada

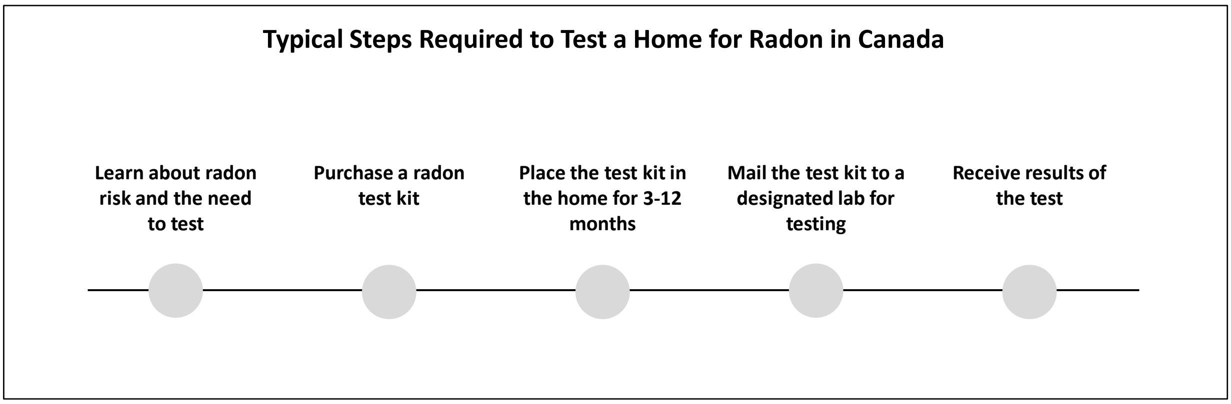


Figure A 2:Ottawa postal route map from Canada Post

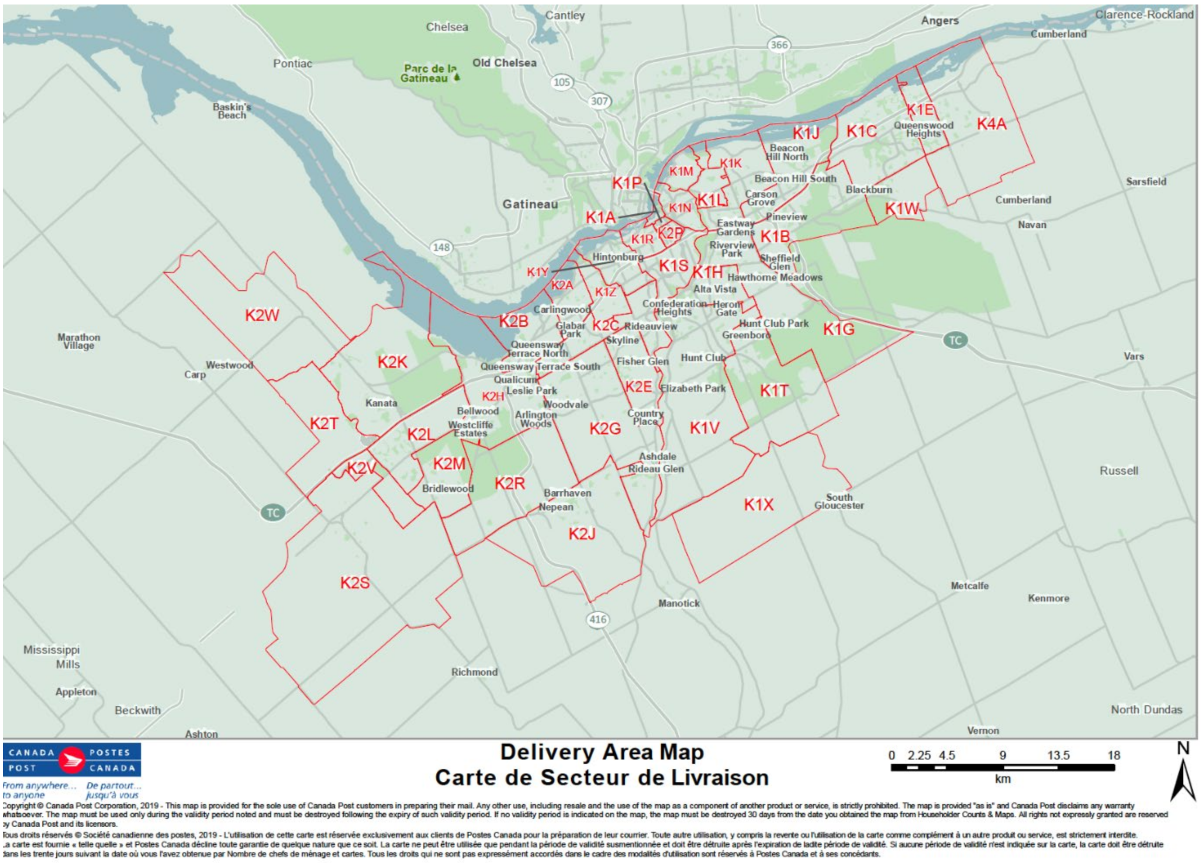
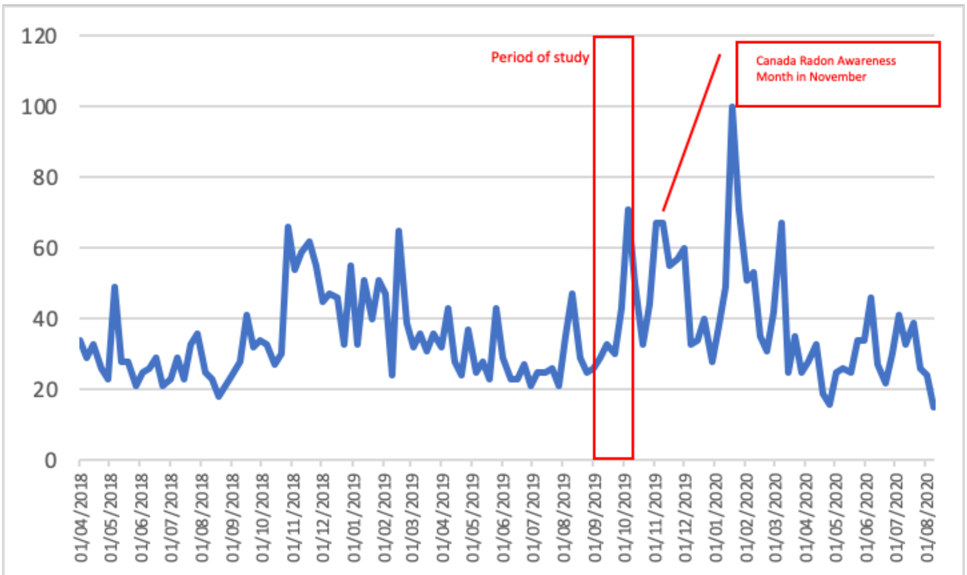


Figure A 3:French translation (at the back of the same postcard)

Treatment A: First Vendor Website *Treatment B: Second Vendor Website*

Figure A 4: Searches for "radon" in Ontario, Canada: Google trends data on Interest over time



Notes: data from Google trends accessed on 01 August 2020. From 01 April 2018 to 01 August 2020, there has been a 5% average increase for the word "radon" on Ontario. Interest over time numbers represent search interest relative to the highest point on the chart for the given region and time. A value of 100 is the peak popularity for the term. A value of 50 means that the term is half as popular. A score of 0 means there was not enough data for this term. While it was not possible to get disaggregated data for Ottawa specifically, Google suggested that it was the most popular location for the search during the specified time frame. "Radon detector", "radon test kit" and "radon testing" were other terms which saw a similar increase in popularity.

Sample size calculation

The expected effect was not known since no pilot study was conducted and we were not aware of any past literature that examines how to increase radon test purchases online through a direct mail nudge. Therefore, we assumed that the effect would be small and positive. The mean of the dependent variable in the control group was assumed to be 0.07. This is based on Census data from Statistics Canada that tells us that 7% of Canadian homes have been tested for radon in the last ten years (Statistics Canada, 2018). We estimated a 2%-point change or effect of 0.02, so the mean of the dependent variable in the treatment group was estimated at 0.09. We assumed that there would be at least 500 addresses on average per postal route based on information from Canada Post (Canada Post, 2019). We assumed the intra-cluster correlation to be 0 since it was unclear if and how correlations within the clusters could explain any variance. This is because each postal route can traverse neighbourhoods with different socio-economic and demographic characteristics. So any within-cluster correlations would be present in both the control and treatment groups. It was however not possible to verify this, as Canada Post does not provide a breakdown of postal routes by socio-economic or other household attributes. The sample size was estimated using Stata using the *power twoporportions* command. In the final sample, we had an average of around 15,043 households across 22 postal route groups (10 in control group and 12 in the combined treatment group i.e. 6 in treatment A and B respectively), and an average of 684 homes per cluster.