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Title: Prebunking messaging to inoculate against COVID-19 vaccine misinformation: An effective strategy for public health

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Key words: prebunking; inoculation theory, COVID-19, vaccine, misinformation; disinformation; public health communication

Abstract:

Background: Vaccination coverage needs to reach more than 80% to resolve the COVID-19 pandemic, but vaccine hesitancy, fueled by misinformation, may jeopardize this goal. Unvaccinated older adults are not only at risk of COVID-19 complications but they may also be misled by false information. Prebunking, based on inoculation theory, involves “forewarning people [of] and refuting information that challenges their existing belief or behavior.” Prebunking may be a promising strategy to combat misinformation.

Objective: To assess the effectiveness of inoculation communication strategies in countering disinformation about COVID-19 vaccines among Canadians aged 50 years and older, as measured by their COVID-19 vaccine intentions.

Method: Applying an online experiment with a mixed pre-post design and a sample size of 2500 participants, we conducted a national randomized survey among English and French-speaking Canadians aged 50 years and older in March 2021. Responses to disinformation messages targeting the safety of the mRNA vaccines given their rapid approval by health authorities were evaluated. Our primary outcome was the intention to receive a COVID-19 vaccine, with attitudes toward COVID-19 vaccine a secondary outcome. The McNemar test and multivariate logistic regression analysis on paired data were conducted when the outcome was dichotomized.
Wilcoxon sign rank test and Kruskal-Wallis were used to test difference scores between pre- and post-tests by condition.

**Results:** Group comparisons between those who received only disinformation and those who received the inoculation message show that prebunking messages may safeguard intention to get vaccinated and have a protective effect against disinformation. Of note, the prebunking message targeting mRNA vaccine safety was more effective than the message explaining rapid approval.

**Conclusion:** Prebunking messages should be considered as one strategy for public health communication to combat misinformation. To increase their effectiveness, prebunking messages need to be framed to target disinformation that negatively impacts the intention to vaccinate.
Background

COVID-19 vaccines infodemic and Misinformation

Effective vaccines against COVID-19, combined with vaccination campaigns that successfully target all communities are critical to ending the pandemic. More than 80% of the population needs to be vaccinated against COVID-19 to potentially achieve herd immunity, depending on vaccine efficacy, the local reproduction rate of the virus and its variants, and the level of transmission (estimate are still under debate)[1-3]. A recent review of data from Canada suggests that the intention to get vaccinated against COVID-19 varied between 68% and 80%, decreasing from May to October 2020[4-7] but increasing again in December[8]. By June 2021, 75% of Canadians had received at least one dose, and 20% had both doses[9]. Vaccine hesitancy, defined as “the decision to delay vaccination or the refusal to vaccinate despite available vaccination services,” could challenge COVID-19 vaccine acceptance. Consistent with previous research[10], safety concerns surrounding new vaccines generate greater vaccine hesitancy and influence intention to receive a COVID-19 vaccine[11-13]. Safety concerns are one of the main reasons cited for being reluctant to vaccinate[8; 14-16].

While acquiring and promoting vaccines to manage the pandemic response, governments have faced an infodemic, an overabundance of information including misinformation (false information, often shared unknowingly) and disinformation (deliberately false or misconstrued information)[17]. It has been hard for people to find trustworthy sources and reliable guidance when they need it[17]. Vaccine opponents were prepared to resist and refuse COVID-19 vaccination[18]. By the time the first two COVID-19 vaccines [Pfizer-BioNTech and Moderna] were authorized by Health Canada (December 2020), false information about the vaccines was already circulating on social media. Multiple circumstances contributed to uncertainties about the
safety of these newly developed vaccines. First, the vaccine development process was exceptionally rapid, amplifying safety concerns[19]. Second, the first vaccines available in Canada used mRNA technology that had not been previously approved for use in human vaccines. Elevated safety concerns over the novel vaccine technology created ideal circumstances for false information to abound, such as claims that «mRNA vaccines will alter your DNA» circulating on the Internet[18]. Third, vaccine acceptance is not static; it is linked to information published in traditional media[18]. Therefore, the way news media covers the anticipation and hype around the vaccine development and campaign could easily worsen the pandemic by amplifying the uncertainties[20].

Several studies indicate that misinformation can decrease vaccine intention[18; 21-23]. A study conducted in France prior to any approval by health authorities, for example, showed that COVID-19 conspiracy beliefs were substantially and negatively related to both positive attitudes toward vaccination science and intention to be vaccinated[22]. A study conducted in the United States (US) and United Kingdom (UK) showed that misinformation around COVID-19 vaccines resulted in a decrease in vaccination intent among those who would otherwise “definitely” want to be vaccinated by 6.4 % in the UK and 2.4% in the US[18].

Certain groups are more vulnerable to misinformation due to various factors, including cognitive reflection, which refers to the capacity to verify information and not rely solely on the first idea that first comes to mind, older age and lower media or digital literacy[24]. Older adults, for example, are more susceptible to being influenced by online misinformation[25], possibly associated with lower digital literacy, social isolation, and a decline in cognitive reflection among some individuals[26; 27]. As well as being more susceptible to misinformation,
unvaccinated older adults were at greater risk for severe outcomes than healthy younger people, leading to the prioritization of older adults for COVID-19 vaccination[28]. In Canada, vaccination started in December 2020, and each province was responsible for its prioritization scheme, schedule, and vaccine administration. Recognizing that COVID-19 vaccine acceptance by older adults is important to protect them from the virus and ending the COVID-19 pandemic, tailored communication strategies addressing misinformation around COVID-19 vaccines are therefore needed more than ever.

**Prebunking: Inoculation theory**

Several strategies have been developed to combat the effect of COVID-19 misinformation[29; 30]. For example, debunking provides detailed and clear refutations of false information after people have been exposed to a falsehood[31]. Similarly, fact-checking aims to ensure the accuracy of information and correct misinformation if necessary[32]. Even if those strategies are effective, due to the enormous quantity of COVID-19 vaccine misinformation, identifying and debunking each message takes time and resources. Moreover, once people are exposed to falsehood, they often continue to retrieve false details from memory despite acknowledging factual corrections, a phenomenon known as the continued influence of misinformation[31]. Accordingly, research has looked at ways to *preempt* misinformation from taking root in the first place. Prebunking is an approach based on inoculation theory, originating from social psychology and following a biomedical analogy[29; 33; 34]. The theory suggests that just as vaccines trigger the production of antibodies by exposing people to a weakened dose of a pathogen, the same can be achieved with information. Inoculation consists of introducing a sense of threat by forewarning people that they may be exposed to information that challenges their existing beliefs or behaviors. Then, one or more (weakened) examples of that information are
presented and directly refuted, which is the process called “prebunking”[35; 36]. By exposing people to a weakened dose of misinformation, it becomes possible to “pre-emptively confer psychological resistance against unwanted persuasion” [25; 37; 38] and cultivate “mental antibodies” [25]. A prebunking message needs two elements to be effective: an explicit warning of an impending threat of being misled and a refutation of the misinformation’s argument[29]. This technique, of “[f]orewarning people that they may be exposed to information that challenges their existing belief or behavior,” has been shown to reduce the impact of misinformation[33; 39]. The effectiveness of inoculation has been demonstrated across many different topics and can reduce susceptibility to misinformation across cultures[25; 29; 40; 41].

The objective of this study was to assess the effectiveness of inoculation communication strategies in countering disinformation about COVID-19 vaccines among French and English Canadians aged 50 years and older, as measured by their intention to get a COVID-19 vaccine.

**Methods**

First, a pilot test was conducted to assess if the impact of different disinformation messages on vaccine intention varies in accordance with province or context (i.e., French vs. English participants) and to adjust the online experiment accordingly. The pilot-test result had the intended effect of decreasing vaccine intention (Pilot-test methodology and results are presented in supplementary file). Then the online experiment was conducted. This study was approved by the Laval University Research Ethics Board (Comité d’éthique en recherche de l’Université Laval, (CERUL).
Data Collection

First, a pilot test (n=603) was conducted from February 19\textsuperscript{th} to February 22\textsuperscript{nd}, and then the online experiment (n=2,500) from March 8 to March 17\textsuperscript{th}, 2021. Both were conducted using a sample from Leger Marketing, a market research and polling firm that maintains a national panel of 400,000 individuals across the 10 Canadian provinces (northern territories were excluded). Their panel is benchmarked to known Census targets, such as age, region, income, primary language, and education, to ensure a representative sample of the Canadian population[42]. Participants aged 50 years and older, understanding French or English, and with internet access who had not yet received any COVID-19 vaccination were eligible to participate in the pilot test and the online experiment. An estimated 9.2\% of the Canadian population had received at least one dose of COVID-19 vaccine by March 20\textsuperscript{th}, 2021, at the time of the online experiment, and most were aged 70 years and more[9]. Vaccination coverage varied across provinces, from 4.2 \% in Nova Scotia to 52.7\% in Yukon[9] (Table 1).

[INSERT TABLE 1 HERE]

Outcome Measure

Our primary outcome measure was the intention to receive a COVID-19 vaccine, based on previous research about intentions to vaccinate[43; 44]. Intention was measured using a 5-point Likert scale (from very likely to very unlikely) to the question: How likely are you to get vaccinated against COVID-19 when you will be eligible to receive the vaccine? Our secondary outcome was vaccine attitudes which we measured using the short 5C psychological scale developed by Betsch and collaborators and adapted to address COVID-19 vaccines[45; 46].
Attitude was measured as a score of 5 items scaled from strongly agree to strongly disagree. For each scale, a numerical value was attributed (see supplementary for detailed).

**Pilot-Testing Messages’ development**
The message development was inspired by the study of van der Linden and colleagues[25; 33]. Disinformation messages were adapted from real posts found on social media (Facebook and VKontakte). Three specific messages were pretested, and the two most influential messages that decrease vaccine intention were used for the online experiment. Message A targeted mRNA vaccine safety, while Message B concerned the fast approval of a COVID-19 vaccine by a federal agency (Figure 1). The third, subsequently unused message alleged that health care professionals and older people are guinea pigs for the COVID-19 vaccine.

[INSERT FIGURE 1 HERE]

**Prebunking message development**
The inoculation intervention consisted of a warning message of an impending threat/attack on one’s prior belief/attitude (affective component). For example: “False claims rely on different techniques such as scaring people with shocking claims: for example, ‘mRNA vaccines can change your DNA forever!’” Previous studies on vaccination and 9/11 conspiracy theories have shown the effectiveness of these techniques[47; 48]. Prebunking messages used for the study are shown in Figure 2.

[INSERT FIGURE 2 HERE]

**Sample size and study design**
Our sample size was calculated based on a statistical threshold of 5% and a baseline intention to vaccinate of 70%. We estimated a sample size of 2,500 participants would be required to detect a statistically significant difference of 5% in intention between the pre- and post-tests for all groups (n=500 for each group), and a difference of 10% between groups (mRNA versus Quick Approval). Respondents’ quotas were set according to demographic province distribution in terms of the population.

Before receiving the intervention, each participant had to answer a set of questions about their intention and attitude toward COVID-19 vaccination and socio-demographic questions (age, gender, income, and their primary language). Then, participants were randomly assigned to three groups: Disinformation group (Group D), Inoculation group (Group I), and the control group. Participants in group D and I were further randomly split to receive Message A (mRNA) or Message B (quick approval). The control group received a message about flowers. Participants in the disinformation group received only a disinformation message (A1 disinformation only on mRNA; B1 disinformation only on quick approval).

Participants in the inoculation group received prebunking message before receiving a disinformation message (A2 prebunking message followed by disinformation on mRNA and B2 prebunking message followed by disinformation on quick approval). Grouping was as follows:

- Disinformation group (D): Group A1 (mRNA) + Group B1 (Quick Approval)
- Inoculation group (I): Group A2 (mRNA) + Group B2 (Quick Approval)

Immediately after receiving one of the three messages, participants had to complete the same questions answered before the intervention. A final debriefing message which debunked the myths was presented to participants who were exposed to disinformation to mitigate the potential harms of the study. The study design is shown in Figure 3.
Data Analysis
The primary outcome of interest, the intention of getting vaccinated, was categorized into two groups, i.e., those who express the intention to get vaccinated (likely-somewhat likely) vs. those who are uncertain or unlikely to get vaccinated (unlikely-somewhat unlikely). We decided to dichotomize the outcome to avoid sparsity, as most responses favor vaccination (more than 80% of individuals are somewhat-to-very-likely to get the vaccine so we have enough information per cell. The approach of dichotomizing the outcome was favored to a mixed ANOVA, as the distribution of the outcome variable is heavily skewed to the left (see figure 1 in the supplementary file), which potentially violates the ANOVA normality assumption. Nonetheless, as a robustness check, we also conducted ANOVA tests of difference-in-difference scores (the pre-post score in the treatment condition minus the pre-post score in the control condition). The results are similar and presented in the supplementary file.

Thus, to measure how many participants changed their minds in the course of the online experiment, a McNemar 2x2 table test (yes/no in pre-post setting) was conducted for each group. To allow comparison between groups and measure the variation of intention while globally assessing the intervention’s effectiveness, logistic regression models on paired data were performed in the repeated measures setting, i.e., with group by time interaction (pre and post). Generalized Estimating Equations (GEE) type estimates were produced to account for the within-subject variation. To be more precise, regression models were adjusted by age, education level, sex, and income. When the outcome of interest is considered in continuum fashion, a Wilcoxon’s signed-rank test, which is based on the score differences between pre and post, was conducted by conditions.
Further, we explored which prebunking message (mRNA or Quick Approval) was more effective in shifting vaccination intention, dichotomized as likely and somewhat likely vs. the others using McNemar’s test as difference scores using Wilcoxon’s signed-rank test. For the secondary outcome, the attitude score based on the 5c scale was also evaluated using the Kruskal-Wallis test. This non-parametric approach was used as an alternative to analysis of variance (ANOVA), assuming data come from a free distribution. Multiple comparison tests were conducted among groups.

All analyses were based on two-sided p-values, with statistical significance defined by $p < .05$. Data were analyzed using SAS version 9.4. We considered p-values and confidence intervals to interpret the findings[49].

**Results**

*Participants’ characteristics*

The distribution of participants’ characteristics is shown in Table 2. Participant characteristics are representative of the Canadian population in terms of sex, age, income, language, education level, and location as per the Canadian census result[50]. Also, participant characteristics were equally distributed across the five groups, suggesting that these groups are comparable for the remainder of the analyses.

[INSERT Table 2 HERE]
**Intention to get vaccinated**

Figure 4 presents the proportion of participants who likely express their intention to get vaccinated against COVID-19 pre-post by conditions. From the McNemar test, for the control group, there is a slightly marginal increase in proportion for those who change their mind toward getting vaccinated, from pre- to post-test \(d = 1.45\% \ [-0.10 \text{ to } 3.005.70], \ p\text{-value} = 0.0673\). At the same time, there is a noticeable decrease in the intention to get vaccinated for group D by \(d = 3.90\% \ [2.40 \text{ to } 5.406.96], \ p\text{-value} = 0.0001\) as, well a decrease for group I, but marginal \(d = 1.23\% \ [-0.05 \text{ to } 2.52], \ p\text{-value} = 0.0603\).

[INSERT Figure 4 HERE]

**Inoculation effect on vaccine intention**

Intention to get vaccinated against COVID-19 among groups was evaluated via pairwise comparison in logistic regression. Compared to the control group, the likelihood of intending to get vaccinated was lower \(OR = 0.63 \ [0.50 \text{ to } 0.80]\) for group D, and \(OR = 0.80 \ [0.65 \text{ to } 0.99]\) for Group I. Comparison between group D and I also supports that the participants in the D group have a lower likelihood of getting vaccinated, compared to I \(OR = 0.79 \ [0.66 \text{ to } 0.94] \ P\text{-value} = 0.0089\). This indicates that despite the fact that both changes in messages are lower than in the control group, the likelihood of getting vaccinated is much more pronounced in group I than in group D. This suggests that prebunking messages may have a protective effect against disinformation on intention to vaccinate. The ANOVA tests of difference in difference converge essentially in the same direction as the pairwise group comparison obtained from a logistic regression model (see supplementary file).
Finally, we tested simple inoculation effects between groups based on message type (message A about mRNA versus message B about quick approval) (Figure 5).

The influence of disinformation messages differed between groups. When compared to the control group, participants who received message A1 (mRNA) express less intention of getting vaccinated against COVID-19 (OR=0.57 [0.42 to 0.77], p-value=0.0002) than participants who received message B1 Quick Approval, (OR=0.69[0.53 to 0.90], p-value=0.0061. On the other hand, compared to C, both inoculation messages A2 mRNA (OR=0.84[0.66 to 1.07], p-value =0.1670) and B2 Quick approval (OR=0.76[0.61 to 0.96], p-value=0.0203) were shown to have some protective effect on vaccine intention. This protective effect was also higher in participants who received message A2 (mRNA) than those who received message B2 (Quick Approval). In addition, looking at the result from the Wilcoxon signed-rank test presented in figure 5, there was no change in group A2 (mRNA) between pre and post period intention to vaccination, as the difference is nearly zero. There was a significant change for groups A1 (mRNA), B1 (Quick Approval), and even B2 (Quick Approval). This indicates that there is a greater inoculation effect (protective factor) with message A (mRNA) compared to message B (Quick Approval).

Changes in vaccine attitude
Changes in attitude(s) toward COVID-19 vaccination was measured with the 5C scale. No significant difference between pre-post surveys was found based on the Kruskal-Wallis test. There was no meaningful result from the multiple comparisons (methods Dwass, Steel, Critchlow-Fligner) (Table 4)

[INSERT Table 4 HERE]

**Discussion**
Studies indicate that misinformation may negatively affect vaccine decisions[18; 22; 23]. In this infodemic era, with the increasing scourge of dis- and misinformation, it is important to use all available effective strategies to counter COVID-19 vaccine misinformation. In our online experiment, we tested the effect of prebunking messages on intention and attitude toward vaccination. Our results show that prebunking messages based on inoculation theory can reduce the impact of misinformation and safeguard positive intentions to vaccinate. Still, that effectiveness may vary depending on the message content. This is consistent with other studies that have shown that inoculation theory can reduce the impact of misinformation[40; 41; 51; 52].

Two types of disinformation messages were used. The message alleging that mRNA vaccines can change DNA had more effect in decreasing vaccine intention compared to the message alleging that vaccine approval was too fast. Also, while both prebunking messages were framed the same way, the inoculation message A (mRNA) had more impact on protecting vaccine intention than message B (Quick Approval). This difference might be explained by the fact that the perceived risk of the COVID-19 vaccine was different since changes in the DNA could be perceived as a greater risk than fast approval. Alternatively, since mRNA vaccine technology was a new concept for most of the general public in the past year, and attitudes about
government and pharmaceutical industry are more longstanding, we may see a greater impact of both disinformation and inoculation of newer information, about which views are less solidified. It would be interesting for further studies to explore disinformation and inoculation on new information in a crisis context. This aspect is interesting because the threat is an important mechanism in the inoculation process by involving various cognitive and affective processes[41; 53-55]. Therefore, it is more important to target messages that can affect vaccine intention. Otherwise, prebunking effectiveness might be more limited [29].

This online experiment had several strengths, including the large number of respondents, inclusion of all provinces, and a sample demographically similar in sex, language, income, education, and location to the general Canadian population 50 years and over. A limitation was that the post-test was performed right after the intervention. Repeated post-test measures over time would have been interesting to determine the length of the effect of inoculation on vaccine intention and identify if a ‘‘booster shot’’ of information correction would be required[35; 52; 55]. Additionally, the pre-post test design, on intention and attitude, may lead to participants constructing or solidifying their preference, which could limit the effect of inoculation. While we noted differences in intention to be vaccinated against COVID-19, our study did not show meaningful results in overall vaccine attitudes. This may be explained by the fact that it is more difficult to shift vaccine attitudes[21; 29]. However, prebunking messages can change attitudes toward the way messages are evaluated by individuals as inoculation aims to train the ability to detect disinformation[56]. And while this was not tested in this online experiment, prebunking messages may heighten awareness in general that misinformation is circulating. This objective of inoculation is essential since, along with low literacy levels, the capacity to detect fake news is associated with the risk of being « anti-vaccine» or « vaccine-hesitant»[57].
Implications for public health communication

While vaccine hesitancy was identified as one of the ten threats to global health in 2019 by the WHO[58], the end of the COVID-19 pandemic depends on high worldwide vaccine acceptance to reach global herd immunity. The results of this study provide new insights for public health communication for COVID vaccines and likely for other vaccines as well. Providing prebunking messages based on inoculation theory is an effective strategy to help counter misinformation. As recent studies indicate, simply providing clear and transparent information on safety and efficacy does not increase COVID-19 vaccine intention[59], as public health authorities should include this strategy in their communication practices. In a pandemic and infodemic context where misinformation flows fast, it could be interesting to use social media as it offers the opportunity to quickly spread prebunking messages, as in this study that replicated social media platforms. Social media use would provide the opportunity to share prebunking messages with target groups while on the same ground of misinformation. To be effective, however, prebunking messages must quickly detect misinformation messages that could be harmful and lead to dangerous behaviors. Therefore, to frame prebunking messages, it is crucial for public health authorities to integrate infodemiology and infoveillance expertise to target the more impactful misinformation messages[29; 60].

Conclusion

The ability to identify misinformation is challenging for most, especially in the context of a public health infodemic[61]. Increasing health and digital literacy skills, and thus the capacity to recognize misinformation is one avenue to mitigate the impact of such information[62]. As
sustained literacy interventions may be difficult to provide for those long out of school,
prebunking messages could be an interesting avenue to help individuals detect and question
misinformation, especially in times of crisis.

Declarations and ethics statements

Ethical approval

This study was approved by the Laval University Research Ethics Board (Comité d’éthique en
recherche de l’Université Laval, (CERUL). 2021-011/02-02-2021.

Disclosure statement

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