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Toward Multidimensional Message Tailoring to Address COVID-19 and Influenza Vaccine-Hesitancy: A Latent Profile Analysis Approach

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ABSTRACT
Vaccines remain the best strategy as the COVID-19 pandemic enters into later stages and governments begin to shed pandemic-control measures. Vaccine hesitancy continues to be a major obstacle in efforts to end the pandemic. This study reports formative evaluation research that adopted a multidimensional approach using latent profile analysis to audience segmentation and message targeting. Within the framework of the integrated behavioral model, data were collected from a US national survey to explore the dimensions in which vaccine-confident vs. -hesitant individuals differed significantly across the topics of COVID-19 and influenza. Latent profile analyses were performed to identify subgroups and establish measurement invariance between COVID-19 and influenza vaccines. Matching message strategies were proposed for the distinctive characteristics of the subgroups for both topics and to be tested in future research.

As the United States moves into the later stages of the COVID-19 pandemic and begins to shed pandemic-control measures, an editorial in *Nature* (December 23, 2022) warned against COVID-19 complacency in 2023 and beyond. One major concern is vaccine hesitancy. As of February 2023, only 69.5% of the U.S population (ages 5+) completed the primary series of COVID-19 vaccine, 33% have received their booster dose, and many fewer, only 16.1% of people eligible for the booster that targets the Omicron variant (Centers for Disease Control and Prevention [CDC], 2023). Three years into a global pandemic, only 61% of individuals in the U.S. are willing to receive a vaccine. As the pandemic progressed, there have even been slight decreases in vaccine acceptance rates, despite evidence that vaccines substantially reduce deaths and severe illnesses, and despite improvements in vaccine attitudes (Dhanani & Franz, 2022). The end of the COVID emergency on May 11 2023, will inevitably decrease vaccine uptake. Despite the end of the COVID-19 emergency, new COVID-19 variants will continue to emerge and jeopardize vaccine efficacy, which contributes to vaccine hesitancy. Overcoming the vaccine hesitancy barriers has been a key step in overcoming the pandemic and will continue to be key to protecting people from COVID-19 long after May 2023.

The picture does not look much better when it comes to the influenza vaccine – the coverage has been consistently lower than the pre-pandemic levels across all age groups. Researchers have compared the COVID-19 vaccine to the case of influenza (e.g., Monto, 2021) that we need to learn to live with the virus, and that booster shots and annual revaccination might be required to avert severe consequences. The importance of reducing vaccine hesitancy becomes paramount if annual COVID-19 revaccination is recommended, as in the case of influenza. On the other hand, the two topics also differ from each other substantially when it comes to novelty, the technology used to develop the vaccines, the uncertainty involved regarding vaccine effectiveness, safety, and potential side effects, and how individuals react to the disease as well as to the vaccines.

There is evidence that it is safe to receive the two vaccines at the same time. Novavax and Moderna are already developing combination vaccines for both COVID-19 and influenza. There is also initial evidence such a combination product might boost vaccine confidence, which is higher than the COVID-19 vaccine alone, but lower than the influenza vaccine alone (Izikson et al., 2022; Lennon et al., 2022). If the barriers and obstacles of vaccine are similar between COVID and influenza, similar intervention strategies can be used to promote the combo or both vaccines. Should there be substantial differences in how hesitant individuals respond to each vaccine, then the design of vaccine promotion interventions should be more nuanced and distinct. In this case, a COVID-influenza combination vaccine might hurt, rather than improve vaccine confidence among hesitant individuals. It is thus imperative that we understand the similarities and differences in the barriers and obstacles to COVID-19 vis-à-vis influenza vaccination uptake.

Between the two topics of COVID-19 and influenza, existing research and practice primarily utilize message or intervention strategies that target a specific aspect (out of several) to promote vaccine uptake, for example, highlighting risk, increasing knowledge and attitude, or emphasizing the effectiveness and safety of vaccine products (e.g., Batteux et al., 2022; Davis et al., 2022; Rao et al., 2018). Traditional message tailoring, either based on demographic variables (e.g., gender and race) or psychological variables (e.g., involvement and motivation) also tends to focus on one variable at a time (see Table 1, Albarracin

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& Glasman, 2016, p. 253). Such a variable-based approach tends to overlook the variability and complexity in behavior and behavior change (see Ogden, 2016) and fails to account for the diverse needs and concerns of individuals, thus are oftentimes ineffective (Verger & Dubé, 2020; Yale Institute of Global Health, 2020). This calls for an audience-centered approach (Kusurkar et al., 2021) that understands the heterogeneity in vaccine-hesitant individuals and identifies meaningful patterns. Such a deeper level of audience segmentation is the prerequisite for multidimensional targeting (Albarracin & Glasman, 2016) and effective and efficient message tailoring in health interventions (Noar et al., 2009; Rimer & Kreuter, 2006).

The primary goal of the current study is to conduct formative research for interventions to promote COVID-19 and influenza vaccination by 1) identifying predictors of vaccine hesitancy within the framework of the integrated model of behavior, 2) developing and identifying the profiles of subgroups in vaccine-hesitant individuals who share a common set of concerns and barriers to vaccination (e.g., Nylund-Gibson et al., 2023), and 3) to compare the vaccine-hesitant subgroups and their profiles between the topics of COVID-19 and influenza. The potential findings from this study provide empirical evidence that guides audience segmentation and message tailoring and have important implications for effective interventions to address vaccine hesitancy.

The integrated behavioral model

The behavioral approach to vaccine hesitancy is adopted in this study (see Bussink-Voorend et al., 2022 for a review of definitions for vaccine hesitancy). Vaccine-related behaviors can range from accepting vaccines with no doubts, to complete refusal with no doubts, with a heterogeneous vaccine hesitancy group between the two polars (MacDonald, 2015). Vaccine-hesitant individuals include those who refuse vaccines and those who delay the acceptance of vaccines despite their availability, effectiveness, and safety (Dubé et al., 2014; Salmon et al., 2015). Any individual who has not received the vaccine, is less than 100% ready, or has not yet decided to receive it (at a measurement moment), is considered hesitant.

Given such an approach to vaccine hesitancy, the integrated behavioral model (Montano & Kasprzyk, 2015; see also Fishbein & Ajzen, 2010; Yzer, 2012) offers clear guidance regarding potential antecedents of behavioral intention to receive a vaccine. Three criteria (see Hornik & Woolf, 1999) can be applied: 1) the proportion of people who are available for change at baseline, 2) the strength of association between the predictors and vaccine intention, and 3) the degree to which any given predictor is likely to be a response to persuasive messages. The model postulates the following antecedents to behavioral intention: feelings/affective states, behavioral beliefs, (descriptive and injunctive) normative beliefs, and control and efficacy beliefs. Background factors such as demographic variables, socio-economic variables, influences from the media/social media, and individual differences variables are assumed to exert their influence on intention through the above-mentioned antecedents in varying ways. There is robust evidence for the utility of the model in understanding and predicting health behaviors (Fishbein & Ajzen, 2010, see also McEachan et al., 2016), which suggests that changing the vaccine-hesitant individuals along the predictors as a whole (in the right direction) would boost their vaccine confidence and increase their likelihood of vaccination.

Predictors of vaccination likelihood

Affective and experiential responses to vaccines contribute to vaccine hesitancy and declines in vaccine uptake and inclination (Chou & Budenz, 2020; Tomljenovic et al., 2020). Anti-vaccination groups have long been using affect appeal as a strategy in promoting misinformation and conspiracy theories, which may have a more powerful influence than didactic scientific statements on probabilities (Chou & Budenz, 2020; Shen & Zhou, 2021). For example, a content analysis study (Bean, 2011) revealed that 76% of anti-vaccination websites employed emotive appeals.

Individuals might have quite different affective responses to COVID-19 vs. influenza and their vaccines. The current COVID-19 pandemic further strengthened the public's collective negative affective feelings (Chou & Budenz, 2020; see also Ofri, 2009, 2022). The fact that COVID-19 vaccines have gone through an unusually rapid development process and the novel technology (i.e., mRNA) used in their development sparked new fears over vaccine safety (e.g., Chou & Budenz, 2020). Sadness occurs in response to the loss of lives and COVID-related pain and suffering in general. With the politicization of the COVID situation, safety measures including mask mandates and lockdowns had been controversial and aroused anger and disgust at disagreeable advocacies from polarized groups. On the other hand, effective and safe vaccines offer hope for the end of the COVID-19 pandemic and the return to normalcy, which can elicit other positive affective states such as happiness and calmness.

Given the nature of the COVID-19 pandemic and influenza, individuals' behavioral beliefs should also vary substantially between the two topics. Behavioral beliefs that precede vaccine intention include cognitive appraisals of the potential outcomes of receiving a vaccine or not. The factors include the threat of the virus (severity and susceptibility), self- and response-efficacy in coping with the disease, effectiveness and safety of the vaccines, self-efficacy to receive the vaccines, and severity and susceptibility of the potential side effects of such vaccines. Descriptive norms (others' behavior), injunctive norms (important others' opinions and expectations), and perceived norms (perceived social pressure) are other types of antecedents to intention. In addition, vaccine hesitancy started long before COVID-19, and COVID-19-related misinformation and conspiracy theories emerged on social media long before COVID-19 vaccines were authorized for emergency use (Larson et al., 2022). There is also the impact and persistence of misinformation on flu vaccines (Annenberg Public Policy Center, 2023).

The integrated behavioral model suggests that the heterogeneity of vaccine-hesitant individuals arises from the differences in these potential antecedents of vaccination likelihood. The paramount task in audience segmentation lies in identifying subgroups of vaccine-hesitant individuals based on the antecedent variables in such a way that the within-subgroups differences are minimized, and the between-subgroups differences maximized. Latent mixture modeling/latent profile analyses (LPA) are person-centered techniques that model between-person heterogeneity by classifying individuals into unobserved groups (latent profiles/classes) with similar (homogenous) patterns (Ferguson et al., 2020; Nylund-Gibson et al., 2023). The process yields a latent categorical variable (group membership). It is assumed that individuals' responses to a set of indicator questions are driven by their class/profile membership, which is similar to the notion of a latent construct that drives scores on scale items in a factor analysis scenario (Kline, 2016). Each of the subgroups possesses a unique set of characteristics that differentiate it from other subgroups. Using barriers and factors associated with the likelihood of vaccination uptake as input data, LPA analyses can identify subgroups among vaccine-hesitant individuals between the topics of COVID-19 and influenza. Individuals within the same subgroup share a set of common characteristics (i.e., profiles, which are defined by their attributes/scores on the barriers and factors that predict vaccination likelihood), while individuals between the subgroups are distinct from each other. In other words, within each subgroup, individuals have similar reasons for vaccine hesitancy; and between the subgroups, the reasons are quite different. This knowledge provides the conceptual guidance and substantive foundation for audience segmentation and message tailoring. Hence, it was asked,

RQ1: On what factors do the vaccine-hesitant and -confident individuals differ?

RQ2: Based on these factors, what are the characteristics/profiles of the subgroups among the vaccine-hesitant individuals?

Given the similarities and differences between the topics of COVID-19 and influenza vaccines, it was asked,

RQ3: Is there invariance between the subgroups of COVID-19 vs. influenza vaccine-hesitant individuals?

The integrated behavioral model also suggests that individuals' historical and cultural background, political ideology or party affiliation, and religious and moral beliefs also contribute to vaccine hesitancy, either directly or indirectly via cognitive appraisals (e.g., John, 2022). In addition, vaccine hesitancy should be considered in historic, political, and sociocultural contexts (Dubé et al., 2013, 2014) or individual differences such as moral foundations (e.g., Amin et al., 2017; Nan et al., 2022). However, these background factors cannot be modified with communication or intervention strategies. Therefore, in this study, we focus on affective states, risk perceptions, attitudes, norms, and efficacy factors as antecedents of vaccine hesitancy and the foundations of audience analysis and message tailoring.

Method

Participants and procedure

Data collection took place in December 2022. Participants were sampled from the general U.S. population recruited through a national paid opt-in online panel comprised of individuals who registered with Qualtrics. Table 1 presents

Table 1. Demographic characteristics of the sample.

	COVID-19 (*N* = 1,131)		Influenza (*N* = 1126)	
	n	%	*n*	%
Gender				
Male	491	43.4%	503	44.7%
Female	634	56.1%	614	54.5%
Non-binary	6	0.5%	9	0.8%
Race				
White	913	80.7%	918	81.5%
Black/African American	143	12.6%	130	11.5%
Hispanic/Latino	102	9%	98	8.7%
Asian or Pacific Islander	31	2.7%	57	5.0%
American Indian or Alaskan Native	35	3.1%	30	2.7%
Other/Prefer not to answer	9	0.8%	13	1.2%
Geographic area				
Urban	366	32.4%	392	34.8%
Suburban	455	40.2%	474	42.1%
Rural	310	27.4%	260	23.1%
Household annual income				
Less than $25,000	270	23.9%	239	21.2%
$25,000–$49,999	332	29.4%	318	28.2%
$50,000–$99,999	322	28.5%	345	30.6%
$100,000–149,999	132	11.7%	152	13.5%
$150,000 and above	75	6.6%	72	6.4%
Education				
Less than high school	39	3.4%	32	2.8%
High school diploma or equivalent	298	26.3%	358	31.8%
Some college, no degree	355	31.4%	334	29.7%
Associate degree	109	9.6%	77	6.8%
Bachelor's degree	223	19.7%	220	19.5%
Master's degree	91	8.0%	99	8.8%
Doctoral or professional degree	16	1.4%	6	0.5%
	M	*SD*	*M*	*SD*
Age	46.61	17.01	46.78	16.91

the demographic information of the sample. Consented participants responded to a set of demographic questions, followed by history of vaccination (COVID-19 and influenza), risk perception related to COVID-19 and influenza, and individual differences including general vaccine hesitancy, involvement with vaccines, vaccine-related moral beliefs before they were randomly assigned to either the topic of COVID-19 or influenza vaccine. The questions within each topic assessed cognitive and affective responses to vaccines, perceived vaccine effectiveness and safety, perceived risks of vaccine side effects, and descriptive and injunctive norms related to the vaccine. Toward the end of the questionnaire, participants reported their attitude toward, and intention to receive the vaccine and their support for a mandatory vaccination policy.

To improve data quality, respondents who failed at attention-checker questions were automatically dropped from the sample. Respondents whose participation lasted less than 1/3 of the mean duration in the soft launch ($M = 13.5$ minutes) were also automatically dropped. Data were also carefully examined for patterns of straight-lining and these cases were dropped when detected.

Measures

The uni-dimensionality of multi-item scales was established with confirmatory factor analysis (CFA). All items were measured on a 7-point Likert scale ranging from "1= Strongly disagree" to "7 = Strongly agree" unless stated otherwise. The measures for risk perceptions were informed by the literature on the protection motivation theory (PMT, Rogers & Prentice-Dunn, 1997) and the extended parallel process model (EPPM, Witte, 1994), and have been used in our previous publications (Zhou et al., 2023a, 2023b).

Vaccination hesitancy

Vaccine hesitancy is formally defined by the WHO as the reluctance or refusal to vaccinate despite the availability of vaccines. This highlights a behavioral approach to defining the construct. Vaccine-related behaviors can range from accepting vaccines with no doubts, to complete refusal with no doubts, with heterogeneous vaccine hesitancy groups between the two polars (MacDonald, 2015). Individuals who have already received or are 100% ready and committed to receiving the vaccine upon availability and/or eligibility are considered vaccine-inclined or -confident. Vaccine-hesitant individuals include those who refuse vaccines and those who delay the acceptance of vaccines despite their availability, effectiveness, and safety. Any individual who has not received the vaccine; is less than 100% ready; or has not yet decided to receive it (at a measurement moment), is considered vaccine-hesitant.

On a 0–100 scale (0% = *not likely at all*, 100% = *absolutely*), participants indicated on a slider either their likelihood (in percentage) of getting annual re-vaccination for COVID-19 if it is recommended by the CDC (cf. Townsend et al., 2023) or the influenza vaccine for the flu season. Those who already received the updated COVID-19 booster shot and the influenza vaccine for the 2022–2023 flu season, and those who reported a 100% likelihood to receive the vaccines were considered vaccine-confident ($n_{\text{Covid-19}} = 324$; $n_{\text{Influenza}} = 414$); those who had not received the vaccine and were less than 100% likely to receive the vaccine were considered vaccine-hesitant ($n_{\text{COVID-19}} = 807$; $n_{\text{Influenza}} = 712$).

Affective responses to vaccines

This set of variables were assessed by asking participants to indicate the extent to which they had the following feelings about COVID-19/influenza vaccines on a 7-point scale (0 = *none of this feeling*, 6 = *a lot of this feeling*) adapted from Dillard and Shen (2018). The affective states and their items (with reliabilities for COVID-19 and influenza) were: hope (hopeful, optimistic, upbeat, α = .82, .87), happiness (happy, glad, delighted, joyful, α = .92, .92), sadness (sad, depressed, dismal, dreary, α = .88, .89), fear (scared, afraid, fearful, α = .92, .89), anger (annoyed, irritated, angry, α=.89, .89), disgust (disgusted, grossed out, repulsed, α = .86, .89), worry (worried, anxious, nervous, α = .89, .88), guilt (guilty, ashamed, embarrassed, α = .89, .88), and regret (regretful, remorseful, contrite, α=.88, .81).

Perceived severity

Perceived severity of COVID-19 and influenza was measured by four items: "COVID-19/the flu is harmful," "dangerous," "COVID-19/the flu is a serious problem nationally," and "in my local community." (α = .86 for COVID-19 and .81 for influenza).

Perceived susceptibility

Perceived susceptibility to COVID-19/influenza was assessed with four items: "There is a chance that I/someone I cared about could contract COVID-19" and "It's possible/there is a chance that I/someone I cared about could get COVID-19/the flu" (α = .86 for COVID-19 and .88 for influenza).

Perceived protection ability

Perceived ability to protect oneself and loved ones from COVID-19/influenza was assessed with six items: "I have the ability to protect myself/the people I care about against COVID-19/the flu," "I know what to do to protect myself/the people I care about from COVID-19/the flu," "If we take precautions against COVID-19/the flu, we will be safe," and "There are steps that anyone can take that will protect from COVID-19/the flu" (α = .85 for COVID-19 and .89 for influenza).

Perceived vaccine effectiveness

Perceived COVID-19 and influenza vaccine effectiveness were assessed with three items: "the COVID-19 vaccines/flu shot is effective/work(s) in preventing COVID-19/the flu and its complications," and "If I get the vaccine, I will be less likely to get COVID-19/the flu" (α = .95 for COVID-19 and .92 for influenza).

Perceived severity of vaccine side effects

Perceived severity of possible vaccine side effects was measured by three items: "The COVID-19 vaccine/flu shot could have serious/harmful/dangerous side effects" (α = .95 for both topics).

Perceived susceptibility to vaccine side effects

Perceived susceptibility to vaccine side effects was assessed by three items: "I could be affected by the side effects of COVID-19 vaccines/flu shot," "There is a chance/It is likely that I might be affected by the side effects of COVID-19 vaccines/flu shot" (α = .94 for COVID-19 and .92 for influenza).

Perceived self-efficacy to receive vaccine

Perceived self-efficacy to receive the COVID-19/influenza vaccines was assessed by three items: "If I want to, I am confident I could get the COVID-19 booster/flu shot," "I have the ability to get the COVID-19 booster/flu shot," and "Getting the COVID-19 booster/flu shot would be difficult for me" (reverse coded) (α = .78 for COVID-19 and .76 for influenza).

Belief in vaccine-related misinformation

Belief in vaccine-related misinformation was assessed with different scales for the two topics. The respective items were generated from two sources: 1) popular medical/public health websites (e.g., CDC, NIH, WebMD) and 2) preliminary computational analysis of posts on Reddit on the two vaccine topics (subreddits). For COVID-19 vaccines, the items were: "COVID-19 vaccines were rushed and wouldn't be effective," "The mRNA COVID-19 vaccines could alter your DNA," "The COVID-19 vaccines could lead to infertility," "The COVID-19 vaccines make your magnetic," The COVID-19 vaccines were made from fetal tissue," "The COVID-19 vaccines have a microchip to track you," and "The COVID-19 vaccines could have long-term health complications." The items for influenza were: "The flu vaccine can give you the flu," "If a person has a chronic illness or is pregnant, they shouldn't get the flu vaccine," "People don't need the flu vaccine every year," "The flu vaccines were rushed and wouldn't be effective," "People who get the flu vaccine still get the flu, so it's not worth it," "If people don't get the flu vaccine early in the season, it's too late now." The belief in vaccine-related misinformation is considered a formative measure whose indicators cause the latent variable, hence alpha reliability is irrelevant (Bollen & Diamantopoulos, 2017)

Attitude toward vaccine

Attitude toward the COVID-19/influenza vaccines was assessed with seven 7-point semantic differential items. The word pairs were: unimportant/important, bad/good, negative/positive, unwise/wise, unpleasant/pleasant, threatening/assuring, and risky/safe (α = .96 for COVID-19 and .95 for influenza).

Descriptive norm

Vaccine-related descriptive norm was measured by four items: "Most people I know/Most of my family and loved ones/Most people I work/go to school with/Most people in my community *have received* the COVID-19/influenza vaccines" (α = .88 for COVID-19 and .89 for influenza).

Injunctive norm

Vaccine-related injunctive norm was measured by four items: "Most people I know/Most of my family and loved ones/Most people I work/go to school with/Most people in my community *think I should* get the COVID-19/influenza vaccines" (α = .92 for COVID-19 and .93 for influenza).

Data analysis strategy

All analyses were conducted in Mplus 8.6. General linear models (GLMs) were estimated to address RQ1. Participants' sex, age, race, and income were entered as controlled covariates in all models. Assuming $\alpha = .05$, two-tailed, a sample size of $N = 1,131$ and $N = 1,126$ respectively yield a statistical power in excess of .90 to detect an effect size of $f = .10$. LPA analyses (Ferguson et al., 2020; Morin et al., 2016; Nylund-Gibson et al., 2023; see also Krawietz & Pett, 2023) were conducted within each vaccine topic and across the two topics to address RQ2 and RQ3.

Results

Factors differentiating vaccine-hesitant and -confident individuals

GLM results showed that controlling for sex, age, race, income, education, and vaccine history, vaccine-confident and -hesitant individuals were significantly different from each other on all the variables (i.e., behavioral beliefs) at $p < .01$, except for hope (p =.09) and happiness (p = .88) within influenza. Table 2 presents the marginal means of the variables between vaccine-hesitant vs. -confident individuals across the two vaccine topics, with Cohen's d ranging from 0.13 to 0.68. Further exploration revealed that happiness ($r = .44$) and hope (r = .38) were significantly correlated with the likelihood of influenza vaccine uptake. Therefore, these two variables related to the influenza vaccine were also retained in the input data for LPA analyses. Only the data on the vaccine-hesitant individuals were used in the LPA analyses. The sample sizes ($n = 804$ for COVID-19 and 712 for influenza) were large enough to yield sufficient statistical power for LPA analyses (Krawietz & Pett, 2023; Weller et al., 2020).

Profiles of vaccine-hesitant individuals

To address RQ2 and RQ3, all variables in Table 2 were used as input data for the LPA analyses. LPA analyses were first performed within each topic to address RQ2. Previous research with data collected by early March in 2021 (i.e., COVID-19 vaccines developed by Pfizer, Moderna, and Johnson & Johnson were authorized for emergency use, but not yet available to the general public) revealed four profiles (i.e., subgroups) among the COVID-19 vaccine-hesitant individuals (Zhou et al., 2023a, 2023b). Therefore, we estimated models with 3, 4, 5, and 6 profiles.

Table 3 presents the fit indices of the estimated LPA models. The following statistical criteria were used for model selection: (1) sample-size-adjusted Bayesian information criterion (SABIC), (2) Akaike information criterion (AIC), (3) Entropy,

Table 2. Marginal means of major variables for vaccine-hesitant vs. -confident Individuals.[a]

Predictor of Vaccine Uptake Likelihood	COVID-19 Hesitant ($n = 807$) $M(SE)$	COVID-19 Confident ($n = 324$) $M(SE)$	COVID-19 Cohen's d $M(SE)$	Influenza Hesitant ($n = 712$) $M(SE)$	Influenza Confident ($n = 414$) $M(SE)$	Influenza Cohen's d
Perceived Severity	4.94 (.05)	5.85 (.09)	0.52	4.92 (.05)	5.37 (.07)	0.27
Perceived Susceptibility	5.39 (.05)	5.97 (.08)	0.34	5.59 (.05)	6.27 (.07)	0.43
Coping Ability	5.48 (.04)	6.18 (.06)	0.57	5.52 (.04)	6.02 (.06)	0.36
Happiness	2.18 (.07)	2.89 (.11)	0.31	2.39 (.07)	2.37 (.10)	.00
Hope	2.58 (.06)	3.39 (.11)	0.38	2.61 (.07)	2.84 (.10)	0.11
Sadness	1.24 (.05)	0.90 (.09)	0.19	0.94 (.05)	0.68 (.07)	0.16
Fear	1.61 (.06)	1.18 (.11)	0.20	1.15 (.06)	0.86 (.09)	0.14
Anger	1.69 (.07)	1.19 (.11)	0.23	1.18 (.06)	0.77 (.09)	0.21
Worry	1.91 (.06)	1.43 (.11)	0.22	1.46 (.07)	1.12 (.09)	0.17
Regret	0.98 (.05)	0.69 (.08)	0.18	0.86 (.05)	0.56 (.07)	0.20
Guilt	0.79 (.05)	0.58 (.08)	0.13	0.76 (.05)	0.40 (.07)	0.24
Disgust	1.13 (.05)	0.82 (.09)	0.17	0.92 (.05)	0.54 (.08)	0.22
Perceived Vaccine Side Effects Severity	4.58 (.06)	3.31 (.10)	0.61	4.07 (.07)	3.48 (.09)	0.29
Perceived Vaccine Side Effects Susceptibility	4.57 (.06)	3.63 (.10)	0.44	4.24 (.07)	3.73 (.09)	0.24
Perceived Vaccine Effectiveness	4.49 (.05)	5.81 (.09)	0.74	4.64 (.06)	5.58 (.08)	0.52
Perceived Vaccine Self-efficacy	5.40 (.04)	6.06 (.07)	0.46	5.52 (.05)	6.35 (.07)	0.57
Belief in Vaccine Misinformation	3.02 (.05)	2.03 (.08)	0.61	5.52 (.05)	2.27 (.06)	0.65
Vaccine Attitude	4.61 (.05)	5.77 (.08)	0.68	4.78 (.05)	5.58 (.07)	0.48
Vaccine Descriptive Norm	3.65 (.03)	3.88 (.06)	0.23	3.27 (.03)	3.50 (.05)	0.22
Vaccine Injunctive Norm	3.35 (.03)	3.83 (.06)	0.41	3.24 (.04)	3.55 (.05)	0.26

Except for happiness ($p = .89$) and hope ($p = .09$) for influenza, all other differences were significant at $p < .01$.

and (4) bootstrapped likelihood ratio test (BLRT). For the two information criteria (i.e., SABIC, AIC), lower values indicate superior fit (Akaike, 1987; Banfield & Raftery, 1993; Sclove, 1987). Entropy indicates how well individuals were classified into the latent profiles, with higher values suggesting a better classification of individuals (Clark & Muthén, 2009). BLRT provides an indication of the superiority of a k-class model over the k-1-class model where a significant p-value suggests that the k-class model significantly improves the fit in comparison to the k-1-class model (McLachlan & Peel, 2000). From the audience segmentation and message tailoring point of view, the size of classes (i.e., if substantial and economically feasible for audience segmentation and message tailoring, Grunig, 1989) was also considered as a substantive criterion.

For COVID-19, while SABIC, AIC, and BLRT all suggested adding a class would improve fit compared to the previous model, the highest entropy value was achieved by the 4- and 5-profile models across both topics. In addition, the size was $n = 31$ (i.e., 3.8% of the total) for the smallest profile in both the 5- and 6-profile solutions. In other words, the smallest group became too small in size such that they are no longer substantial and might not be meaningful or possible to service economically (Grunig, 1989; see also Atkin & Salmon, 2013). Hence, the 4-profile model was obtained for COVID-19 (RQ2).

For influenza, while SABIC, AIC, and BLRT all suggested that adding a class improved fit compared to the previous model, entropy clearly favors a 4-profile solution. In addition, for a 5-profile solution, the size was $n = 41$ (i.e., 5.8% of the total) for the last profile; and for a 6-profile solution, the sizes were $n = 43$ (i.e., 5.8% of the total) and 20 (i.e., 2.8% of the total) for the smallest two profiles. They also became too small in size to be substantial or meaningful. Therefore, the 4-profile solution was obtained for influenza as well (RQ2).

Two-group LPA analyses were performed to address RQ3, with vaccine topic as the grouping factor. A two-group LPA model assesses measurement invariance (i.e., similarity in latent profile solutions) between the two vaccine topics (Morin et al., 2016; Olivera-Aguilar & Rikoon, 2017). Across the two topics, configural invariance addresses if there are the same number of profiles, structural invariance examines if the within-profiles means and dispersion invariance assesses if the

Table 3. Fit indices of LPA models.

Number of Class	SABIC	AIC	Entropy	BLRT p-value
COVID-19				
3	67756.16	67601.35	0.93	.001
4	**66647.30**	**66453.03**	0.94	.001
5	65804.59	66083.32	0.94	.001
6	65087.89	65361.08	0.94	.001
Influenza				
3	57357.68	57215.62	0.93	.001
4	**56578.92**	**56400.64**	0.95	.001
5	55935.84	55721.35	0.93	.001
6	55438.26	55188.55	0.94	.001
Two-group				
3	101436.60	101129.28	0.95	.001
4	**99582.38**	**99186.95**	0.96	0.001
5	98573.67	98090.13	0.95	.001
6	97621.18	97049.53	0.94	.001

within-profiles variability of the input variables are equal, and distributional invariance investigates if the sizes of the profiles are equal. Given the clear and substantial differences between COVID-199 and influenza and their vaccines, only configural invariance was assessed in this study. As in the within-topic LPA analyses, model fit was compared across 3, 4, 5, and 6-profile solutions. While SABIC, AIC, and BLRT all suggested that adding a class improved fit compared to the previous model, entropy clearly favors a 4-profile solution. Therefore, the 4-profile solution was obtained.

Across the two topics, each individual was classified into one of the four profiles based on membership probabilities estimated from the model where the profile with the highest probability was shown to be the group they belong to. Table 4 presents the distribution of individuals in each profile and Table 5 the latent class variable patterns. The diagonal in Table 5 presents the likelihood that individuals would belong to a specific profile in a group (i.e., COVID-19 influenza) rather than other profiles. The ideal scenarios would be 100% on the diagonal and 0 in the off-diagonal cells (i.e., analogous to the notion of simple structure in factor analysis, high loadings on the factor an item belongs to, and 0 loadings on other factors). The results showed a clear pattern of configural invariance between COVID-19 and influenza (RQ3). Table 6 presents the estimated means on each indicator for the four profiles within- and between-topic. Figure 1 provides a visual presentation of the means (relative to the vaccine-confident individuals). Note that vaccine-confident individuals' characteristics include high levels of risk perception, higher levels of positive affects and lower levels of negative affects toward vaccines, low levels of perceived risk related to vaccine side effects, high self-efficacy to get vaccinated, low levels of vaccine-related misbeliefs, high perceived vaccine effectiveness, positive attitude toward vaccines, and high levels of vaccine-related descriptive and injunctive norms. Despite the significant differences when compared to vaccine-confident individuals, the hesitant individuals had high levels of perceived ability to cope (with the viruses) and vaccination self-efficacy. Their descriptive and injunctive norms were also comparable. The differences among the hesitant individuals were minimal in these aspects. We turn to the distinct profiles of the subgroups next.

Individuals in Profile 1 ($n_{Covid-19} = 89$, $n_{Influenza} = 65$) had the lowest intention to get vaccinated (3.8% for COVID-19 and 7.5% for influenza). When compared to the vaccine-confident individuals, this group stood out by low risk perceptions (severity and susceptibility), low positive affects (happiness and hope), and high negative affects (sadness, fear, anger, worry, and disgust), high levels of beliefs in misinformation, high perceived risk of vaccine side effects (severity and susceptibility), negative attitude toward vaccine (i.e., below the scale mid-point), and low levels of both descriptive and injunctive norms, and they did not think the vaccines were effective. They were *the Paranoids*.

Profile 2 ($n_{Covid-19} = 329$, $n_{Influenza} = 302$) was the biggest in size. Members of this group had the highest COVID-19 vaccination intention (68.7%) among the vaccine-hesitant individuals, but the second lowest influenza vaccination intention (23.5%). They were closer to vaccine-confident individuals in terms of risk perception and affective reactions to COVID-19 vaccines (but not for influenza). Their characteristics were relatively low perceived vaccine effectiveness, high perceived risk of harmful vaccine side effects, and more negative attitude toward vaccine (the differences were more pronounced for influenza). They were the *Less-informed*.

Profile 3 ($n_{Covid-19} = 226$, $n_{Influenza} = 232$) were almost opposite to Profile 2 in terms of vaccination intention, with the second lowest COVID-19 vaccination intention (17.6%), but the highest influenza vaccination intention (69.1%) among the hesitant individuals. Their common features were higher levels of perceived risk from vaccine side effects (the differences were more pronounced for COVID-19), lower levels of perceived vaccine effectiveness, and more negative attitudes toward vaccines. This group was somewhat similar to Profile 2 (the Less-informed). The key differences lied in their higher beliefs in misinformation and stronger negative effects toward vaccines. They can be labeled as the *Mis-informed*.

Profile 4 ($n_{Covid-19} = 163$, $n_{Influenza} = 113$) had similar intentions to receive the COVID-19 booster shot (52.9%) and influenza vaccine (44.8%). They were comparable to the

Table 4. Distribution and size of each profile.

Vaccine Topic/Group	Latent Profile 1	2	3	4
Group 1 (COVID-19, *n* = 807)	89	329	226	163
Group 2 (Influenza, *n* = 712)	65	302	232	113
Total (*n* = 1,519)	154	631	458	276

Table 5. Patterns of latent profile variable (in percentages).

Profile	Group	1.1	1.2	2.1	2.2	3.1	3.2	4.1	4.2
1.1	COVID-19	**97.8**	0	0	0	0.8	0	1.4	0
1.2	Influenza	0	**96.0**	0	2.1	0	2.8	0	1.9
2.1	COVID-19	0	0	**97.1**	0	2.2	0	0.7	0
2.2	Influenza	0	0.9	0	**96.0**	0	0.3	0	0
3.1	COVID-19	0.6	0	3.4	0	**95.2**	0	0.8	0
3.2	Influenza	1.5	0	0	3.4	0	**94.0**	0	0.8
4.1	COVID-19	0	0	0	0	0.6	0	**97.1**	0
4.2	Influenza	0	0.9	0.3	0.3	0	1.5	0	**98.2**

Table 6. Estimated means(standard errors) of indicators for latent profiles.

	Profile 1		Profile 2		Profile 3		Profile 4	
Variables	COVID	Influenza	COVID	Influenza	COVID	Influenza	COVID	Influenza
Severity	3.57	4.26	5.40	4.37	4.30	5.25	5.25	5.19
	(0.24)	(0.29)	(0.07)	(0.10)	(0.15)	(0.08)	(0.18)	(0.10)
Susceptibility	4.82	5.75	5.54	5.70	5.17	5.52	5.51	5.59
	(0.22)	(.19)	(0.08)	(0.08)	(0.12)	(0.10)	(0.11)	(0.10)
Coping Ability	5.18	5.75	5.71	5.26	5.28	5.88	5.40	5.34
	(0.14)	(0.15)	(0.05)	(0.08)	(0.08)	(0.06)	(0.09)	(0.09)
Happiness	0.60	0.80	3.00	0.82	1.03	3.84	2.54	2.76
	(0.18)	(0.26)	(0.15)	(0.11)	(0.12)	(0.17)	(0.14)	(0.11)
Hope	0.86	0.85	3.46	1.05	1.37	4.02	2.81	2.98
	(0.19)	(0.29)	(0.13)	(0.12)	(0.13)	(0.15)	(0.13)	(0.13)
Sadness	2.39	1.95	0.57	0.29	0.54	0.58	3.09	4.12
	(0.25)	(0.23)	(0.05)	(0.07)	(0.06)	(0.06)	(0.13)	(0.15)
Fear	3.27	3.22	0.84	0.40	0.98	0.68	3.40	3.37
	(0.25)	(0.28)	(0.09)	(0.14)	(0.13)	(0.07)	(0.15)	(0.18)
Anger	4.66	3.53	0.76	0.57	1.12	0.61	3.20	3.24
	(0.21)	(0.61)	(0.08)	(0.07)	(0.12)	(0.06)	(0.13)	(0.17)
Worry	3.43	3.60	1.18	0.78	1.35	1.04	3.59	3.56
	(0.24)	(0.27)	(0.11)	(0.15)	(0.15)	(0.08)	(0.13)	(0.16)
Disgust	3.41	2.76	0.41	0.26	0.42	0.51	2.77	2.84
	(0.21)	(0.63)	(0.04)	(0.05)	(0.07)	(0.05)	(0.15)	(0.18)
Regret	1.33	1.00	0.46	0.19	0.36	0.69	2.82	2.91
	(0.24)	(0.17)	(0.04)	(0.05)	(0.05)	(0.07)	(0.18)	(0.16)
Guilt	0.77	0.64	0.36	0.14	0.19	0.56	2.66	2.86
	(0.31)	(0.14)	(0.04)	(0.03)	(0.04)	(0.06)	(0.21)	(0.21)
Vaccine Effectiveness	1.64	2.55	5.64	3.87	3.02	5.54	4.65	4.51
	(0.16)	(0.35)	(0.07)	(0.12)	(0.18)	(0.10)	(0.22)	(0.15)
Self-efficacy	4.40	5.07	5.76	5.68	5.03	5.56	4.94	4.57
	(0.23)	(0.23)	(0.06)	(0.08)	(0.11)	(0.10)	(0.10)	(0.11)
Side-effects Severity	6.58	5.98	3.60	4.45	5.50	3.28	4.87	4.65
	(0.11)	(0.37)	(0.13)	(0.11)	(0.09)	(0.15)	(0.18)	(0.13)
Side-effects Susceptibility	6.06	5.63	3.89	4.54	5.00	3.57	4.83	4.70
	(0.17)	(0.44)	(0.12)	(0.09)	(0.11)	(0.14)	(0.13)	(0.13)
Misinfo- belief	4.83	4.44	2.20	3.37	3.59	2.70	3.65	4.06
	(0.14)	(0.28)	(0.07)	(0.08)	(0.11)	(0.11)	(0.16)	(0.11)
Attitude	1.63	2.23	5.78	3.88	3.23	5.88	4.77	4.56
	(0.15)	(0.42)	(0.08)	(0.12)	(0.15)	(0.08)	(0.21)	(0.14)
Descriptive Norm	2.61	2.46	4.09	2.67	3.07	3.79	3.68	3.36
	(0.11)	(0.15)	(0.04)	(0.06)	(0.08)	(0.07)	(0.11)	(0.10)
Injunctive Norm	2.02	1.99	3.92	2.56	2.58	3.90	3.49	3.37
	(0.11)	(0.17)	(0.05)	(0.07)	(0.09)	(0.06)	(0.13)	(0.10)

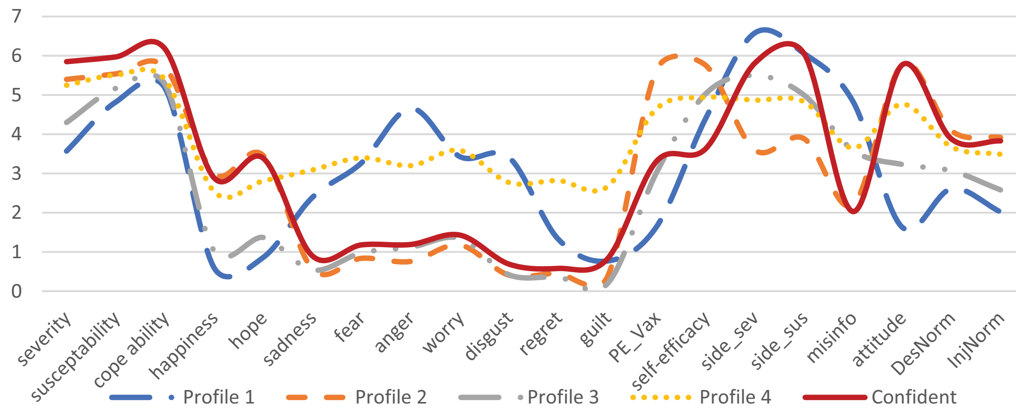
confident individuals in terms of perceived risks, perceived vaccine effectiveness and positive affects, and positive attitude toward vaccines (although at lower levels) but were distinct when it came to higher levels of negative affects, perceived vaccine side effects, and beliefs in misinformation. They can be labeled as the *Concerned*.

Discussion

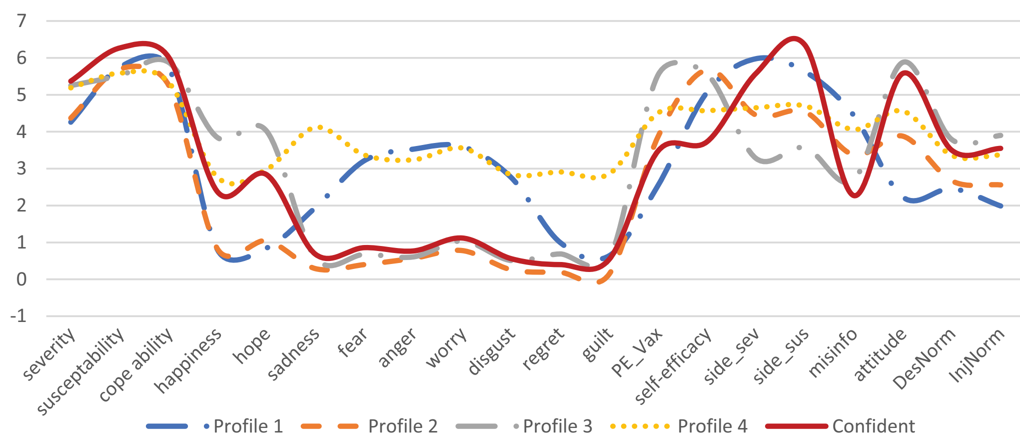
Consistent with the *Nature* (December 23, 2022) Editorial, our data in this study suggested that vaccine hesitancy is one of the most important obstacles in ending the pandemic – over 70% of the individuals were hesitant to receive the COVID-19 booster shot despite the accumulating evidence for the effectiveness and safety of the vaccines. When compared with data collected in 2021, before COVID-19 vaccines were just authorized for emergency use but not available to the general public, the profiles of vaccine-hesitant individuals shifted (Zhou et al., 2023a, 2023b). This was expected given that the pandemic unfolded further, new variants of the SARS-CoV-2 viruses emerged (e.g., the Omicron variants), and the vaccines got updated. The heterogeneity in vaccine-hesitant individuals decreased slightly and the characteristics of subgroups were featured by the common obstacles to vaccination uptake centered around 1) effectiveness of the vaccine, 2) risks of vaccine side effects, 3) vaccine-related misinformation, and 4) affective responses to vaccines (probably due to the appraisals of the risks if vaccine side effects and misinformation).

There was also configural measurement invariance between COVID-19 and influenza. That is, there was the same number of profiles, each with similar characteristics between the two topics. On the other hand, the size of each sub-group, and the descriptives of the indicator variables were not equal (i.e., there was no structural or distributive invariance), which was expected given that 1) influenza is a familiar virus, 2) influenza vaccines are made with "old" technology with a much longer history (than mRNA), and 3) there have been more (and probably better) data and evidence for the effectiveness, safety, and possible side effects of influenza vaccines.

Configural invariance suggested there might remain substantial differences between COVID-19 vs. influenza vaccine hesitancy, in particular the groups of Less-information and Mis-informed. Despite their similarities in obstacles to vaccine uptake, their intentions to receive a COVID-19 booster shot and influenza vaccine were dramatically different, and the patterns were flipped between the two profiles. This suggested



(a)



(b)

Figure 1. (a) Profiles of influenza vaccine-hesitant (vs. -confident) Individuals. (b) Profiles of influenza vaccine-hesitant (vs. -confident) individuals.

that a product that combines COVID-19 and influenza vaccines probably would not be a good idea to these individuals since the low intention of one vaccine (i.e., 17.6% for COVID-19 among the Misinformed and 23.5% for influenza among the Ill-informed) would inhibit the intention to receive the other vaccine. For the Paranoid and the Concerned, their intentions to receive the COVID-19 booster shot and the influenza vaccine were similar. The combination shot would most likely facilitate vaccination uptake.

On the other hand, the respective characteristics of the profiles across COVID-19 and influenza vaccines were quite consistent, which suggested that the subgroups can be targeted with similar message strategies. The premise for message design strategy lies in that messages should address the most outstanding obstacles to vaccination uptake for each profile in such a way that the members of the respective profiles would be moved in the direction of vaccine-confident individuals. The advantages of message targeting based on latent profiles lie in the multidimensional nature (Albarracin & Glasman, 2016), that is, the audience segmentation and message targeting are based on information from the 20 indicator variables involved in the LPA analyses, rather than a single, or a few, moderators.

The *Paranoids* were different from the vaccine-confident individuals in almost every indicator variable including perceived risks of the virus and vaccine side effects, beliefs in misinformation, affective responses, and perceived effectiveness of and attitude toward vaccines. Potential message strategies for this group should appeal to affect, probably by presenting scientific evidence for the vaccine effectiveness, and pre- or de-bunk vaccine-related misinformation related to harmful vaccine side effects and conspiracy theories.

The *Less-informed* individuals are characterized with low perceived vaccine effectiveness, high perceived risk of harmful vaccine side effects, and consequently, more negative attitude toward vaccine (the differences were more pronounced for influenza). Potential message strategies should focus on scientific evidence of the effectiveness and safety of vaccines. More and updated empirical evidence from scientific studies would be conducive.

The *Mis-informed* individuals are featured with higher levels of perceived risk from vaccine side effects (the differences were more pronounced for COVID-19), lower levels of perceived vaccine effectiveness, and more negative attitudes toward vaccines. In addition to the mean differences in the above-mentioned indicator variables, this group also had stronger negative affects when compared to the *Less-informed* group. This group can probably be targeted with similar message strategies as the *Less-informed* one, with the potential addition of affect appeals to appease the negative affects (e.g., with gain-framed messages).

The *Concerned* group was featured with higher levels of perceived risks of vaccine side effects, beliefs in misinformation, and negative affects, despite the relatively higher levels of perceived vaccine effectiveness and positive attitude toward vaccines. Messages targeting this group should focus on scientific evidence and more data on the side effects of vaccines, and debunking and/or pre-bunking vaccine-related misinformation.

Limitations and directions for future research

There has been a consensus in the literature that people are heterogeneous in terms of their reasons for vaccine hesitancy (e.g., Dubé et al., 2013; Salmon et al., 2015). LPA analysis is a data-driven and person-centered approach to analyzing such heterogeneity and investigating potential latent subgroups among vaccine-hesitant individuals. The distinct characteristics that differentiate the subgroups provide the substantive and conceptual foundations for multidimensional, deep-level audience segmentation and message tailoring. This study builds upon previous ones (Zhou et al., 2023a, 2023b) and demonstrates that 1) there are regularities among vaccine-hesitant individuals, the substance and content of which might shift as the pandemic develops (e.g., variants of the virus, development of vaccines and medicines). However, the patterns in the latent profile remain robust and meaningful. 2) The latent profiles of vaccine-hesitant individuals might be invariant across multiple vaccines (e.g., COVID-19 and influenza in this study). And 3) such measurement invariance can have important implications for developing message strategies to promote vaccine confidence and uptake, as well as for the feasibility of a combination shot that contains two vaccines. However, given the data-driven approach, it remains an empirical question if the results would be in the same pattern when it comes to other vaccine topics, at a different time, or with different samples. Overall, such a person-centered, data-driven, and latent variable approach offers a means of deep-level audience segmentation and message tailoring, which is more effective and more efficient than the traditional variable-centered (i.e., moderators) approach.

The findings from this study should be interpreted with its limitations in mind. First, this study was a cross-sectional study. Although we learned that the profiles of vaccine-hesitant individuals shifted in the past, we are unable to predict if and how it will continue to shift without longitudinal data. Second, more data and replications of the patterns of the latent profiles and measurement invariance between COVID-19 and influenza vaccines (and potentially other vaccines) would greatly enhance the validity and generalizability of the findings. Third, the sample was based on convenient sampling from Qualtrics panels. The demographic composition of the sample did not match the national population, which limited the generalizability of the findings. Moreover, the overwhelming majority of white participants and small numbers of minority ethnic groups prevented us from meaningfully examining potential racial differences in the latent profiles. Such studies could shed light on effective means of message designs to help address the racial disparities in vaccine hesitancy. Fourth, the purpose of audience segmentation ultimately lies in message targeting and tailoring. To a certain degree, the message strategies proposed for each profile were speculative. Their effectiveness and if they are most effective to the individuals in the matching profiles will have to be tested in empirical studies.

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Data availability statement

Data file is available at: https://osf.io/acxur/?view_only=48851d578711412bbb2b5e0c56c225b9.

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