Vaccine xxx (xxxx) xxx

Contents lists available at ScienceDirect

Vaccine

journal homepage: www.elsevier.com/locate/vaccine

Integrating the person-centered approach with the study of vaccine hesitancy: Applying latent profile analysis to identify vaccine hesitancy subpopulations and assess their relations with correlates and vaccination outcomes

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ARTICLE INFO

Article history:
Received 12 October 2022
Received in revised form 26 May 2023
Accepted 15 June 2023
Available online xxxx

Keywords:
Vaccine
Vaccination
Vaccine hesitancy
Latent profile analysis
Person-centered analyses
Vaccine word-of-mouth
Political ideology
Political orientation
Political party

ABSTRACT

In scholarly and popular discussions of vaccine hesitancy, authors have repeatedly referred to different "types" of vaccine hesitant individuals; however, almost all modern research on vaccine hesitancy utilizes variable-centered approaches to identify the relation of variables rather than a person-centered approach to identify subpopulations, which suggests that a discrepancy exists between conceptual discussions and empirical research on vaccine hesitancy. For this reason, the current article conducts a latent profile analysis (LPA) on the dimensions of a well-supported vaccine hesitancy measure, which assess hesitancy towards vaccines in general. We also assess the relations of the resultant profiles (e.g., subpopulations) with relevant self-reported outcomes and correlates, wherein most of our outcomes are associated with COVID-19 and flu vaccines. Our LPA results support the existence of eight vaccine hesitancy profiles. The profile with the most unfavorable vaccination outcomes (e.g., willingness, receipt, and word-of-mouth) was associated with greater perceptions that vaccines cause health risks and unneeded when healthy; the profile with the most favorable vaccination outcomes was associated with low levels of all vaccine hesitancy dimensions. The other profiles produced a clear gradient between these two extremes. The profiles also differed regarding their standing on correlates, but the clearest difference was their relation with political orientation. Profiles with more unfavorable vaccination outcomes were associated with conservatism, whereas profiles with more favorable vaccinations outcomes were associated with liberalism. These results provide a new perspective for current understandings of vaccine hesitancy and open several avenues for future research.

1. Introduction

During the COVID-19 pandemic, both academic and popular outlets alike recognized that many individuals possess negative perceptions and attitudes towards vaccines that cause them to refuse vaccination, which resulted in a significant number of preventable illnesses and deaths [29,57,62]. This widespread observation pushed the construct of vaccine hesitancy to the forefront of scholarly and public discourse. While multiple definitions have been attributed to vaccine hesitancy in research (discussed below), it is often defined as "the specific situation of having concerns about vaccines, regardless of actual vaccine receipt" [34]. Vaccine hesitancy is therefore recognized to be a multidimensional construct, as people can have many different types of concerns regarding vaccines [30,79,91]. One person may have concerns regarding the health risks of vaccines, for instance, whereas another person may have concerns regarding the inconvenience of receiving a vaccine. From studies applying this definition and similar others, authors have empirically supported that vaccine hesitancy is indeed a primary determinant of vaccination behaviors, such as receipt [27,32,33,68,97,103].

Several self-report scales have been created to measure vaccine hesitancy [3,30,73,91]. While each has their strengths and weaknesses, Howard's [50] Multidimensional Vaccine Hesitancy Scale (MVHS) is among those with the most conceptual, psychometric, and validity support. Howard [50] observed that many prior measures of vaccine hesitancy could only be applied with certain populations (e.g., parents), few were constructed via the traditional

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https://doi.org/10.1016/j.vaccine.2023.06.057
0264-410X/

scale development process, and none seemed to gauge the construct's full content domain. For these reasons, the author underwent the scale development process to develop a more comprehensive measure of vaccine hesitancy that could be applied to most people. The result of this process was an eight-dimension measure with satisfactory psychometric and validity evidence. These dimensions and their descriptions are provided in Table 1. Both this initial investigation and subsequent studies [51,53] have supported that two dimensions produce the strongest relations with vaccination outcomes: Health Risks, the belief that vaccines pose health risks, and Healthy, the belief that vaccines are not needed because the person is healthy. This evidence that certain dimensions are stronger predictors than others supports the need to study vaccine hesitancy in a multidimensional manner; studying vaccine hesitancy as a unitary construct blends together the differing effects of these dimensions and may produce ambiguous results, whereas studying separate dimensions enables researchers to disentangle these effects and understand the true nature of vaccine hesitancy [35,69].

In scholarly and popular discussions of vaccine hesitancy, however, authors have repeatedly referred to different "types" of vaccine hesitant individuals [39,47,90]. For instance, these discussions have referred to people that are vehemently suspicious of the health risks and benefits of vaccines while also referencing people who may only have slight suspicions [3,30,73]. These discussions have likewise proposed groups of people with entirely different clusters of concerns, suggesting that people concerned with health risks and benefits are significantly different than those who may be concerned with aspects such as cost, inconvenience, and accessibility [39,47,90]. While prior research using the MVHS has supported that the dimensions of vaccine hesitancy indeed relate to differing outcomes, these studies have not undergone a person-centered approach to identify subpopulations (e.g., types) of individuals regarding their vaccine hesitancy. This suggests that a disconnect exists between modern discussions and extant empirical research on the construct.

For this reason, the current article performs a latent profile analysis (LPA) on the MVHS dimensions. LPA identifies profiles (i.e., subpopulations) of participants across a set of studied variables [1,89,94]. Individuals are then assigned to the profiles that they most likely represent, and members of a common profile are more similar than members of differing profiles regarding the studied variables [96,108]. Conducting LPA on the MVHS can therefore identify which subpopulations (i.e., profiles) exist regarding the dimensions of vaccine hesitancy, bridging the person-centered approach to the study of vaccine hesitancy [70]. After identifying these profiles, we then test whether these profiles differently relate to self-reported outcomes and correlates. We chose to study the outcomes and correlates that are most prominent in discussions of vaccine hesitancy [31,41,50,51,92]. These outcomes include flu and COVID-19 vaccination willingness; flu, COVID-19, and other vaccination receipt; as well as positive and negative word-of-mouth. These correlates include age, gender, location, health insurance status, and political ideology.

Table 1
Multidimensional Vaccine Hesitancy Scale Dimensions and Descriptions.

Dimension	Definition Each of the following definitions begin with, "The belief that…"
Health Risks	Vaccines have substantial health risks.
Cost	Vaccines are expensive.
Physical Pain	Vaccination is physically painful.
Inconvenience	Vaccines are difficult to receive.
Personal Reactions	Vaccines cause reactions specific to the respondent (e.g., allergies).
Accessibility	Vaccines are scarce.
Healthy	Vaccines are not needed because the respondent is healthy.
Forget	Vaccines are easy to forget about.

From these efforts, the current article provides several contributions to research and practice. First, prior discussions of vaccine hesitancy often refer to it as a relatively homogenous construct, such that people are either high or low on their standing [31,41,92]. Multidimensional measures, such as Howard [50], added nuance to the study of vaccine hesitancy, showing that the construct itself is heterogeneous; people's vaccine hesitancy is not simply high or low, but it rather varies across a number of dimensions. The current article adds even further to this nuance by recognizing additional heterogeneity via a person-centered analysis to identify subpopulations based on these dimensions, acknowledging that a one-size fits all approach is inappropriate for discussions of vaccine hesitancy. Such a discovery suggests that stricter constraints must be made for the generalizability of research on vaccine hesitancy, but also that researchers should consider more focused investigations into specific subpopulations. The processes that lead to vaccination may significantly differ between subpopulations, and separate models may need to be constructed for these subpopulations.

Second, resultant profiles are defined by their distinguishing characteristics, such as elevated means for specific dimensions. Dimensions that distinguish multiple profiles or even strongly distinguish a single profile may be particularly important for the dynamics of vaccine hesitancy. Such a finding could provide significant support for the future applications of theories associated with the distinguishing dimensions to understand vaccination. For instance, a profile may have a very elevated mean for perceptions that needles are painful (i.e., Physical Pain), which would be a distinguishing vaccine hesitancy dimension. This could imply that theories associated with phobias may be necessary to understand vaccine hesitancy for members of this profile, as staunch fears of the physical pain could be a significant deterrent of vaccination for these specific people. Authors could apply theories such as nonassociative theory [23,75] and fear module theory [23,78] to understand and ultimately encourage vaccination for these individuals, resulting in novel theoretical integrations and directions for future research.

Third, linking profiles to outcomes can identify which subpopulations demand greater attention for future research and practice. Not all vaccine hesitancy profiles may be associated with reduced rates of vaccination, indicating that these subpopulations may not need to be investigated as much as those with reduced rates of vaccination. Future research could thereby progress in a more focused manner with more immediate and greater real-world impacts. Such efforts are necessary during and after the COVID-19 pandemic, as the need for targeted research that can provide accurate and impactful insights regarding vaccine hesitancy is explicitly clear in the quickly changing modern world [70,72,86].

Fourth, our discussion highlights benefits of the person-centered approach. Extant research on vaccine hesitancy almost exclusively applies variable-centered analyses (e.g., correlation, regression, ANOVA) [70], resulting in a field largely limited to variable-centered approaches. By deviating from these analyses and approaches, the current article enables a novel shift in perspective can be linked to additional theoretical implications. These implications range from increasing the complexity of existing theories typically studied via the variable-centered approach to the adaptation of person-centered theories that have yet to be applied to vaccine hesitancy [54,109].

Fifth, identifying subpopulations with vaccine hesitancy can allow the development of more effective interventions that are specifically catered for these subpopulations. General interventions

could be developed intended to be particularly effective for certain subpopulations, such as an intervention that provides information regarding the safety and benefits of vaccines for those who may be vehemently suspicious of the health risks and benefits of vaccines. Researchers could also develop adaptive interventions. Adaptive interventions provide different intervention components based on the characteristics of the individual [60,82]. Based on our identified subgroups, a future effort could initially categorize an individual into a specific subpopulation, and then certain intervention components could be provided to individuals based on their respective subpopulation. For example, a person who is categorized as being suspicious of health risks and benefits could be provided an intervention reinforcing the safety and benefits of vaccines, whereas a person who is categorized as being concerned regarding the cost, inconvenience, and accessibility of vaccines could be provided information about locations to receive free or low-cost vaccines. Vaccination rates could significantly increase by utilizing the results of our person-centered approach. Therefore, the current article provides significant benefits to both scholarly and applied efforts.

Before reporting our study, however, additional attention should be given to the definition and measurement of vaccine hesitancy as well as prior research using person-centered analyses to study vaccine hesitancy. We first review these two aspects to better position our study in extant research, such that our implications and impact are more apparent.

1.1. Vaccine hesitancy definition and measurement

An array of definitions has been attributed to vaccine hesitancy [34,50–52,67,80]. Bussink-Voorend et al. [16] recently reported a systematic review of these definitions in 422 sources, discovering that prevalent conceptualization of vaccine hesitancy have included cognition/affect, behavior, and aspects of the decision-making processes. Several subcategories are included in each of these categories, such as cognition/affect including the subcategories of concerns, doubts, beliefs, attitudes, and others. The authors argued that vaccine hesitancy should be conceptualized as indecision during the vaccination decision making process, rather than cognition, affect, or especially behavior. The authors also highlighted, however, that many conceptualizations and operationalizations of vaccine hesitancy include items reflecting cognition or affect, including the three most popularly applied instruments in their review, the parent attitudes about childhood vaccines survey [80], the vaccine hesitancy scale [16], and the SAGE instrument [67]. Thus, significant uncertainty exists in the present literature regarding the most appropriate approaches to define and measure vaccine hesitancy, despite the authors' suggestion to conceptualize it as indecision in the vaccination decision making process.

We chose to use Howard's [50–52] MVHS due to prior conceptual, psychometric, and validity support. Notably, Balgiu et al. [7] reinvestigated the psychometric properties and validity of the MVHS, finding significant support and concluding that, "the MVHS is suitable for medical practice and for research on the analysis of vaccination behaviors and intentions" (p. 1). In developing the MVHS, Howard [50–52] acknowledged the variations of attributed definitions to vaccine hesitancy. The author recognized that a number of researchers have defined vaccine hesitancy as decisional conflict, distinguishing it from cognitions and attitudes about vaccines [12,13,85]; however, they also stressed that some authors consider these cognitive and attitudinal aspects to be too established to now be meaningfully separated [34] and, like Bussink-Voorend et al. [16], noted that the most popular measures of vaccine hesitancy include items representing cognitions and attitudes. For instance, the Vaccine Hesitancy Scale [67] includes the item, "New vaccines carry more risks than old vaccines." (p. 4172). For these reasons, the author developed a vaccine hesitancy scale from a conceptualization consistent with extant instruments.

While the MVHS is supported and lends itself well to person-centered analyses, we recognize the current complexity regarding the definition of vaccine hesitancy. Definitions and commonly applied instruments often reflect cognitions and attitudes, but future research may increasingly distinguish these aspects from definitions of vaccine hesitancy solely focused on indecision. If the case, however, the present results still provide important insights on vaccine hesitancy and vaccination behaviors. Both Howard [50–52] and Bussink-Voorend et al. [16] noted that, if vaccine hesitancy is defined solely as indecision, then cognitions and attitudes are immediate and primary antecedents of vaccine hesitancy, and understanding these aspects subsequently improves our understanding of vaccine hesitancy. It is even possible that, while conceptually distinct, cognitions and attitudes may relate to indecision strongly enough that they are not empirically distinct. Therefore, findings regarding vaccine hesitancy when using scales reflecting cognitions and affect are still meaningful if the definition reflecting indecision alone becomes more commonplace, as these results would provide insights into closely related antecedents to vaccine hesitancy that are pivotal to the vaccination decision-making process.

1.2. Person-centered analyses of vaccine hesitancy

Variable-centered analyses, such as regression and ANOVA, are used to assess the relations between variables [1,89,94]. For instance, researchers often perform regression analyses to test the relation between various personal characteristics and vaccine hesitancy. Person-centered analyses, such as latent class analysis (LCA) and LPA, are used to identify subgroups of participants, and then the relations of these subgroups with outcomes are assessed with variable-centered analyses [54,96,108,109]. For example, LPA can be used to identify subgroups of participants based on their personal characteristics, and then the association of these subgroups with vaccine hesitancy can be tested via ANOVA. This example is a common approach taken when using LCA and LPA to study vaccine hesitancy.

Zhang et al. [113], for example, performed an LPA on the Big Five personality traits, and they then assessed the relation of the personality profiles with vaccine perceptions; Gong [45] identified profiles via LPA on participants' media use, and they related the emergent profiles to vaccination outcomes; and other authors have performed similar investigations [5,17,88]. With these studies, it could be questioned whether the most appropriate variables were chosen for LCA and LPA. While providing nuance to the relation between antecedents and vaccine hesitancy is laudable, identifying the profiles themselves produces important insights into the studied construct(s) [54,89,94,96,109]. As mentioned, prior articles have suggested that different types of people exist regarding their vaccine perceptions, and these studies do not directly investigate this possibility.

Several researchers have performed LCA and LPA to investigate constructs more directly relevant to vaccine hesitancy. These results are generally consistent when analyzing unidimensional measures. Wagner et al. [102] identified subgroups of vaccine acceptors, vaccine ambivalent, and vaccine rejectors with a measure of vaccine attitudes; Rossen et al. [87] identified subgroups of acceptors, fence sitters, and rejecters with a measure of vaccine confidence; Weiss et al. [106] identified the subgroups of positive attitudes, fearful/uncertain attitudes, and critical attitudes of parental attitudes; and others have found similar groupings when assessing unidimensional measures that were likewise defined by

the valence of responses [21,56,63,64]. While conducting LCA or LPA on unidimensional measures can provide some insights, they are limited because emergent groupings are defined by participants' valence on the one dimension. Categorizing participants as high-to-low provides few insights beyond variable-oriented approaches, as many variable-oriented analyses assess linear relations among variables.

Alternatively, a number of studies have performed LPA on the 5C scale of vaccination antecedents, which is perhaps the only multidimensional measure or framework associated with vaccine hesitancy to be studied via a person-centered analysis in multiple investigations. Eger et al. [36] discovered three profiles: receptors, sceptics, and opponents. Zhang et al. [112] discovered four profiles: believers, middlemen, free riders, and contradictors; Portoghese et al. [84] discovered four profiles: believers, meddler, hesitant, and rejector; and Kwok et al. [61] discovered four profiles: believer, apathetic, fence-sitter, and skeptic. Leung et al. [70] discovered five profiles: believers, meddlers, outsiders, skeptics, and contradictors. While these results found varying numbers of profiles, each of them was again largely differentiated by their valiance, such as having positive (e.g., believers), moderate (e.g., middlemen, meddler, hesitant, fence-sitter), or negative (e.g., opponent, contradictor, rejector, skeptic) perceptions regarding vaccines across all 5C dimensions. Because researchers have regularly proposed different types of vaccine hesitant individuals beyond their valence, investigations using other relevant constructs should be considered to determine whether they indeed identify these suggested types.

Fewer authors have studied collections of other perceptions, emotions, and behaviors related to vaccination via LCA and LPA. When conducted, the emergent profiles are most often defined by attributes other than valence alone, and they are instead defined by unique combinations of standings on these variables [98,104,114]. These results show that emergent profiles associated with vaccine hesitancy may not always be defined by their valence, and unique subgroups may require person-centered analyses to identify and investigate. At the same time, it is difficult to holistically interpret these other studies, as different profiles emerge based on the selection of constructs. Therefore, limitations can be seen in present person-centered analyses of vaccine-related constructs, whether studying unidimensional measures, multidimensional frameworks, or multiple related constructs.

The current article advances these prior investigations. We provide direct inferences into vaccine hesitancy itself by studying a modern operationalization of the construct, the MVHS, enabling the emergent profiles themselves to provide important insights into why people may refrain from vaccination. The varied and comprehensive nature of the scale's dimensions also suggest that subgroups may emerge that are defined by more than their valence alone, thereby integrating the ideal aspects of prior studies on both the 5C model and collections of vaccine-related constructs. Assessing the relations of these subgroups with outcomes and correlates also provides further support for both their uniqueness and meaningfulness. Therefore, our results resolve certain tensions in the current literature, providing guidance on the meaningful subgroups that exist regarding vaccine hesitancy and their relations with vaccination outcomes.

2. Method

2.1. Participants

The current study utilized participants from three extant datasets [50,51,53]. Each dataset included the MVHS and several other common measures, enabling the present article to study them as a single merged dataset. The first consisted of 556 participants recruited from Prolific ($Age_{\bar{x}}$ = 26.55, Age_{SD} = 9.00, 41 % female, 22 % in Western English-speaking country); the second consisted of 265 participants recruited from MTurk ($Age_{\bar{x}}$ = 40.10, Age_{SD} = 11.99, 52 % female, 88 % in Western English-speaking country); and the third consisted of 190 participants recruited from MTurk ($Age_{\bar{x}}$ = 39.98, Age_{SD} = 12.03, 50 % female, 89 % in Western English-speaking country). Prolific and MTurk are online platforms that connect those needing tasks completed, like taking a survey, with those willing to complete the tasks for compensation. Studies have supported that Prolific and MTurk can produce valid results when abiding by the precautions taken in the current article [2,71,81]. We reviewed IP addresses and Prolific/MTurk IDs to remove any duplicate participants (n = 0). Each dataset included several attention checks (e.g., "Please mark agree to show that you are paying attention"), and participants were removed if they failed any (n = 54). We lastly removed participants who failed to complete multiple scales (n = 3). The sample sizes reported above reflect the samples after removing these participants. The aggregated dataset included participants from many different countries (41 % United States, 13 % Portugal, 11 % Poland, 8 % United Kingdom, 5 % Mexico, 4 % Italy, 18 % other), which is more fully detailed in Supplemental Material A.

2.2. Measures

Psychometric and validity support for all measures were provided in the original sources utilizing these datasets. For this reason, this support is not repeated in the current article. Unless noted otherwise, all scales used a 1 (Strongly Disagree) to 7 (Strongly Agree) response format.

Multidimensional Vaccine Hesitancy Scale (MVHS). The 32-item, 8-dimension MVHS was administered [50]. Table 1 and the text above includes descriptions of the dimensions. Each dimension produced a Cronbach's alpha of 0.87 or above.

Flu and COVID-19 Vaccination Willingness. Flu vaccination willingness and COVID-19 vaccination willingness were measured via two items each. The items read, "Please indicate how willing you would be to get a [flu vaccine/COVID-19 vaccine (or booster vaccine shot if already received vaccine[1])] next year if it was [free/US$40.00]." Participants responded on a 1 (Extremely Unwilling) to 7 (Extremely Willing) scale. The Cronbach's alpha for flu vaccine willingness was 0.76, and the Cronbach's alpha for COVID-19 vaccine willingness was 0.85.

Flu, COVID-19, and Other Vaccine Receipt. Flu vaccine receipt was measured via the item, "Have you received the flu vaccine within the past year?" Responses of "Yes" were coded as "1" and responses of "No" were coded as "0". COVID-19 vaccine receipt was measured by the items, "Have you ever received the COVID-19 vaccine?", and "Have you tried to receive the COVID-19 vaccine but were unable to receive it due to factors outside your control?" These items were coded into a single variable, such that responses were coded as "1" if participants answered "Yes" to either and "0" if participants answered "No" to both. Other vaccine receipt was measured by the item, "Are you up to date on your vaccines other than the flu vaccine?" Responses of "Yes" were coded as "1" and responses of "No" were coded as "0". Flu and other vaccine receipt were administered to all three samples, whereas COVID-19 vaccine receipt was administered to the second and third samples alone.

Word-of-Mouth. Negative word-of-mouth and positive word-of-mouth were measured with three items each. The negative word-of-mouth items read, "I share negative information about

[1] The text reading, "(or booster vaccine shot if already received vaccine)", was not included in the measure administered to the first dataset, as the COVID-19 booster was not developed yet.

vaccines on social media", "I tell others about negative effects of vaccines", and "I talk to others about the downsides of vaccines." The positive word-of-mouth items read, "I share positive information about vaccines on social media", "I tell others about the benefits of vaccines", and "I talk to others about the positive effects of vaccines." Negative word-of-mouth had a Cronbach's alpha of 0.85, and positive word-of-mouth had a Cronbach's alpha of 0.89. These two scales were only administered to the second and third samples alone.

Correlates. Participants reported their age in years and gender with response options of "female" (1), "male" (0), and "other". Because very few participants responded as other, these responses were excluded from analyses. Participants also reported their current location, which was coded as Western English-Speaking countries (e.g., U.S.A. and United Kingdom) (1) and other (0). Participants were asked whether they had health insurance with response options of "Yes" (1) and "No" (0). Lastly, participants reported their political ideology. The scale ranged from 1 (Strongly Conservative) to 7 (Strongly Liberal) for the first sample, and the scale ranged from 1 (Strongly Conservative) to 9 (Strongly Liberal) for the second and third samples. For this reason, we rescaled the responses for the first sample to match the scale of responses for the second and third samples with the following formula: $y = \left(\frac{x - xmin}{xrange} * yrange\right) + 1$.

2.3. Procedure

All procedures occurred online. Each study began by providing participants information and asking for their consent by clicking a button to proceed. The first study utilized a cross-sectional design, wherein participants completed all surveys after providing their consent. The second and third studies utilized time-separated designs, wherein each measurement occasion was separated by a week. Correlates were measured at Time 1 or 2, vaccine hesitancy was measured at Time 3, and outcomes were measured at Time 4.

2.4. Analyses

We performed an LPA using the eight dimension scores of the MVHS with the mclust and tidyLPA packages in R 4.1.1, following best-practice recommendations for the analysis [89,94,96,108]. LPA identifies profiles of individuals in an iterative process, in which the analysis provides the model fit indices for solutions with a successive number of profiles. The researcher must identify which number of profiles is the ideal solution based on fit indices and theoretical rationale.

We used a maximum likelihood estimation procedure with non-parametric bootstrapped estimates (1,000 replications). We first tested the viability of differing variance and covariance structures. We then performed analyses with 1 profile and tested solutions with an increasing number of profiles until model fit was similar for three successive models, which prevents terminating the process too early and inappropriately selecting a local optimum solution. The utilized model fit indices were primarily the Integrated Complete-data Likelihood (ICL), Bayesian Information Criterion (BIC), and Akaike Information Criterion (AIC) values. This resulted in the analysis of 12 models, ranging from 1 to 12 profiles. We then assessed the theoretical rationale of the best fitting models, choosing the appropriate solution based on both its model fit and theoretical interpretability. After identifying the profiles, we assessed group differences regarding outcomes and correlates via one-way ANOVA and post hoc tests. We used the Games-Howell post hoc test, as it does not assume equal variances. Lastly, for all analyses reported in the primary text, we utilized a pairwise deletion approach to missing data; however, Supplemental Material B also reports a reanalysis using a multivariate imputation by chained equations approach to addressing missing data [111]. All inferences were consistent between the two sets of analyses, strongly supporting the robustness of our findings.

3. Results

Our analyses began by assessing the viability of differing variance and covariance structures. Using mclust (and tidyLPA) terminology, we tested EEI (Model 1), EEE (Model 3), VVI (Model 2), and VVV (Model 6) models (see Wardenarr [105] for model descriptions). Almost all VVI and VVV models failed to converge. While common, failing to converge precludes models with these structures from being interpreted [9,15,101]. The best fitting EEE models included profiles without any assignments, indicating that these models should not be interpreted because they are overestimated or over-extracted [54,94,109]. The best fitting EEI models each converged and included assignments to each profile. For these reasons, we inspected the EEI models in favor of the others.

Model fit values indicated that a nine-profile solution was the best fitting model (ICL = 24,789, BIC = 24,487, AIC = 24,054) (Table 2). When analyzing this solution, however, four of the nine profiles included a small number of assignments (3.1 %-4.9 %), and it was difficult to theoretically interpret several of profiles. These features suggest that the nine-profile solution is also overestimated or over-extracted, and adjacent models should be assessed. The ten-profile solution encountered similar issues (ICL = 25,366, BIC = 24,824, AIC = 24,347), whereas the eight-profile solution did not (ICL = 25,013, BIC = 24,661, AIC = 24,272). The eight-profile solution included a more appropriate number of participants assigned to each profile (all $\geq$4.4 %), and each of the profiles could be clearly interpreted. The average probability for participants' most likely latent class membership was 86 % for the eight-profile solution. Each of these findings are supportive of the eight-profile solution, indicating that it should be interpreted [10,89,94,108]. Therefore, we chose to interpret the eight-profile solution.[2]

Table 3 provides the number of participants and means of the eight MVHS dimensions for each profile. Fig. 1 provides a visual representation of the profile means. Inspecting the profile means produced clear descriptions of the profiles. The first profile consisted of elevated vaccine hesitancy dimensions; it had the highest mean of Health Risks, and its only moderate mean was Accessibility. We label this profile, Distrusting, because members were particularly suspicious of the health risks associated with vaccines. The second profile consisted of all elevated vaccine hesitancy dimensions, and it had the highest mean for four of eight dimensions. We label this profile, Contrarian. The third profile consisted of mostly moderate means, but it had a slightly elevated mean for Health Risks and the highest mean for Healthy. We label this profile, Unnecessary, as Healthy was its distinguishing feature. The fourth profile consisted of moderate means, but it had a slightly elevated mean for Health Risks and Personal Reactions. We label this profile, Reactions. The fifth profile consisted almost entirely of moderate means, but it had elevated means for Cost and Accessibility. We label this profile, Inaccessible. The sixth profile consisted almost entirely of low means, but it had the highest mean of Physical Pain. We label this profile Pain Phobia. The seventh profile consisted almost entirely of low means, but it had an elevated

[2] The seven-profile model also produced appropriate fit (ICL = 24,895, BIC = 24,643, AIC = 24,299). The interpretation of all seven profiles were consistent with seven of the eight profiles in the eight-profile solution. Because the additional eighth profile was interpretable (Pain Phobic), we chose the eight-profile solution. It should be recognized, however, that interpretations were similar between the seven- and eight-profile models.

Table 2
Latent Profile Analysis Model Fit Indices.

Number of Profiles	ICL	BIC	AIC	LL	df	BLRT p
1	27,420	27,420	27,341	−13,655	16	–
2	25,895	25,812	25,689	−12,820	25	0.01
3	25,566	25,364	25,195	−12,564	34	0.01
4	25,398	25,139	24,928	−12,421	43	0.01
5	25,220	24,964	24,709	−12,302	52	0.01
6	25,047	24,800	24,500	−12,189	61	0.01
7	24,895	24,643	24,299	−12,079	70	0.01
8	25,013	24,661	24,272	−12,057	79	0.01
9	24,789	24,487	24,054	−11,939	88	0.01
10	25,366	24,824	24,347	−12,076	97	0.83
11	25,357	24,797	24,276	−12,032	106	0.01
12	25,350	24,802	24,237	−12,003	115	0.01

Note: ICL = Integrated Complete-data Likelihood; BIC = Bayesian Information Criterion; AIC = Akaike Information Criterion; LL = Log-Likelihood; df = Degrees of Freedom; BLRT p = Bootstrapped Likelihood Ratio Test P-Value.

Table 3
Resultant Profile Means and Percentage of Sample Membership.

	Profile 1	Profile 2	Profile 3	Profile 4	Profile 5	Profile 6	Profile 7	Profile 8
Health Risks	5.42	4.07	3.97	3.75	2.66	2.40	2.39	2.04
Cost	3.92	4.60	3.28	3.15	3.71	3.25	3.27	2.34
Physical Pain	4.54	4.24	3.22	3.23	3.25	5.65	3.51	2.19
Inconvenience	3.88	4.27	2.61	2.17	2.67	1.98	2.53	1.35
Personal React.	4.30	3.69	1.54	2.76	1.92	1.28	1.31	1.17
Accessibility	1.64	4.36	1.44	1.75	3.56	1.31	1.43	1.15
Healthy	4.33	4.17	4.66	2.16	2.78	1.70	2.01	1.42
Forget	3.90	4.44	3.23	2.33	3.04	1.73	4.37	1.52
n	46 (4 %)	44 (4 %)	107 (10 %)	94 (10 %)	49 (5 %)	93 (11 %)	135 (13 %)	443 (43 %)
Description	Distrusting	Contrarian	Unnecessary	Reactions	Inaccessible	Pain Phobic	Forgetful	Accepting

Note: Personal React. = Personal Reactions. Response options for the vaccine hesitancy dimensions ranged from 1 (Strongly Disagree) to 7 (Strongly Agree).

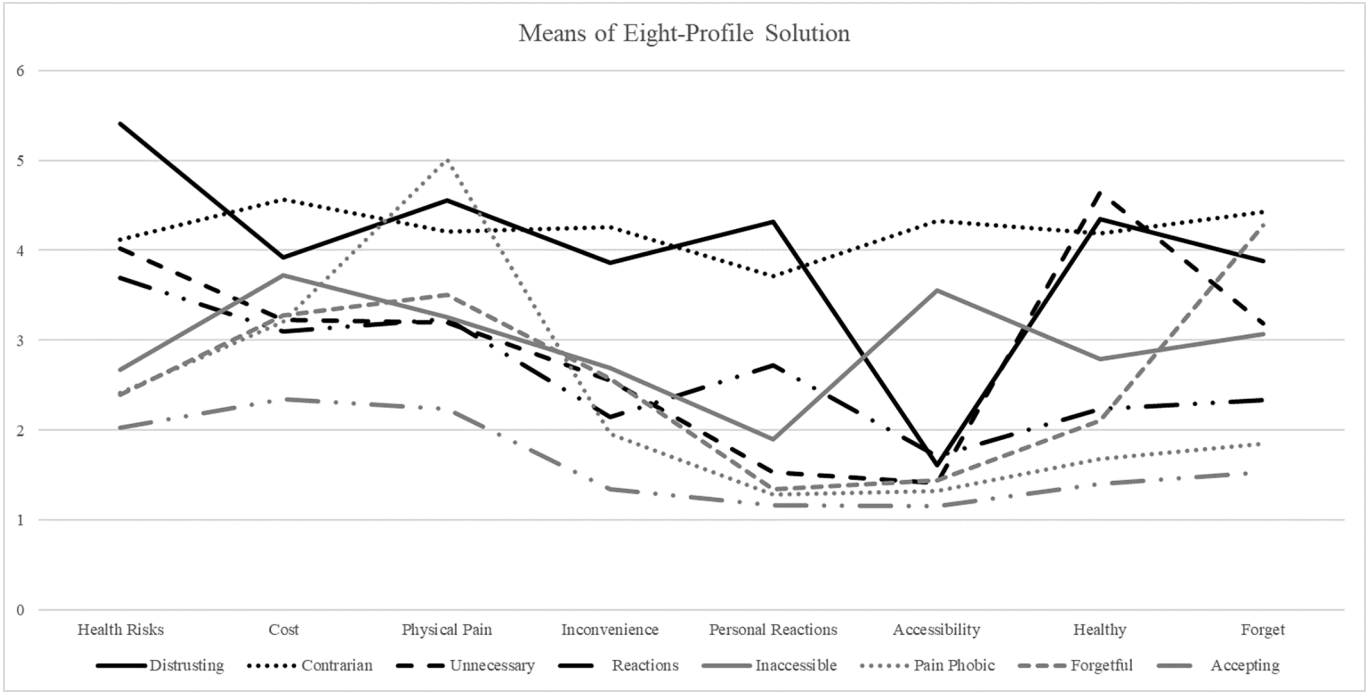

Fig. 1. Visual Representation of Profile Means.

mean for Forget. We label this profile, Forgetful. The eighth profile consisted of the lowest means for all dimensions. We label this profile, Accepting.

With the profiles identified, we then conducted one-way ANOVAs with post hoc tests to assess whether group membership is associated with differences in our outcomes (Table 4). The profiles produced relatively consistent gradients of means across the outcomes. The Distrusting profile produced the least favorable means towards vaccines for six of seven outcomes, including willingness (flu vaccine $\bar{x}$ = 1.92; COVID-19 vaccine $\bar{x}$ = 2.23), receipt (flu vac-

Table 4
Profiles with Outcome Means and Post Hoc Test Results.

	Profile 1	Profile 2	Profile 3	Profile 4	Profile 5	Profile 6	Profile 7	Profile 8
Flu Willingness	1.92[a]	3.99[b]	2.87[c]	4.14[b]	4.44[b]	4.28[b]	4.71[b]	5.25[d]
COVID Willingness	2.23[a]	4.00[bc]	3.18[ab]	4.67 [cd]	4.98[cde]	5.14[de]	5.50[ef]	5.80[f]
Flu Received	.02[a]	.25[abc]	.13[ab]	.28[bc]	.31[bc]	.23[b]	.25[b]	.44[c]
COVID Received[a]	.16[a]	.50[abc]	.43[ab]	.76[c]	.88[c]	.92[c]	.84[c]	.94[c]
Other Received	.49[a]	.59[ab]	.77[ac]	.82[bcd]	.74[acd]	0.92 [cd]	.81[bcd]	.94[d]
Neg. Word-of-Mouth[a]	3.35[ab]	3.93[a]	2.71[ac]	2.35[bcd]	1.83[cde]	1.64[de]	1.53[e]	1.39[e]
Pos. Word-of-Mouth[a]	1.93[a]	3.79[bc]	2.37[ab]	3.82[c]	4.69[c]	4.60[c]	4.33[c]	5.00[c]
Description	Distrusting	Contrarian	Unnecessary	Reactions	Inaccessible	Pain Phobic	Forgetful	Accepting

Note: One-way ANOVAs were significant at a 0.001 level for all outcomes (all p <.001). Means with the common superscript letters are not significantly different (p >.05), whereas those without common superscript letters are significantly different (p <.05). Sample sizes for analyses involving flu vaccine willingness, COVID-19 vaccine willingness, and received flu vaccine ranged between 958 and 959. The sample size for analyses involving other vaccines received was 816. The sample size for the outcomes of COVID-19 vaccine received, negative word-of-mouth, and positive word-of-mouth ranged between 402 and 403. Sample sizes differed because not all outcomes were measured with each of the original obtained samples.

[a] Measures of COVID-19 vaccination receipt, positive word-of-mouth, and negative word-of-mouth were only administered to participants obtained via MTurk (n = 455).

cine $\bar{x}$ = 0.02; COVID-19 vaccine $\bar{x}$ = 0.16; other vaccine $\bar{x}$ = 0.49), and positive word-of-mouth ($\bar{x}$ = 1.93). Members of the Distrusting profile were most resistant to vaccines.

Unnecessary produced slightly more favorable means than Distrusting for each outcome, and Contrarian produces slightly more favorable means than Unnecessary for five of seven outcomes. Contrarian's mean for negative word-of-mouth did counter this trend, as it was the highest mean of negative word-of-mouth for all the profiles ($\bar{x}$ = 3.93). Reactions produced slightly more favorable means than Contrarian for six of seven outcomes. Inaccessible, Pain Phobic, and Forgetful produced similar means for all outcomes, and these were typically more favorable than Reactions. Accepting produced the most favorable means across all outcomes, including willingness (flu vaccine $\bar{x}$ = 5.25; COVID-19 vaccine $\bar{x}$ = 5.80), receipt (flu vaccine $\bar{x}$ = 0.44; COVID-19 vaccine $\bar{x}$ = 0.94; other vaccine $\bar{x}$ = 0.94), and word-of-mouth (negative $\bar{x}$ = 1.39; positive $\bar{x}$ = 5.00). Accepting profile members are the most receptive to vaccines.

Together, the order of profiles from least to most favorable towards vaccination outcomes was: Distrusting < Unnecessary < C ontrarian < Reactions < Inaccessible, Pain Phobic, Forgetful < Accept ing. Readers should refer to Table 4 to determine which comparisons were statistically significant. These are not reported in the primary text due to space concerns.

We lastly assessed correlates of the profiles (Table 5). The profiles did not significantly differ across health insurance status, but they did differ across age, gender, location, and political ideology. Members of the Distrusting ($\bar{x}$ = 37.15) and Reactions profiles ($\bar{x}$ = 36.73) were somewhat older than the other profiles, whereas members of the Forgetful profile ($\bar{x}$ = 28.16) were somewhat younger. The Contrarian (36 % female) and Inaccessible profiles (29 % female) were more represented by men, and the Pain Phobic profile (68 % female) was more represented by women. Members of the Distrusting (63 %) and Reactions profiles (62 %) were more likely to be from Western English-speaking countries. The Distrusting ($\bar{x}$ = 4.30) profile was associated with a conservative political ideology; the Contrarian ($\bar{x}$ = 4.92), Unnecessary ($\bar{x}$ = 4.90), and Reactions ($\bar{x}$ = 5.36) profiles were associated with a moderate political ideology; and the Inaccessible ($\bar{x}$ = 5.95), Pain Phobic ($\bar{x}$ = 6.57), Forgetful ($\bar{x}$ = 6.14), and Accepting ($\bar{x}$ = 6.34) profiles were associated with a liberal political ideology. While large differences were not observed for most correlates, a gradient across the profiles was seen for political ideology.

4. Discussion

Our goals were to identify participant subgroups with the MVHS's dimensions and to assess relations of these subgroups with relevant outcomes and correlates. An LPA identified eight subgroups that we labeled: Distrusting, Contrarian, Unnecessary, Reactions, Inaccessible, Pain Phobic, Forgetful, and Accepting. These profiles were each characterized by their participants' unique standings on the dimensions, indicating that more than valence alone defines subpopulations of participants when studying the MVHS via person-centered analyses. When paired with the finding that a sizable number of participants were assigned to each profile, our results provide significant support that interpreting all eight profiles is warranted.

Distrusting was characterized by elevated levels of almost all dimensions, but a particularly elevated mean for Health Risks. Contrarian was distinguished by its high means for all dimensions, including the highest for four of eight dimensions. Unnecessary was demarcated by moderate levels of all dimensions except Health Risks and Healthy, which it had the highest mean for the

Table 5
Profiles with Correlate Means and Post Hoc Test Results.

	Profile 1	Profile 2	Profile 3	Profile 4	Profile 5	Profile 6	Profile 7	Profile 8
Age	37.15[a]	31.25[ab]	31.74[ab]	36.73[a]	33.00[ab]	31.58[ab]	28.16[b]	33.15[a]
Gender	.52[ab]	.36[a]	.44[a]	.52[ab]	.29[a]	.68[b]	.49[ab]	.41[a]
Location	.63[a]	.43[a]	.56[a]	.62[a]	.43[a]	.43[a]	.46[a]	.53[a]
Health Insurance	.65[a]	.66[a]	.75[a]	.76[a]	.63[a]	.72[a]	.77[a]	.80[a]
Political Ideology	4.30[a]	4.92[ab]	4.90[a]	5.36[ab]	5.95[bc]	6.57[c]	6.14[c]	6.34[c]
Description	Distrusting	Contrarian	Unnecessary	Reactions	Inaccessible	Pain Phobic	Forgetful	Accepting

Note: One-way ANOVAs were significant at a 0.001 level for the correlates of age, gender, and political ideology (all p <.001). A one-way ANOVA for the correlates of location was significant at a 0.05 level (p =.045). A one-way ANOVA for the correlates of health insurance was not significant (p =.11). Means with the common superscript letters are not significantly different (p >.05), whereas those without common superscript letters are significantly different (p <.05). Sample sizes for analyses involving correlates ranged from 998 to 1,010. Sample sizes did not greatly differ because all correlates were measured with each of the original obtained samples.

latter. Reactions was characterized by moderate overall means but elevated levels of Health Risks and Personal Reactions. Similarly, Inaccessible was distinguished by moderate levels of most dimensions, but it had higher means for Cost and Accessibility. Pain Phobia had low means for all dimensions except Physical Pain, and Forgetful similarly had low means for all dimensions except Forget. The final profile, Accepting, was demarcated by low means for all dimensions. Participants assigned to these profiles clearly and meaningfully differed across the dimensions, and the nature of their vaccine hesitancy should therefore be interpreted based on profiles rather than broad generalizations intended to describe all participants.

These profiles also produced a gradient of relations with vaccination outcomes. The order from least to most favorable relations with outcomes was: Distrusting < Unnecessary < Contrarian < Reactions < Inaccessible, Pain Phobic, Forgetful < Accepting. Variations in outcomes from the least to most favorable profiles were also large. For example, the COVID-19 vaccination rate of the Distrusting profile was 16 %, whereas the vaccination rate of the Accepting profile was 94 %. Some differences were evident regarding the profiles' correlates, indicating that some are more representative of certain types of people than others. Perhaps most notably, political ideology also demonstrated a gradient across the profiles. Distrusting was associated with a conservative ideology; Contrarian, Unnecessary, and Reactions were associated with a moderate ideology; and Inaccessible, Pain Phobic, Forgetful, and Accepting were associated with liberal ideologies. These results further support the utility of the person-centered approach and the merits of interpreting all eight profiles. Not only could participants be assigned to distinct profiles defined by the vaccine hesitancy dimensions, but important outcomes and correlates were systematically associated with these profiles. These results suggest that people are better understood by investigating the dynamics of their representative profile rather than proposing broad generalizations, which provides many implications for research and practice.

4.1. Theoretical implications and future research directions

4.1.1. Profile considerations

Our study supported that the finer-grained approach of the person-centered approach is warranted in the study of vaccine hesitancy. Meaningful subgroups defined by their standing on vaccine hesitancy dimensions were observed in our sample, indicating that meaningful subpopulations likewise exist in the population. These subgroups were also shown to have different mean levels of various outcomes and correlates, and it is likely that other dynamics likewise differ across these groups (e.g., relations of dimensions, outcomes, and correlates). Traditional variable-centered approaches largely overlook the heterogeneity of populations produced by these subpopulations; however, the person-centered approach can model the nature of this heterogeneity and determine whether emergent patterns relate to important outcomes. Therefore, the person-centered approach may be key to understanding vaccine hesitancy.

Further, our person-centered findings suggest limitations on prior generalizations. That is, researchers of vaccine hesitancy often assume that their findings generalize to the general population, but multiple subpopulations should instead be recognized within the general population. Prior findings may only generalize to certain subpopulations, and future research should test which subpopulations most closely relate to prior findings utilizing general samples. Future research should also perform focused investigations into individual subpopulations, understanding that global insights may not be possible and narrower insights into specific subpopulations may be more appropriate. It may be particularly beneficial to investigate subpopulations with the most detrimental vaccination outcomes, such as Distrusting and Unnecessary, to determine whether prior insights may be particularly misleading for them. Novel theoretical perspectives may be necessary to understand members of these subpopulations and how to improve outcomes for these members, and we provide direct recommendations for relevant theoretical perspectives when detailing our implications and future directions below, such as the use of phobia theories to understand members of the Pain Phobic profile and the application of the procrastination perspectives to study the Inaccessible and Forgetful profiles.

Additionally, our investigation resolves tensions in the current literature. Prior studies have utilized person-centered designs to investigate individual constructs and multidimensional models. Many of these studies have produced profiles that are differentiated by the valance of responses alone, which provides modest benefits beyond variable-centered analyses [36,61,70]. Other studies have investigated multiple constructs not a part of a unifying framework [98,104,114]. While these studies have produced profiles defined by more than valence, it is difficult to holistically interpret their results due to different constructs being included from study-to-study. Identifying our eight-profile model provides substantial contributions because these profiles represent unique subsets of participants defined by more than valence, and each dimension is included within a well-supported framework. Future researchers should replicate the current results to assess the robustness of our identified profiles, which can provide assurances that these subpopulations – and, in turn, the MVHS – are key to understanding vaccine hesitancy.

Our study identified both dimensions that distinguished multiple profiles and dimensions that strongly distinguish a single profile. Regarding the former, research on the MVHS dimensions has identified Health Risks and Healthy as strongest predictors of vaccination outcomes [50,51,53], and these dimensions distinguished multiple profiles in our study. It is even more so noteworthy, therefore, that the profiles distinguished by Health Risks and Healthy were also those most associated with detrimental vaccination outcomes. Future research should perform more focused analyses of these two dimensions, including the application of relevant theory. We suggest that the approach-avoidance framework may be particularly apt [20,37,38]. This framework suggests that separate cognitive systems are associated with the approach towards positive stimuli and the avoidance of negative stimuli, which emerges in traits, states, perceptions, and behaviors. Health Risks may be associated with a heighted avoidance orientation, as it involves avoiding perceived negative outcomes of vaccination; whereas Healthy may be associated with a reduced approach orientation, as it involves overlooking the positive outcomes of vaccination. Such integrations could explain why these two dimensions and their associated profiles consistently, strongly, and detrimentally relate to vaccination outcomes.

These two dimensions can also link the present conceptualization of vaccine hesitancy with other theories, frameworks, and models. Several "C" models of vaccination antecedents have been developed, including the 3C, 5C, and 7C models [42,43,74,99]. Each of these models build upon the prior version. The original 3C model (and the subsequent two) includes the categories of confidence, complacency, and convenience [43,99]. Confidence references to perceptions about the efficacy and safety of vaccines and the systems that recommend and deliver them. While the former too broad to be the exact opposite of Health Risks, it does share strong similarities with the vaccine hesitancy subdimension. Complacency refers to perceptions about the low risks of vaccine-preventable diseases, which is a near synonym of Healthy. Lastly, convenience refers to perceived easy of access and ability to understand vaccination [42,43,74,99], which partially overlaps with Inconvenience and Access.

The MVHS includes several dimensions that are not included in the 3C, 5C, and 7C models, and the 5C and 7C models likewise include dimensions that are not included in the MVHS, such as calculation, collective response, and conspiracy [74,99]. Nevertheless, the overlap of features between the MVHS and the 3C model suggests that prior approaches and theoretical lenses to understand the 3C, 5C, and 7C models may be particularly apt for investigating the MVHS. Any prior study utilizing the 3C, 5C, and 7C models should be reinvestigated utilizing the MVHS to assess potential differing relations with antecedents, outcomes, and moderating effects. The MVHS may capture more variance in outcomes, enabling researchers to better understand what ultimately results in vaccination decisions. This may also be the reason that the MVHS's dimensions but not the 7C constructs produced profiles that were defined by more than valence alone. Furthermore, an array of theories have been used with the 3C, 5C, and 7C models, which can be used to identify further relations of the MVHS. For instance, authors have used both the health belief model and theory of planned behavior to propose relations of these models' dimensions [8,49]. These theories should be generalized to propose similar relations for the MVHS, widening the theorical scope surrounding this conceptualization of vaccine hesitancy.

The dimensions of Personal Reactions, Cost, Accessibility, Physical Pain, and Forget also distinguished individual profiles. While prior research has not supported that these dimensions are strong predictors of vaccination outcomes when studied via the variable-centered approach with general samples [50,51,53], our results suggest that these dimensions may be particularly important for certain people. Future research should perform focused analyses on each of these dimensions for the subpopulations that they distinguish. For example, it may be necessary to apply theories associated with phobias to understand vaccination decisions for members of the Pain Phobic profile (distinguished by Physical Pain). Theories such as nonassociative theory [23,75] and fear module theory [23,78] could be used to understand how these phobias develop, but they could also be used to discover how these phobias impact the performance of relevant behaviors such as vaccination. Phobia theories differ regarding whether and which cognitive and affective mechanisms are involved in responses to fear-invoking stimuli, which could be applied to uncover whether these mechanisms are indeed involved with the decision to vaccinate for those of the Pain Phobic subpopulation. While only one example avenue, these proposals nevertheless demonstrate that even a single profile discovered in the current study should lead to rich directions for future research.

It should also be highlighted that unique co-occurrences of vaccine hesitancy dimensions occurred across the profiles. The means of Health Risks and Healthy varied similarly across the profiles. In unreported analyses, these two dimensions also produced the second largest inter-correlation. Their significant association may be due to their relevance to misinformation. That is, speculation that vaccines are dangerous and not needed for healthy individuals are among the most commonly shared misinformation about vaccines [52,53,107], and people who have one belief may often also have the other because they are regularly jointly exposed to this information. Further, Inconvenience and Forget also had similar variations across the profiles, and they produced the strongest inter-correlation. Those who delay receiving vaccines because they perceive them as inconvenient may also regularly be those who ultimately forget to receive vaccines – a behavioral cycle that can be seen in research on procrastination [40,115]. These co-occurrences highlight the need for future longitudinal research on the development of vaccine hesitancy. The association of dimensions arise from common predictors, which may also cause them to jointly distinguish multiple profiles; however, it is still presently unclear exactly how these profiles develop over time, and how people may transition between profiles. Future research should apply latent transition analysis to investigate this question, which can model participants' longitudinal changes between profiles – perhaps ultimately identifying what causes co-occurrences and transitions [24,65,66].

4.1.2. Outcome and correlate considerations

The importance of studying vaccine word-of-mouth should be highlighted. Most studies on vaccine hesitancy only investigate its relation with vaccination willingness and receipt [3,30,73,91]. While these two are the primary personal outcomes of vaccine hesitancy, word-of-mouth influences more than just the actor. Instead, it influences whether multiple people become vaccinated. For this reason, future research should continue to assess the relation of vaccine hesitancy with this outcome, and studies should test whether certain antecedents predict vaccination willingness and receipt but not word-of-mouth (and vice versa). It should not be assumed that predictors of the former necessarily relate to the latter and predictors of the latter necessarily relate to the former.

While all differences among the profiles regarding their correlates could lead to important future research directions, political ideology produces perhaps the clearest gradient across the profiles. It is often assumed that political ideology causes vaccine hesitancy, but no studies have utilized robust research design to test this casual effect. Political ideology and vaccine hesitancy may instead be common outcomes of a separate antecedent, causing them to appear related with more common research designs. Similarly, the current article only investigated political ideology as done in ample prior research, but authors have called for research to study political ideology and political party affiliation together [25,28]. These authors have observed that the two, while closely related, can differently relate to outcomes. Some profiles may be associated with political ideology but not party affiliation (and vice versa), which could provide insights into how political dynamics are intertwined with vaccination.

More specifically, many justifications have been used to propose a relation between political orientation and vaccine hesitancy. Those with a conservative ideology typically score higher on measures of intuitive (rather than analytic) thinking style and cognitive rigidity [6,58,59]. These inherent individual differences may cause conservatives to be naturally hesitant towards vaccines, as thoughtful deliberation and mental flexibility about the benefits of vaccines may be necessary to develop a willingness to receive them. Likewise, various theories suggest that people have inherent differences in their valued morals and civil liberties, such as moral foundations theory [22,26,46], which have been suggested to be causes of political orientation and vaccine hesitancy. For instance, particularly valuing sanctity, liberty, and autonomy may relate to both greater conservative beliefs and vaccine hesitancy. If these mechanisms are valid justification, then political ideology may have a stronger relation with vaccine hesitancy than party affiliation, as the determining mechanism is inherently tied to individual differences associated with political ideology rather than social interactions with parties.

Alternatively, researchers have also suggested and supported that members of conservative political parties are more likely to both share and receive vaccine misinformation and conspiracy theories [76,110]. While those who initially engage with these political parties may not have strong feelings regarding vaccinations, these perceptions may develop and strengthen over time due to the information reinforced by members. In turn, this may cause those otherwise indifferent to vaccines to be particularly resistant. If the case, then party affiliation may have a stronger association with vaccine hesitancy than political orientation due to the importance of theses social ties, and conservatives may develop their

vaccine hesitancy over time after repeated interactions with other conservatives.

Certain justifications, however, relate to both ideology and affinition. For instance, conservatives are more likely to distrust scientists, which is likely to produce greater hesitancy towards vaccines; however, it is unclear whether this distrust is due to their individual differences or perceptions developed over time [6,48,77]. Understanding these relations can lead to more nuanced theory surrounding political orientation and vaccine hesitancy. It can both suggest whether theories more closely associated with ideology or affiliation should be applied, but it can also provide insights into the temporal development of vaccine hesitancy – whether caused by individual differences or social connections. This deeper understanding can lead to the creation of more effective interventions, as for example, researchers could understand the critical moments to prevent the development of vaccine hesitancy – ultimately resulting in greater vaccine uptake.

A benefit of the current study is the inclusion of participants from many different countries. While no findings can be guaranteed to broadly generalize (discussed below), our methodology does provide more assurances that our results identified profiles that emerge across cultures than studies utilizing fewer countries. It should also be highlighted that no profile was exclusively (un) observed in Western English-speaking countries, as the location of members within each profile ranged from 43 % to 63 % in Western English-speaking countries. Future researchers should investigate, however, the two profiles that were slightly more likely to be observed with participants from Western English-speaking countries, Distrusting and Reactions. Vaccine misinformation may be more widespread in Western English-speaking countries; likewise, popularly shared misinformation differs across countries, and vaccine misinformation in Western English-speaking countries may be particularly potent [14,83,93]. Both possibilities would cause more people from these countries to fall into the Distrusting profile, as the representative people may develop stronger beliefs about the greater risks and fewer benefits of vaccines. Vaccine misinformation may similarly cause people to believe that they are more likely to have allergic reactions to vaccines, which would again cause more people from Western English-speaking countries to be represented in the Reactions profile. The spread of misinformation should be monitored in other countries, and it should be assessed whether membership of the Distrusting and Reactions profiles grow within countries if misinformation becomes more prolific. If the cause, then robust quasi-experimental evidence could be provided that the membership of two particularly important vaccine hesitancy profiles is, at least in part, determined by vaccine misinformation [18].

4.1.3. Methodological considerations

Our profiles were obtained from a merged dataset of three general samples. Future research should investigate whether different profiles emerge when studying certain types of samples. For instance, samples representing individuals from specific countries may produce different profiles, as vaccine hesitancy is known to differ across countries [27,33,68,97,103]. Future research should replicate the current results using samples taken from specific populations, as doing so can lead to more specific insights and interventions that are more effective for those countries of interest.

Our LPA was conducted with recommended practices. Subsequent ANOVAs and post hoc tests are typical to assess profile differences, and these analyses can provide accurate inferences with variables of the present nature – including dichotomous outcomes [44]. Future researchers should investigate the person-centered dynamics of LPA using other approaches and analyses. We discussed latent transition analysis above, but researchers should also consider the use of multilevel LPA and experimental designs with LPA to study vaccine hesitancy. Countries and even regions within countries (e.g., states) had very different policies during the COVID-19 pandemic, often closely tied to the ideology of the political party in power [4,19]. These policies had a strong influence on both vaccination and other preventive behaviors, but they also shaped people's perceptions about vaccines [100]. Given the importance of higher-level influences on individual-level behaviors and perceptions, a necessary next step may be to assess the effect of regional policy on vaccine hesitancy profile membership via multilevel LPA.

Likewise, a primary goal of research on vaccine hesitancy is to determine how to shift perceptions to be more favorable [31,55], and a growing literature has investigated the use of experimental designs with LPA [11,95]. That is, researchers have sought best approaches to develop and test interventions to move participants among profiles. The study of vaccine hesitancy is apt for this approach. Researchers could test whether those in more resistant profiles (e.g., Distrusting) can be moved to other profiles. If so, they could also test whether they could immediately be moved to the most accepting profiles (e.g., Accepting) or whether they would need to be moved to more intermediate profiles (e.g., Personal Reactions and Accessibility). Therefore, while the present application of LPA is a significant advancement, many more advancements should be made regarding the application of person-centered analyses to study vaccine hesitancy.

4.2. Practical implications and future applied directions

Our results provide insights into which subpopulations may benefit the most from public health interventions. The profiles with the most room for improvement was Distrusting. While these individuals may be resistant to messaging regarding vaccines, they are certainly the ones who could benefit the most. It may be potentially more fruitful, however, to target members of the Unnecessary profile. These members had markedly low flu and COVID-19 vaccination rates, but they had moderate rates for other vaccinations. Their behaviors may be due to a general lack of knowledge rather than distrust or moral conviction, and messaging to these individuals regarding the health benefits of these vaccines may be particularly effective.

The Reactions, Inaccessible, and Forgetful profiles had moderate outcome means, indicating that effective interventions could still have notable outcomes. Future interventions should target the distinguishing dimensions for members of these profiles, resulting in concise and effective programs. While members of the Pain Phobic profile had high rates of COVID-19 and other vaccination, they had low levels of flu vaccination. Members of the Pain Phobic category may be reluctant to receive a yearly vaccination, but they may be willing to receive more infrequent vaccinations that prevents more serious outcomes. To increase vaccination rates with these individuals, it may be important to stress the health benefits of flu vaccines, such that the benefits of routinely receiving the vaccine outweighs the detriments of physical pain.

Our results can also lead to the creation of adaptive interventions, in which components are provided based on the characteristics of the person [60,82]. Practitioners can categorize people into our identified subpopulations, and components could be provided to people based on their categorization. A person categorized in the Forgetful profile, for example, could be given periodic reminders to get vaccinated, whereas a person categorized in the Inaccessible profile could be provided information regarding where to receive vaccines. By doing so, the interventions could be less cumbersome, because each person would not need to undergo all possible intervention components – only those relevant to their profile. Adaptive interventions are often more effective than traditional interven-

tions, and the current results could therefore be utilized to improve vaccination rates [60,82].

4.3. Limitations

A strength of the current article is the use of multiple datasets obtained via different sampling sources. This approach enabled our study to obtain a wide range of participants, representing multiple countries, age ranges, political orientations, and other attributes. It could be questioned, however, whether the use of multiple datasets altered our results. For this reason, we provide a series of analyses in Supplemental Material C. We show that many outcomes and correlates did, in fact, differ across the three datasets. We also report a series of ANCOVAs reassessing our primary analyses – differences among profiles regarding the outcomes and correlates – while controlling for the participants' representative dataset. All interpretations were consistent between our primary analyses and these supplemental analyses, strongly supporting the robustness of our findings. While the outcomes and correlates differed across the datasets, these differences did not meaningfully impact the interpretation of our results.

Our dataset was representative of participants from many different countries, which is fully detailed in Supplemental Material A. The representativeness of our dataset enabled the current study to assess the percentage of participants from Western English-speaking countries assigned to each profile. While the diversity within our dataset is a strength of the present work, future researchers should replicate the current results within their specific subpopulations of interest, as the current results cannot be assumed to generalize to all contexts. Researchers should assess whether the present results replicate when retested with samples representative of specific countries as well as racial/ethic groups within those countries. By doing so, researchers could identify potential boundaries of extant theory, and they could develop more effective interventions that are guided by the results obtained for those subpopulations.

Online services were also utilized to recruit our participants. While modern best-practice recommendations were used in collecting the present data [2,71,81], future researchers should replicate the current results using differing sampling criterion and approaches. Notably, participants must have been fluent in the English language to participate in the current studies, and the current results should be replicated with samples fluent in other languages to assess the generalizability of our findings.

We applied Howard's [52,50–51] vaccine hesitancy scale due to prior psychometric and validity support, and it also has greater content coverage than other scales. Nevertheless, many other conceptualizations and operationalizations of vaccine hesitancy exist, and researchers should reinvestigate the current findings with alternative measures. Vaccine hesitancy is often believed to have close associations with morals or civil liberties, as some people believe that vaccines infringe upon their sanctity, liberty, and autonomy. Howard's [52,50–51] scale does not include dimensions that directly relate to morals or civil liberties. While research has supported that Health Risks and Healthy are related to constructs associated with morals, such as the Dark Triad [51], researchers should identify measures that capture aspects of vaccine hesitancy associated with morals or civil liberties to more directly investigate these dynamics.

Similarly, many definitions for vaccine hesitancy are prevalent in the current literature [16]. The MVHS includes items reflecting cognition and affect, but some definitions consider vaccine hesitancy to solely be indecision in the vaccination decision making process. If future research solely adopts this definition, the current article still provides meaningful results, as cognition and affect is a primary and immediate antecedent to indecision. At the same time, researchers would need to reconsider how the present study and many other studies using similar measures fit into the vaccination decision making process. For this reason, a fruitful direction for future research may be to *meta*-analytically assess whether measures for vaccine hesitancy systematically produce differing relations with antecedents and outcomes, and whether these differences can be explained by variations in their operational definitions.

5. Conclusion

Our study utilized the MVHS to identify eight profiles of vaccine hesitancy, and it showed that these profiles differently relate to both outcomes and correlates. A strength of the present article is the variation of tested outcomes, both in the type (e.g., willingness, receipt, and word-of-mouth) and target vaccination (e.g., COVID-19, flu, and other). Future research can utilize these results to investigate new research directions, such as the application of novel theory. Future practice can develop targeted or adaptive interventions that address distinguishing dimensions for members of certain profiles, potentially resulting in greater vaccination rates. The current study may thus be the first of many person-centered investigations into the MVHS.

Data availability

Data will be made available on request.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2023.06.057.

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