Race, ethnicity and COVID-19 vaccine concerns: A latent class analysis of data during early phase of vaccination

Jen-Hao Chen [a,*], Cheng-Shi Shiu [b]

[a] Department of Sociology and Department of Psychology, National Chengchi University, Taiwan
[b] Department of Social Work, National Taiwan University, Taiwan

ARTICLE INFO

ABSTRACT

Racial gaps in vaccine uptake in the United States have been widely reported. Existing studies, however, have not explored how individuals' concerns about COVID-19 vaccines are clustered. In this study, racial and ethnic background is linked to constellations of COVID-19 vaccine concerns during the early phase of vaccines in the United States, using the Household Pulse Survey (N = 60,492). Latent class analysis reveals five distinct classes of vaccine concerns: general skepticism, distrust of science and the government, safety, a desire to wait and see, and vague uncertainty. Compared to Whites, people of color more consistently report vaccine hesitancy due to safety and a desire to wait and see, rather than distrust of science and the government. Whites, however, more consistently report general skepticism and distrust of science and the government. Our findings suggest that distrust of science and government is not central to racial minorities' vaccine hesitancy, but it is so for Whites.

1. Introduction

Society-wide uptake of the COVID-19 vaccine is critical for ending the pandemic and resuming normal economic and social activities in the United States. However, racial and ethnic disparities in vaccine uptake have been reported since vaccination began, with Blacks and Hispanics having lower vaccination coverage than Whites (Kaiser Family Foundation, 2021). At the same time, disadvantaged racial and ethnic communities have been hit the hardest by the COVID-19 pandemic, with higher incidence rates (Holtgrave et al., 2020; Kim & Bostwick, 2020; Tai et al., 2021), higher fatality rates (Millett et al., 2020), and poorer prognosis (Holtgrave et al., 2020). As such, addressing the racial gap in vaccine uptake is of paramount importance. Indeed, efforts have been made to improve vaccine access among racial minorities and individuals in disadvantaged and marginalized communities (Centers for Disease Control and Prevention, 2021b). In addition to issues of vaccine access, efforts to increase vaccine uptake need to consider concerns that lead to vaccine hesitancy, and how those concerns differ by race and ethnicity.

Much of the earlier discourse related to racial disparities and the COVID-19 vaccine is limited in two aspects. First, most of the studies simply treat race and ethnicity as a predictor in statistical models without explaining why race and ethnicity, as a social construct, influences vaccine concerns. These studies often lack a clear conceptual framework that explains how racial and ethnic backgrounds are linked to vaccine concerns. Second, individuals' views toward the COVID-19 vaccine are often complex and made up of a related set of concerns, rather than a single concern. However, extant studies either focus on a single concern, e.g., trust in the government or concern about side effects, or analyze multiple concerns but treat each one independently (e. g., Nguyen et al., 2021; Park et al., 2021). A better understanding of COVID-19 vaccine hesitancy will likely come from investigating multiple vaccine concerns and uncovering how they cluster together. In this study, we outline an alternative approach to studying COVID-19 vaccine concerns, with careful attention to the variation by race and ethnicity.

1.1. A constellation approach to vaccine concerns

Vaccine concerns can be defined as the collective patterns of attitudes and beliefs toward a vaccine among individuals who refuse vaccination. Vaccine concerns reflect the meanings and reasonings individuals attribute to their vaccination decision; as such, they are important for understanding vaccine hesitancy (Salmon et al., 2015). Informed by the long history of social science research that demonstrates individuals' health-related attitudes, beliefs, and lifestyles are deeply shaped by their structural positions in society (Cockerham, 2005; Pampel et al., 2010), we similarly posit that COVID-19 vaccine concerns

---

* Corresponding author.
  E-mail address: jenhao@nccu.edu.tw (J.-H. Chen).

do not arise in a vacuum and are instead socially and structurally patterned.

Furthermore, prior studies of health beliefs suggest that it is rare for individuals to only have one belief or concern—instead individuals more often have multiple concerns that correlate with each other, resulting in distinct clusters (e.g., Bardenheier et al., 2020; Burdette et al., 2017; Mollborn et al., 2014). Beliefs and concerns may cluster by subgroup because individuals experience similar structural conditions that lead to developing similar patterns of concern. For example, individuals with unstable employment or employment that offers no remote work option may be more concerned about vaccine side effects and taking time off work for that illness, so they are then more likely to also develop a "wait and see" belief. Given that public health interventions are often targeted to distinct communities or subgroups, a more person-centered understanding of how vaccine concerns cluster differently across subpopulations could improve such interventions.

The prior studies of health beliefs and vaccine concerns leads toHypothesis 1: *Multiple clusters (i.e., constellations) of vaccine concerns will be identified.*

1.2. Race/ethnicity and constellations of COVID-19 vaccine concerns

We propose that constellations of vaccine concerns will differ by individuals' racial and ethnic background for strong reasons. In the United States, race is a fundamental factor affecting life experiences and health (Laster, 2020; Phelan & Link, 2015; Williams & Collins, 2001). Structural racism shapes the everyday life experiences of people of color, particularly Blacks and Hispanics. In particular, the structural advantages and disadvantages of different racial and ethnic groups may help shape two broad domains of vaccine concern: (1) assessments of the social costs of the COVID-19 vaccine and (2) trust of the healthcare system and the vaccines.

First, racial and ethnic groups may have different experiences that influence their assessments of the costs and benefits of receiving a vaccine. It is well-documented that the risks and consequences of COVID-19 infection vary substantially by race and ethnicity, with much evidence that Black and Hispanic communities have been hit harder by COVID-19 than White communities (Holtgrave et al., 2020; Kim & Bostwick, 2020; Tai et al., 2021). Given that people of color are at a higher risk, it follows that they may therefore be more likely than Whites to express the need for a vaccine, and less likely to express 'unneeded' as a reason for refusing the COVID-19 vaccine. At the same time, racial minorities' structural disadvantages may create psychosocial barriers to actually receiving the COVID-19 vaccination. First and foremost, predominately Black and Hispanic communities often do not have enough healthcare providers and are considered to be medically underserved areas (Gaskin et al., 2012; Qato et al., 2014). Such a shortage of healthcare resources makes it more difficult to access COVID-19 vaccination. Compared to Whites in better-resourced communities, racial minorities may need to travel a longer distance, spend extra time, and navigate an unfamiliar area to obtain a COVID-19 vaccine—especially during the early phase of vaccination when there were fewer vaccine sites available.

Furthermore, the side effects of the COVID-19 vaccination are not negligible and may be a greater concern for racial minorities. Even though severe allergic reactions are rare, side effects are commonly reported including tiredness, headache, and fever (U.S. Centers for Disease Control and Prevention, 2021). Importantly, these side effects can generate additional social costs disproportionately for racial minorities. For example, people of color are more likely to work in public-facing, service sector jobs that do not offer paid sick leave or have the option for remote work. As such, racial minorities may find the COVID-19 vaccine more intolerable because it could disrupt their work and family responsibilities. This reasoning aligns with prior research that finds that disadvantaged populations are less likely than others to feel empowered and in control of their lives (Mirowsky & Ross, 2003), in this

case because they have fewer resources and options to manage the side effects of vaccination.

In fact, several qualitative studies have revealed heightened concerns in Black communities about the side effects of vaccination, especially in the early phase when the vaccines had not been fully approved by Food and Drug Administration (Bogart et al., 2021; Momplaisir et al., 2021). There is also some suggestive evidence that greater concern about the vaccine's side effects have led to a higher likelihood of a "wait and see" belief in Black and Hispanic communities (Head et al., 2020; Nguyen et al., 2021). Taken together, this discussion of the structural disadvantages of racial minorities and prior research leads to Hypothesis 2: *Black and Hispanic individuals will be more likely to have constellations of vaccine concerns characterized by 'side effects' and 'wanting to wait and see'.*

Whites and Asian Americans, however, do not face the same structural disadvantages as Blacks and Hispanics. Both groups have a relatively higher socioeconomic position, being more likely to hold STEM-related professional jobs and less likely to fall into poverty (Akee et al., 2019; Landivar, 2013; Shrider et al., 2021). As such, Whites and Asian Americans have more resources to manage the potential side effects of the COVID-19 vaccine. This discussion leads to Hypothesis 3: *Whites and Asian Americans will be less likely to have constellations of vaccine concerns characterized by 'side effects' and 'wanting to wait and see'.*

Next, we consider the issue of trust, which is an important domain in the literature on vaccine hesitancy. Studies of trust in vaccines conceptualize it as multilevel, involving trust in the institutions and government as well as in the scientific development and production of the vaccine (Freimuth et al., 2017; Latkin, Dayton, Yi, Colon, & Kong, 2021, 2021b). In this study, we posit that structural racism and the disadvantaged position of people of color in society will influence their trust of the COVID-19 vaccine on different levels. First, due to institutionalized and structural racism, racial and ethnic minorities generally report a poorer experience when interacting with the medical system and the government (Cuevas et al., 2016; Feagin & Bennefield, 2014; Williams & Williams-Morris, 2000). These negative experiences may lead to distrust of the medical system and lower levels of medical adherence (Greer et al., 2014). Furthermore, the dark history of slavery in the U.S. and memories of the infamous Tuskegee study considerably shape the attitudes of individuals in Black communities, including lower confidence in and heightened distrust of the healthcare system and the government (Brandon et al., 2005; Freimuth et al., 2001, 2017).

Beyond institutionalized and structural racism, distrust can be more directly about the vaccine itself. The development of the COVID-19 vaccines is historically unprecedented. Traditional vaccine development often takes more than ten years from the initial stage to the clinical trials (Andre et al., 2008; Greenwood, 2014). The development of vaccines is prolonged and time-consuming because careful study and monitoring are necessary to ensure safe deployment (Li et al., 2021). However, facing a global public health emergency, both pharmaceutical companies and the governments agreed to speed up the process. In the U.S. for example, multiple COVID-19 vaccine candidates entered clinical trials less than six months after the outbreak and were conditionally approved for emergency use in ten months, a record-breaking speed in vaccine development history (FDA, 2021). Because the COVID-19 vaccines were developed relatively quickly, concerns about insufficient studies and rushed development may generate distrust, even though the FDA insists that safety standards for approval were consistent with previous approved vaccines. There is some evidence that minorities show a higher level of distrust toward vaccines in development because they are less likely to enroll in clinical trials (Murthy et al., 2004) than Whites. Some scant, initial survey evidence suggests this type of distrust is operating with respect to the COVID-19 vaccine, finding that Blacks have less trust of the vaccine and are more likely to say they want to wait for additional evidence before getting vaccinated (Kaiser Family Foundation, 2021). This discussion leads to Hypothesis 4: *Disadvantaged racial and ethnic minorities (i.e., Blacks and Hispanics) will be more likely than Whites and Asian Americans to have clusters of vaccine concerns that*

are characterized by a high level of distrust.

2. Methods

2.1. Data: Household Pulse Survey

The Household Pulse Survey (HPS) is a nationwide, repeated cross-sectional, online survey administered by the U.S. Census Bureau that aims to understand the experiences of individuals during the COVID-19 pandemic starting from late April 2020. The survey was conducted weekly through July 2020 and bi-weekly thereafter. Adult respondents were randomly selected from the U.S. Census Bureau's Master Address File and were contacted by email and text message if both were available, by email if no cellphone number was available, and by text if no email was available. The list of contact email addresses and cellphone numbers in the U.S. Census Bureau's Master Address File were randomly selected until exhausted. Both the email and cellphone text message contained a link to the survey questionnaire; the survey takes approximately 20 min to complete. For each wave of data collection, the U.S. Census Bureau sought to complete 93,500 surveys, but the actual number completed varied slightly from wave to wave. Due to the COVID-19 pandemic and mode of data collection, responses rates were under 10% (Fields, 2021; U.S. Census Bureau, 2021). Despite being an online repeated cross-sectional survey and having relatively low response rates, the HPS remains one of the best publicly available U.S.

national datasets that allows for an in-depth analysis of this study's research questions. Questions about the COVID-19 vaccine were added to the 22nd wave of the survey (i.e., the period from January 6–18, 2021). Many important studies have relied on the HPS data to understand vaccine coverage and vaccine hesitancy in the United States (e.g., Do & Frank, 2022; Hsieh et al., 2022; Nguyen et al., 2021; Tram et al., 2021).

This study focuses on the early phase of vaccination and uses six waves of data collected from January 6 to March 29, 2021. Because the focus of this study is on racial and ethnic disparities in COVID-19 vaccine hesitancy, we excluded respondents from the study who had already received the COVID-19 vaccine or who said they will "definitely" or "probably" get it when it is available. The final analytic sample includes 60,492 adults (aged 18 or over). Table 1 shows the social and demographic characteristics of respondents in the sample.

2.2. Classification of race and ethnicity

The Household Pulse Survey asks each respondent to self-identify his or her racial and ethnic background. First, the question asks if the respondent is of Hispanic, Latino, or Spanish origin. Next, the question asks the respondent's race, allowing the respondent to mark all racial categories that apply. The racial categories are detailed, including White, Black, American Indiana, Asian Indian, Chinese, Filipino, Japanese, Korean, and so on. However, to protect confidentiality, the public

Table 1
Descriptive statistics of the household pulse survey, January 6 to March 29, 2021.

| | Full Sample | By Race and Ethnicity | | | | |
		Non-Hispanic White	Black	Hispanic	Asian	Others
Sample size	60,492	42,926	6705	6376	1093	3392
	Mean or Percentage	Mean or Percentage	Mean or Percentage	Mean or Percentage	Mean or Percentage	Mean or Percentage
Age	47.30 (14.49)	48.61 (14.49)	43.00 (12.60)	43.91 (14.73)	46.42 (14.71)	45.78 (14.67)
Female	65.0%	63.2%	77.8%	66.9%	58.8%	61.8%
Education						
High school or less	23.2%	22.0%	25.0%	29.9%	15.0%	25.9%
Some college or associate's degree	43.8%	44.1%	43.1%	43.3%	31.7%	46.2%
Bachelor's degree	21.6%	23.0%	18.7%	16.1%	32.2%	17.1%
Graduate degree	11.3%	10.9%	13.3%	10.7%	21.1%	10.8%
Living arrangements						
Living alone	14.5%	15.2%	17.1%	9.5%	11.1%	13.4%
Married, with spouse only	17.8%	21.2%	8.3%	9.5%	15.3%	12.6%
Married, intergenerational	35.2%	35.9%	25.0%	39.7%	42.6%	34.0%
Not married, multi-adult	14.3%	13.7%	14.3%	15.6%	16.0%	15.8%
Not married, intergenerational	17.6%	13.4%	34.7%	25.0%	14.2%	23.6%
Unknown	0.6%	0.6%	0.6%	0.7%	0.8%	0.6%
Household income						
Less than $25,000	12.3%	10.7%	18.6%	14.9%	9.5%	16.0%
$25,000 - $49,999	18.8%	18.1%	21.9%	19.9%	14.8%	19.9%
$50,000 - $99,999	23.5%	25.3%	16.8%	19.7%	21.3%	21.6%
$100,000 and above	17.4%	19.9%	7.3%	12.6%	21.5%	18.7%
Missing	28.1%	26.0%	35.4%	33.0%	32.8%	29.3%
Employment status						
Working for pay	61.5%	62.6%	58.8%	59.0%	60.3%	57.8%
Retired	9.4%	11.1%	4.8%	4.7%	7.3%	7.0%
Not working	28.6%	25.8%	36.1%	35.7%	31.9%	34.7%
Missing	0.5%	0.5%	0.3%	0.7%	0.5%	0.4%
Health insurance coverage	58.0%	60.0%	52.6%	51.2%	52.9%	58.0%
Resident state political environment						
Democratic	45.0%	49.9%	37.7%	30.9%	25.2%	46.2%
Republican	33.8%	31.0%	34.3%	46.6%	57.8%	36.8%
Swing	22.2%	19.1%	28.0%	22.5%	17.0%	15.0%
Depression						
No Depression	62.7%	64.9%	55.3%	57.0%	61.6%	59.3%
Depression	17.0%	16.5%	17.8%	19.0%	14.1%	20.2%
Missing	20.3%	18.6%	26.8%	24.0%	24.3%	20.6%
Anxiety						
No Anxiety	58.5%	60.9%	51.3%	52.5%	57.9%	53.6%
Anxiety	21.3%	20.6%	22.0%	23.5%	17.9%	25.7%
Missing	20.2%	18.5%	26.7%	24.0%	25.2%	20.6%

version of the dataset combines ethnic groups that have relatively few respondents in them. As such, this study can classify respondents' race and ethnicity into one of only the following five groups: White, Black, Hispanic, Asian, or Others. Respondents were classified as Hispanic if they were of Hispanic, Latino, or Spanish origin, irrespective of race.

2.3. Concerns about the COVID-19 vaccine

Because the focus of the study is on vaccine hesitancy, the sample includes only respondents who had not yet received the COVID-19 vaccine. These respondents were asked to report their intention to get a vaccine. Respondents who did *not* answer 'definitely yes' to the question about their likelihood of getting a COVID-19 vaccine were asked about their reasons for vaccine hesitancy or refusal in the follow-up question. The survey provided ten possible reasons and participants could check all reasons that applied to them. The provided reasons were: (1) 'I am concerned about possible side effects of a COVID-19 vaccine', (2) 'I don't know if a COVID-19 vaccine will work', (3) 'I don't believe I need a COVID-19 vaccine', (4) 'I don't like vaccines', (5) 'My doctor has not recommended it', (6) 'I plan to wait and see if it is safe and may get it later', (7) 'I think other people need it more than I do right now', (8) 'I am concerned about the cost of a COVID-19 vaccine', (9) 'I don't trust COVID-19 vaccines', and (10) 'I don't trust the government.' Table 2 displays the distribution of vaccine concerns toward COVID-19 by race and ethnicity.

2.4. Analytical strategy

This study investigates the underlying patterns across vaccine concerns using latent class analysis (LCA) via Mplus. Latent class analysis allows us to capture variation in COVID-19 vaccine concerns that involve more than one domain. Unlike a factor analysis that is concerned with the structure of variables (i.e., correlations), LCA examines a typology based on the structure of cases (i.e., clusters of subtypes). Rather than rank-ordering measures along separate, underlying continua, a typology estimates a multivariate mixture of groups of cases, which better aligns with the person-centered approach of this study. Using this method, the analytic strategy will (1) identify reasons for COVID-19 refusal into different clusters (i.e., constellations of vaccine concerns) and (2) examine the association between racial and ethnic group membership and cluster of vaccine concerns, net of demographic and socioeconomic characteristics.

The statistical analysis proceeded as follows. First, we used respondents' answers to the ten COVID-19 vaccine concerns to construct the latent classes. Next, we tested models with two to six latent classes for fit to identify the most appropriate and parsimonious model. Maximum likelihood estimation with robust standard errors was used. The following fit statistics were used to assess and compare across models: Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), Vuong-Lo-Mendell-Rubin Likelihood Ratio Test (VLMR-

LRT), and entropy. Lower AIC and BIC values indicate a better fit, whereas an entropy value closer to 1 indicates a clearer delineation of classes. The likelihood ratio test (VLMR-LRT) was used to compare the nested models. A significant *p* value indicates that the added class improves the fit of the model. By comparing these fit statistics along with the interpretability of the classifying results, the optimal number of classes was obtained (Nylund-Gibson & Choi, 2018).

After deciding the optimal number of classes, this study used the three-step approach to study the associations between latent class membership and socio-demographic factors (Asparouhov & Muthén, 2014). This approach involves first using only the indicators to enumerate optimal class numbers, then creating the most likely class variable with the class posterior distribution from step 1, followed by regressing the most likely class on predicting variables while taking misclassification into account (Vermunt, 2010). This three-step approach can prevent classification shifts due to distributions and combination of predictors in the structural models (Bakk & Kuha, 2020).

In addition to race and ethnicity, a full set of covariates were included in the statistical analysis that may predict respondents' latent class membership, including the following: age of respondent, gender, educational attainment (high school or less, some college or associate's degree, bachelor's degree, graduate degree), employment status (working for pay, not working for pay, retired), living arrangements (living alone, living with married spouse only, married living in intergenerational family, not married living with other adults, not married living with children, unknown), health insurance coverage (yes or no), household income (in four categories), and indicators of major depression (yes or no) and generalized anxiety disorder (yes or no). A missing category for each of the above variables was used to enable use of the full sample. The statistical models also included a control for the political environment of respondents' residential state (Democratic, Republican, swing).

3. Results

3.1. Descriptive statistics

Table 2 shows the distribution of the ten different vaccine concerns by race and ethnicity. Regardless of race and ethnicity, the top three reasons for vaccine hesitancy were: worried about the side effects of a vaccine (51%), want to wait and see if the vaccine is safe and works well (43%), and do not trust COVID-19 vaccines (34%). Very few respondents (i.e., less than 4%) indicated concern about the cost of the vaccine. Table 2 also clearly shows some interesting variations by race and ethnicity. For example, non-Hispanic Whites are more likely than other racial and ethnic groups to indicate that they do not need a vaccine. Asians are more likely than other groups to indicate that they want to "wait and see" before receiving a vaccine. Blacks more often indicated "I don't trust the COVID-19 vaccine" than all other racial and ethnic groups. Interestingly, a higher proportion of non-Hispanic Whites than

Table 2
Distribution of vaccine concerns by race and ethnicity.

	Full Sample (N = 60,492)	By Race and Ethnicity				
		Non-Hispanic White (N = 42,926)	Black (N = 6705)	Hispanic (N = 6376)	Asian (N = 1093)	Others (N = 3392)
(1) Side effects	51.8%	51.3%	54.2%	51.1%	51.1%	55.0%
(2) Don't know if vaccine will work	21.9%	21.7%	21.7%	22.2%	23.7%	23.7%
(3) Don't believe I need the vaccine	23.9%	26.3%	13.0%	19.9%	17.0%	24.8%
(4) Don't like vaccines	13.4%	13.2%	13.9%	12.9%	12.9%	17.0%
(5) Doctor has not recommended	7.1%	7.0%	7.8%	6.7%	4.6%	8.7%
(6) Wait and see	43.2%	42.3%	48.5%	43.6%	49.55	41.9%
(7) Other people need it more	21.0%	21.9%	15.3%	20.6%	23.7%	21.6%
(8) Cost of vaccine	3.9%	3.5%	4.0%	5.8%	5.6%	5.1%
(9) Don't trust COVID-19 vaccines	34.3%	34.2%	36.9%	31.7%	26.0%	38.3%
(10) Don't trust the government	26.9%	27.5%	23.2%	25.0%	17.7%	32.8%

Blacks indicated one of their reasons for not getting the vaccine was that they "don't trust the government."

3.2. Fit Statistics and Optimal Number of Classes

Table 3 displays diagnostic statistics for the LCA by number of classes. These statistics allow for comparison across classes and determine the optimal number of classes. Taken together, these fit statistics suggested that the best solution is to use five classes. Although some of the fit statistics suggested a six-class solution was the best fit for the data, we chose the five-class solution because it has higher interpretability along with good discrimination between classes, as well as the second best AIC (45755) and BIC (46415) and highest entropy (0.76). More specifically, as compared with the four-class solution, the five-class solution showed lower AIC, BIC and log-likelihood values. The VLMR-LRT also reach significance, suggesting that the five-class solution fitted better than the four-class solution to the data. In contrast, although compared with the five-class solution the six-class solution had lower AIC, BIC and log-likelihood values with a significant VLMR-LRT, the entropy of the six-class solution dropped substantially, suggesting that the additional class may not generate clear-cut classifications. Therefore, we chose the five-class solution as our final model. Although our entropy did not pass the conventional cut-off value (0.8), it has been documented that entropy is negatively correlated with sample sizes (Tein et al., 2013). Given the large sample size in this analysis, our classification results displayed reasonably sufficient separation (Asparouhov & Muthén, 2014; Bakk & Kuha, 2020).

Table 4 shows the estimated probabilities for each LCA indicator. From this data, respondents were classified into five distinct classes, as follows:

(1) General skepticism: High level of distrust concerning every aspect of the vaccine
(2) Science and government distrust: Distrust in government administration and the scientific development of the vaccine
(3) Safety and hesitancy: Concerns about side effects and a preference to "wait and see"
(4) Just wait and see: No evidence of distrust, but simply does not want to get the vaccine now
(5) Not quite sure: Low level of distrust across all aspects of the vaccine

Respondents in each class display different views toward the COVID-19 vaccine, as illustrated in Supplementary Fig. 1. About 5 percent the sample belonged to Class 1 (general skepticism), characterized by strong concerns about every aspect of the vaccine. Individuals in this group not only had concerns about potential side effects but were also skeptical of the effectiveness of the vaccine, believed they do not need the vaccine, and showed strong distrust toward the vaccine and government.

About 14 percent of the sample belonged to Class 2 (science and government distrust), characterized by high levels of distrust toward the science around the COVID-19 vaccine and the government, as well as strong concerns about the vaccine's potential side effects. This group also had some concerns on whether the vaccine was truly effective, and some belief that they do not personally need the vaccine.

About 24 percent of the respondents belonged to Class 3 (safety and hesitancy), characterized by high concerns about the potential side effects of the COVID-19 vaccine and a high probability of wanting to "wait and see." However, unlike respondents in Class 2, respondents in Class 3 did not show high levels of distrust toward the science around the COVID-19 vaccine or the government. As such, the main concern in Class 3 was whether the vaccine would cause any side effects, which made these respondents want to wait for more people to receive the vaccination so there is more evidence available on its effects. We selected Class 3 as our reference group for the subsequent multinomial logistic regression (Table 5) because the concern pattern of Class 3 is a reasonable baseline. Given the novelty and uncertainty of COVID-19, its rapid onset, and the newness of its biomedical treatments and prevention—the concerns that characterize Class 3 can be understood as a moderate and reasonable reaction.

About 12 percent of the respondents belonged to Class 4 (just wait and see), distinctly characterized by an extremely high level of wanting to wait and see without expressing any other concerns. Respondents in this class had no other concerns but just wanted to wait and see. Finally, about 45 percent of the respondents belonged to Class 5 (not quite sure). Respondents in this group had reasons for vaccine hesitancy that were less clearly articulated, i.e., members of this group expressed relatively low levels of concern for each of the ten reasons.

4. Results from multinominal logistic regression

Table 5 shows the results from the multinomial logistic regression that links race and ethnicity to each of the five classes of vaccine hesitancy, net of the effect of demographic and socioeconomic characteristics. Compared to Whites, Blacks were less likely to be in the "general skepticism" class, "science and government distrust" class, and "not quite sure" class. Hispanics and Asians were also less likely to be in the "science and government distrust" class than Whites. Asians were also less likely to be in the "not quite sure" class than Whites. The pattern in the results suggests that Blacks do not show higher levels of distrust than all other racial and ethnic groups toward the COVID-19 vaccine or the government.

5. Discussion

In December 2020, the Pfizer-BioNTech and Moderna vaccines were approved for emergency use in the United States. Shortly thereafter, the U.S. government launched an ambitious plan to vaccinate at least 70 percent of its population (with at least one dose) by July 4, 2021 (National Public Radio, 2021). In late-May 2021, 38.9 percent of the U.S. population was fully vaccinated (two doses) and 48.9 percent was partially vaccinated (one dose; Centers for Disease Control and Prevention, 2021a). By mid-February 2022, 64 percent of the U.S. population was fully vaccinated, and 76 percent was partially vaccinated. About 40 percent of the fully vaccinated population had also received a booster vaccine (U.S. Centers for Disease Control and Prevention, 2022). However, by mid-February 2022, the U.S. public's interest in the vaccine remained lower than most OECD countries (Ritchie et al., 2022) and racial-ethnic disparities in vaccination remained substantial (Kaiser Family Foundation, 2021; 2022). Having reached the point where most

Table 3

Fit statistics for latent class analysis.

Number of Classes	Log-likelihood	N of free parameters	VLMR-LRT	AIC	BIC	Entropy
2	−285191***	21	−302947***	570425	570614	0.726
3	−280811***	32	−285191***	561686	561873	0.738
4	−278606***	43	−280811***	557298	557686	0.757
5	−277289***	54	−278606***	554686	555172	0.759
6	−276398***	65	−277289***	552927	553512	0.684

Note: VLMR-LRT = Vuong-Lo-Mendel-Rubin likelihood ratio test; AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion.

Table 4
Estimated probabilities of vaccine concerns between classes.

	Class 1	Class 2	Class 3	Class 4	Class 5
	N = 3096 (5.1%)	N = 8634 (14.2%)	N = 14266 (23.6%)	N = 7300 (12.1%)	N = 27196 (45.0%)
(1) Side effects	0.98	0.82	0.86	0.15	0.29
(2) Don't know if vaccine will work	0.88	0.43	0.38	0.00	0.05
(3) Don't believe I need the vaccine	0.69	0.53	0.16	0.00	0.20
(4) Don't like vaccines	0.49	0.31	0.09	0.00	0.10
(5) Doctor has not recommended	0.34	0.07	0.09	0.01	0.05
(6) Wait and see	0.66	0.23	0.91	1.00	0.07
(7) Other people need it more	0.61	0.06	0.41	0.07	0.14
(8) Cost of vaccine	0.25	0.02	0.08	0.00	0.01
(9) Don't trust COVID-19 vaccines	0.89	0.97	0.32	0.00	0.19
(10) Don't trust the government	0.70	0.77	0.22	0.01	0.16
Description of each class	General skepticism: Distrust in general and concerning every potential issue of vaccine	Science and government distrust: Distrust in government administration and the scientific development of vaccine	Safety and hesitancy: Concerns about side effects and a preference to "wait and see"	Just wait and see: No evidence of distrust but simply does not want to do so now	Not quite sure: Very modest level of distrust and/or strong opinions for vaccine hesitancy

people who are enthusiastic about the vaccine have received it, the challenge the U.S. now faces is persuading individuals who are considered "vaccine hesitant" to accept the vaccine. In this context, understanding and addressing any racial and ethnic differences around vaccine hesitancy that exist is even more critical. The findings of this study not only reflect how beliefs clustered in early phase of vaccination but also have important implications for addressing COVID-19 related health inequality persists today.

Overall, we find partial support for the research hypotheses. First, there is evidence that vaccine concerns tend to cluster and that distinct constellations of vaccine concerns exist. Our analysis used LCA to divide survey respondents who were refusing the COVID-19 vaccine into five distinct classes based on their reasons for refusing the vaccine: general skepticism (5 percent of sample), distrust of science and government (14 percent of sample), safety and hesitancy (24 percent of sample), a general desire to wait and see accompanied by no other concerns (12 percent of sample), and those who were not quite sure, i.e., had only modest concerns across all ten reasons (45 percent of sample). In this way, the findings from this study suggest moving interventions away from a simple, single-concern focus and toward the more nuanced, multiple reasons that people hold at once. For example, for the individuals in Class 3 who are concerned about potential side effects and a preference for going slowly and waiting for more information, an intervention would be most effective if it provided more safety information while also elucidating the costs of delay. This messaging can complement existing health messaging approaches that, based on prior research, focus on a single issue (Bogart et al., 2021).

Second, the constellation of concerns about the COVID-19 vaccine in the adult population varies by race and ethnicity, in sometimes surprising ways. More specifically, the results support that Black and Hispanic adult—compared to Whites—are more likely to belong to the 'safety and hesitancy' group, which is characterized by heightened concerns about side effects and wanting to wait and see before getting the vaccine. However, contrary to our expectation, Asian respondents are also more likely to belong to the safety and hesitancy group than Whites, similar to their Black and Hispanic peers. This surprising finding suggests that factors other than material constraints may also impact how Asian Americans perceive the risks and benefits of COVID-19 vaccination. Although Asian Americans may have more socioeconomic

advantages and thus less concern about disruptions from vaccine side effects on their work and family lives, it could be that their higher education level translates to greater concerns about possible long-term side effects from the vaccines, especially given that at the time of data collection the vaccines had not been fully tested or obtained full approval from the Food and Drug Administration.

Third, we also find evidence that racial and ethnic backgrounds are associated with different constellations of vaccine concerns that characterized by distrust toward the vaccine and government, although the directions of associations are unexpected. Our results show that—compared to Whites—Asian, Black, and Hispanic adults are less likely to belong to the 'distrust of science and government' group, which is characterized by elevated distrust of science and the government. Our finding departs somewhat from the prior literature that overwhelmingly cites racial minorities' distrust of government and the healthcare system as the main explanatory factor for their vaccine hesitancy (e.g., Jamison et al., 2019). Certainly, distrust of the medical system is widely present in minority communities and has contributed to the current epidemiological-political context of COVID-19. However, this study's findings suggest that minority communities' initial distrust may be specific to the newness and rapid development of the COVID-19 vaccine and may be changing. The data used in the current study were first collected in January 2021, around the time of the presidential transition. Up to that point, racial and ethnic minority communities had suffered a disproportionately large disease burden (Holtgrave et al., 2020; Kim & Bostwick, 2020; Tai et al., 2021), and the disease containment measures of the Trump administration were widely perceived as inadequate and not trustworthy, particularly among racial and ethnic minority communities (Woko et al., 2020). Our finding that racial and ethnic minorities' more recent concerns (i.e., January 2021 through May 2021) are about the vaccines' side effects rather than general distrust of the government and healthcare system suggests that the Biden administration's deployment of the vaccine and related public health initiatives may be succeeding at generating trust and hope in the hardest-hit communities. However, it must also be noted that our analysis found that individuals in the "other" racial category, which includes Native Americans and people of mixed races, were more likely to cite distrust of the science and the government as a reason for vaccine hesitancy, indicating these vulnerable populations may still feel anxious about the

Table 5

Results of Latent Class Mixture Model (3-step approach) in Predicting Latent Class Membership.

	Class 1 vs Class 3 Coefficient (SE)	Class 2 vs Class 3 Coefficient (SE)	Class 4 vs Class 3 Coefficient (SE)	Class 5 vs Class 3 Coefficient (SE)
Age	0.013*** (0.003)	0.018*** (0.002)	0.035*** (0.002)	0.035*** (0.001)
Female	−0.866*** (0.066)	−0.614*** (0.041)	0.043 (0.045)	−0.470*** (0.031)
Race and Ethnicity (ref: Non-Hispanic White)				
Black	−0.446*** (0.118)	−0.308*** (0.066)	0.099 (0.061)	−0.105* (0.044)
Hispanic	0.019 (0.100)	−0.348*** (0.072)	0.078 (0.064)	0.045 (0.045)
Asians	−0.317 (0.227)	−0.982*** (0.197)	−0.006 (0.133)	−0.243** (0.094)
Others	0.340** (0.116)	0.082 (0.081)	−0.220* (0.094)	−0.033 (0.061)
Education (ref: High school or less)				
Some college	−0.211* (0.085)	−0.249*** (0.053)	−0.396*** (0.053)	−0.464*** (0.039)
Bachelor's degree	−0.336*** (0.100)	−0.429*** (0.061)	−0.659*** (0.062)	−0.706*** (0.045)
Graduate degree	−0.153 (0.115)	−0.510*** (0.076)	−0.656*** (0.074)	−0.694*** (0.053)
Living arrangements (ref: Living alone)				
With married spouse only	−0.278* (0.124)	0.149* (0.076)	0.002 (0.076)	−0.082 (0.055)
Intergenerational family	−0.256* (0.101)	0.133* (0.067)	0.134* (0.066)	−0.077 (0.047)
Not married multi-adult	−0.097 (0.110)	−0.063 (0.078)	−0.105 (0.076)	−0.163* (0.053)
Not married with children	−0.062 (0.113)	0.171* (0.076)	0.042 (0.074)	−0.039 (0.053)
Unknown	0.739 (0.384)	1.060*** (0.287)	0.344 (0.336)	0.756** (0.244)
Household income (ref: Less than $25,000)				
$25,000 - $49,999	−0.224* (0.112)	−0.203** (0.076)	−0.166* (0.075)	−0.222*** (0.053)
$50,000 - $99,999	−0.305** (0.115)	−0.079 (0.074)	−0.164* (0.075)	−0.251*** (0.054)
$100,000 and above	−0.253* (0.129)	−0.223** (0.082)	−0.220** (0.081)	−0.294*** (0.058)
Missing	−0.005 (0.135)	−0.053 (0.092)	0.085 (0.092)	0.028 (0.066)
Employment status (ref: Not working)				
Employed	−0.255** (0.073)	−0.108* (0.047)	−0.128** (0.046)	−0.300*** (0.033)
Retired	−0.479** (0.157)	−0.116 (0.090)	−0.181* (0.086)	−0.426*** (0.067)
Health insurance coverage	−0.476*** (0.097)	−0.198** (0.070)	−0.029 (0.072)	−0.397*** (0.049)
Resident state political environment (ref: Republican)				
Democratic	−0.149* (0.072)	−0.172*** (0.044)	−0.094* (0.044)	−0.123*** (0.031)
Swing	−0.021 (0.084)	0.003 (0.051)	−0.040 (0.052)	−0.015 (0.037)
Depression (ref: No Depression)				
Depression	0.153 (0.105)	0.141* (0.067)	−0.152* (0.074)	0.037 (0.049)
Missing	0.000 (0.387)	−0.588* (0.262)	0.533 (0.239)	−0.090 (0.195)
Anxiety (ref: No Anxiety)				
Anxiety	0.338** (0.099)	−0.024 (0.063)	−0.048 (0.067)	−0.028 (0.045)
Missing	−0.276 (0.402)	0.463 (0.260)	−0.277 (0.241)	−0.107 (0.196)

Note: ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

healthcare system, new administration and its policies.

These findings have several implications. First, extant research on COVID-19 vaccine hesitancy has primarily focused attention on racial and ethnic minorities. Furthermore, prior studies on vaccine hesitancy in the White population have focused predominantly on child vaccination (i.e., Reich, 2016). This focus ignores vaccine hesitancy in the adult population as a public health issue, and potentially unfairly stigmatizes racial and ethnic minorities as vaccine hesitant. Given that Whites still occupy the majority of U.S. population, understanding their vaccine concerns is crucial for fighting the COVID-19 pandemic. Findings from this study highlight the underlying patterns of vaccine concerns among racial and ethnic groups during the early period of vaccine availability, which may help practitioners understand and address the seemingly unique reasons that people from all racial and ethnic groups sometimes choose to reject COVID-19 vaccination. The data presented in this study may assist in more accurate, tailored planning for early vaccine rollouts during future pandemics.

Before concluding, we acknowledge several limitations of this study. First, the analysis is cross-sectional and is not able to determine if the underlying patterns of vaccine hesitancy change over time. With this data and analytic techniques, we cannot directly assess the extent to which respondents' views about the COVID-19 vaccine may be driven by changing lives and experiences during the pandemic. Second, although the provision of ten reasons is fairly comprehensive, the Household Pulse Survey does not exhaust all potential reasons for vaccine hesitancy. Third, because the publicly available dataset collapsed the original, more finely-grained racial and ethnic groups into five categories, it does mask some information on race and ethnicity. For example, we

were not able to examine variations in reasons for vaccine hesitancy within subpopulations of Asians and Hispanics. Fourth, unfortunately, the HPS in these waves did not include questions about physical health, such as self-rated health or disability. It is possible that possible racial and ethnic differences in physical health that we were unable to assess may have resulted in different patterns of vaccine concerns. Finally, although the HPS is a national survey, it is not nationally representative. Prior studies suggest that, compared to estimates from the nationally representative American Community Survey, HPS respondents have greater educational attainment, are more likely to be women, and are slightly more likely to be White (Donnelly & Farina, 2021). As such, information about the most disadvantaged racial and ethnic minorities may be underestimated in this study's analysis.

In conclusion, the findings from this study make clear that there are significant variations in individuals' reasons for COVID-19 vaccine hesitancy in the United States, that their different reasons cluster together into certain key typologies, and that individuals' race and ethnicity is associated with these typologies. Because different reasons for vaccine hesitancy will require different strategies to undo, public health actions and interventions will be more effective at increasing vaccine uptake if they tailor their approach to patterns that occur, especially in racial and ethnic minority communities. Overall, our study provides a more comprehensive understanding of the underlying patterns of reasoning among individuals who have refused the vaccine, across racial and ethnic groups. This information is useful for thinking about how groups respond to public health emergencies and how we study it and may be of paramount importance as the U.S. works to increase vaccine uptake among in the months and years to come.

Funding

Compliance with ethical standards

On behalf of all authors, the corresponding author states that there is no conflict of interest. This study received no funding support. This study relied on secondary data analysis and did not directly involve human participants through primary data collection. The U.S. Census Bureau obtained informed consent for all participants of the Household Pulse Survey.

Data availability statement

The datasets generated during and/or analyzed during the current study are available in the web site of the U.S. Census Bureau, https://www.census.gov/programs-surveys/household-pulse-survey/datasets.html.

Author statement

Jen-Hao Chen: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Supervision; Validation; Visualization; Writing - original draft; Writing - review & editing. ***Cheng-Shi Shiu***: Formal analysis; Investigation; Methodology; Software; Validation; Visualization; Writing - review & editing.

Declaration of competing interest

There is no conflict of interest to disclose.

Acknowledgement

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2022.101073.

References

Akee, R., Jones, M. R., & Porter, S. R. (2019). Race matters: Income shares, income inequality, and income mobility for all U.S. Races. *Demography, 56*(3), 999–1021. https://doi.org/10.1007/s13524-019-00773-7

Andre, F., Booy, R., Bock, H., Clemens, J., Datta, S., John, T., Lee, B., Lolekha, S., Peltola, H., Ruff, T., Santosham, M., & Schmitt, H. (2008). Vaccination greatly reduces disease, disability, death and inequity worldwide. *Bulletin of the World Health Organization, 86*(2), 140–146. https://doi.org/10.2471/blt.07.040089

Asparouhov, T., & Muthén, B. (2014). Auxiliary variables in mixture modeling: Three-step approaches using M plus. *Structural Equation Modeling: A Multidisciplinary Journal, 21*(3), 329–341. https://doi.org/10.1080/10705511.2014.915181

Bakk, Z., & Kuha, J. (2020). Relating latent class membership to external variables: An overview. *British Journal of Mathematical and Statistical Psychology, 74*(2), 340–362. https://doi.org/10.1111/bmsp.12227

Bardenheier, B. H., Lindley, M. C., Ball, S. W., de Perio, M. A., Laney, S., & Gravenstein, S. (2020). Cluster Analysis: Vaccination attitudes and beliefs of healthcare personnel. *American Journal of Health Behavior, 44*(3), 302–312. https://doi.org/10.5993/ajhb.44.3.3

Bogart, L. M., Dong, L., Gandhi, P., Ryan, S., Smith, T. L., Klein, D. J., Fuller, L. A., & Ojikutu, B. O. (2021). *What contributes to COVID-19 vaccine hesitancy in Black communities, and how can it be addressed (Research Report)*. RAND Corporation. https://www.rand.org/pubs/research_reports/RRA1110-1.html.

Brandon, D. T., Isaac, L. A., & LaVeist, T. A. (2005). The legacy of tuskegee and trust in medical care: Is tuskegee responsible for race differences in mistrust of medical care? *Journal of the National Medical Association, 97*(7), 951–956.

Burdette, A. M., Needham, B. L., Taylor, M. G., & Hill, T. D. (2017). Health lifestyles in adolescence and self-rated health into adulthood. *Journal of Health and Social Behavior, 58*(4), 520–536. https://doi.org/10.1177/0022146517735313

Centers for Disease Control and Prevention. (2021a). *COVID-19 vaccinations in the United States*. Retried June 30, from https://covid.cdc.gov/covid-data-tracker/#vaccinations

Centers for Disease Control and Prevention. (2021b). *Ensuring equity in COVID-19 vaccine distribution*. Retried June 30, from https://www.cdc.gov/vaccines/covid-19/planning/health-center-program.html.

Centers for Disease Control and Prevention. (2022). COVID-19 vaccinations in the United States. Retried February 20, from https://covid.cdc.gov/covid-data-tracker/#vaccinations.

Cockerham, W. C. (2005). Health lifestyle theory and the convergence of agency and structure. *Journal of Health and Social Behavior, 46*(1), 51–67. https://doi.org/10.1177/002214650504600105

Cuevas, A. G., O'Brien, K., & Saha, S. (2016). African American experiences in healthcare: "I always feel like I'm getting skipped over". *Health Psychology, 35*(9), 987–995. https://doi.org/10.1037/hea0000368

Do, D. P., & Frank, R. (2022). Prior COVID-19 infection: An underappreciated factor in vaccine hesitancy in the USA. *Journal of Public Health*. https://doi.org/10.1093/pubmed/fdab404. *fdab404*.

Donnelly, R., & Farina, M. P. (2021). How do state policies shape experiences of household income shocks and mental health during the COVID-19 pandemic? *Social Science & Medicine, 269*, Article 113557. https://doi.org/10.1016/j.socscimed.2020.113557

Feagin, J., & Bennefield, Z. (2014). Systemic racism and US health care. *Social Science & Medicine, 103*, 7–14. https://doi.org/10.1016/j.socscimed.2013.09.006

Fields, J. (September 24, 2021). *Revisiting the balance: The household Pulse survey in a total survey quality framework [conference presentation]. International total survey error workshop: Total survey error in the age of COVID-19, virtual conference*. United States.

Freimuth, V. S., Jamison, A. M., An, J., Hancock, G. R., & Quinn, S. C. (2017). Determinants of trust in the flu vaccine for African Americans and Whites. *Social Science & Medicine, 193*, 70–79. https://doi.org/10.1016/j.socscimed.2017.10.001

Freimuth, V. S., Quinn, S. C., Thomas, S. B., Cole, G., Zook, E., & Duncan, T. (2001). African Americans' views on research and the Tuskegee Syphilis study. *Social Science & Medicine, 52*(5), 797–808. https://doi.org/10.1016/S0277-9536(00)00178-7

Gaskin, D. J., Dinwiddie, G. Y., Chan, K. S., & McCleary, R. R. (2012). Residential segregation and the availability of primary care physicians. *Health Services Research, 47*(6), 2353–2376. https://doi.org/10.1111/j.1475-6773.2012.01417.x

Greenwood, B. (2014). The contribution of vaccination to global health: Past, present and future. *Philosophical Transactions of the Royal Society B: Biological Sciences, 369* (1645). https://doi.org/10.1098/rstb.2013.0433, 20130433–20130433.

Greer, T. M., Brondolo, E., & Brown, P. (2014). Systemic racism moderates effects of provider racial biases on adherence to hypertension treatment for African Americans. *Health Psychology, 33*(1), 35–42. https://doi.org/10.1037/a0032777

Head, K. J., Kasting, M. L., Sturm, L. A., Hartsock, J. A., & Zimet, G. D. (2020). A National Survey assessing SARS-CoV-2 vaccination intentions: Implications for future public health communication efforts. *Science Communication, 42*(5), 698–723. https://doi.org/10.1177/1075547020960463

Holtgrave, D. R., Barranco, M. A., Tesoriero, J. M., Blog, D. S., & Rosenberg, E. S. (2020). Assessing racial and ethnic disparities using a COVID-19 outcomes continuum for New York State. *Annals of Epidemiology, 48*, 9–14. https://doi.org/10.1016/j.annepidem.2020.06.010

Hsieh, Y. L., Rak, S., SteelFisher, G. K., & Bauhoff, S. (2022). Effect of the suspension of the J&J COVID-19 vaccine on vaccine hesitancy in the United States. *Vaccine, 40*(3), 424–427. https://doi.org/10.1016/j.vaccine.2021.11.085

Jamison, A. M., Quinn, S. C., & Freimuth, V. S. (2019). "You don't trust a government vaccine": Narratives of institutional trust and influenza vaccination among African American and white adults. *Social Science & Medicine, 221*, 87–94. https://doi.org/10.1016/j.socscimed.2018.12.020

Kaiser Family Foundation. (2021). *KFF COVID-19 vaccine monitor - April 2021*. Retried June 30, from https://www.kff.org/coronavirus-covid-19/poll-finding/kff-covid-19-vaccine-monitor-april-2021/.

Kaiser Family Foundation. (2022). KFF COVID-19 vaccine monitor dashboard. Retried Feburary 20, from https://www.kff.org/coronavirus-covid-19/dashboard/kff-covid-19-vaccine-monitor-dashboard/?utm_source=web&utm_medium=trending&utm_campaign=COVID-19-vaccine-monitor#equity.

Kim, S. J., & Bostwick, W. (2020). Social vulnerability and racial inequality in COVID-19 deaths in Chicago. *Health Education & Behavior, 47*(4), 509–513. https://doi.org/10.1177/1090198120929677

Landivar, L. C. (2013). Disparities in STEM employment by sex, race, and Hispanic origin. *Education Review, 29*(6), 911–922.

Latkin, C. A., Dayton, L., Yi, G., Colon, B., & Kong, X. (2021). Mask usage, social distancing, racial, and gender correlates of COVID-19 vaccine intentions among adults in the US. *PLoS One, 16*(2), Article e0246970. https://doi.org/10.1371/journal.pone.0246970

Latkin, C. A., Dayton, L., Yi, G., Konstantopoulos, A., & Boodram, B. (2021). Trust in a COVID-19 vaccine in the U.S.: A social-ecological perspective. *Social Science & Medicine, 270*, Article 113684. https://doi.org/10.1016/j.socscimed.2021.113684

Li, Y., Tenchov, R., Smoot, J., Liu, C., Watkins, S., & Zhou, Q. (2021). A comprehensive review of the global efforts on COVID-19 vaccine development. *ACS Central Science, 7*(4), 512–533. https://doi.org/10.1021/acscentsci.1c00120

Millett, G. A., Jones, A. T., Benkeser, D., Baral, S., Mercer, L., Beyrer, C., Honermann, B., Lankiewicz, E., Mena, L., Crowley, J. S., Sherwood, J., & Sullivan, P. S. (2020). Assessing differential impacts of COVID-19 on black communities. *Annals of Epidemiology, 47*, 37–44. https://doi.org/10.1016/j.annepidem.2020.05.003

Mirowsky, J., & Ross, C. E. (2003). *Education, social status, and health*. Routledge. https://doi.org/10.4324/9781351328081

Mollborn, S., James-Hawkins, L., Lawrence, E., & Fomby, P. (2014). Health lifestyles in early childhood. *Journal of Health and Social Behavior, 55*(4), 386–402. https://doi.org/10.1177/0022146514555981

Momplaisir, F., Haynes, N., Nkwihoreze, H., Nelson, M., Werner, R. M., & Jemmott, J. (2021). Understanding drivers of COVID-19 vaccine hesitancy among Blacks. *Clinical Infectious Diseases, 73*(10). https://doi.org/10.1093/cid/ciab102

Murthy, V. H., Krumholz, H. M., & Gross, C. P. (2004). Participation in cancer clinical trials: Race-, sex-, and age-based disparities. *JAMA, 291*(22), 2720–2726. https://doi.org/10.1001/jama.291.22.2720

Nguyen, K. H., Srivastav, A., Razzaghi, H., Williams, W., Lindley, M. C., Jorgensen, C., Abad, N., & Singleton, J. A. (2021). COVID-19 vaccination intent, perceptions, and reasons for not vaccinating among groups prioritized for early vaccination—United States, September and December 2020. *Morbidity and Mortality Weekly Report, 7*(60), 217–222. https://doi.org/10.15585/mmwr.mm7006e3external icon

Nguyen, K. H., Nguyen, K., Corlin, L., Allen, J. D., & Chung, M. (2021). Changes in COVID-19 vaccination receipt and intention to vaccinate by socioeconomic characteristics and geographic area, United States, January 6 – March 29, 2021. *Annals of Medicine, 53*(1), 1419–1428. https://doi.org/10.1080/07853890.2021.1957998

Nylund-Gibson, K., & Choi, A. Y. (2018). Ten frequently asked questions about latent class analysis. *Translational Issues in Psychological Science, 4*(4), 440–461. https://doi.org/10.1037/tps0000176

Pampel, F. C., Krueger, P. M., & Denney, J. T. (2010). Socioeconomic disparities in health behaviors. *Annual Review of Sociology, 36*(1), 349–370. https://doi.org/10.1146/annurev.soc.012809.102529

Park, V. T., Dougan, M., Meyer, O., Nam, B., Tzuang, M., Park, L., Vuong, Q., & Tsoh, J. (2021). Differences in COVID-19 vaccine concerns among Asian Americans and Pacific Islanders: The COMPASS survey. *Journal of Racial and Ethnic Health Disparities*. https://doi.org/10.1007/s40615-021-01037-0

Phelan, J. C., & Link, B. G. (2015). Is racism a fundamental cause of inequalities in health? *Annual Review of Sociology, 41*, 311–330. https://doi.org/10.1146/annurev-soc-073014-112305

Qato, D. M., Daviglus, M. L., Wilder, J., Lee, T., Qato, D., & Lambert, B. (2014). "Pharmacy deserts" are prevalent in chicago's predominantly minority communities, raising medication access concerns. *Health Affairs, 33*(11), 1958–1965. https://doi.org/10.1377/hlthaff.2013.1397

Reich, J. A. (2016). *Calling the shots*. New York University Press.

Ritchie, H., Mathieu, Edouard, Rodés-Guirao, Lucas, Appel, Cameron, Giattino, Charlie, Ortiz-Ospina, Esteban, Hasell, Joe, Macdonald, Bobbie, Beltekian, Diana, & Roser, Max (2022). Coronavirus pandemic (COVID-19). Published online at OurWorldInData.org. Retrieved February 20 from:, [Online Resource] https://ourworldindata.org/coronavirus.

Salmon, D. A., Dudley, M. Z., Glanz, J. M., & Omer, S. B. (2015). Vaccine hesitancy: Causes, consequences, and a call to action. *Vaccine, 33*(27), D66–D71. https://doi.org/10.1016/j.vaccine.2015.09.035

Shrider, E. A., Kollar, M., Chen, F., & Semega, J. (2021). *Income and poverty in the United States: 2020. Current population reports*. US Census Bureau. Retried from: https://www.census.gov/library/publications/2021/demo/p60-273.html.

Tai, D. B. G., Shah, A., Doubeni, C. A., Sia, I. G., & Wieland, M. L. (2021). The disproportionate impact of COVID-19 on racial and ethnic minorities in the United States. *Clinical Infectious Diseases, 72*(4). https://doi.org/10.1093/cid/ciaa815

Tein, J.-Y., Coxe, S., & Cham, H. (2013). Statistical power to detect the correct number of classes in latent profile Analysis. *Structural Equation Modeling: A Multidisciplinary Journal, 20*(4), 640–657. https://doi.org/10.1080/10705511.2013.824781

Tram, K. H., Saeed, S., Bradley, C., Fox, B., Eshun-Wilson, I., Mody, A., & Geng, E. (2021). Deliberation, Dissent, and Distrust: Understanding distinct drivers of COVID-19 vaccine hesitancy in the United States. In *Clinical infectious diseases*. An Official Publication of the Infectious Diseases Society of America. https://doi.org/10.1093/cid/ciab633.

Vermunt, J. K. (2010). Latent class modeling with covariates: Two improved three-step approaches. *Political Analysis, 18*(4), 450–469. https://doi.org/10.1093/pan/mpq025

Williams, D. R., & Collins, C. (2001). Racial residential segregation: A fundamental cause of racial disparities in health. *Public Health Reports, 116*(5), 404–416. https://doi.org/10.1093/phr/116.5.404

Williams, D. R., & Williams-Morris, R. (2000). Racism and mental health: The African American experience. *Ethnicity and Health, 5*(3–4), 243–268. https://doi.org/10.1080/713667453

Woko, C., Siegel, L., & Hornik, R. (2020). An investigation of low COVID-19 vaccination intentions among Black Americans: The role of behavioral beliefs and trust in COVID-19 information sources. *Journal of Health Communication, 25*(10), 819–826. https://doi.org/10.1080/10810730.2020.1864521