

1 Vaccine hesitancy during the COVID-19 pandemic: A latent class analysis of middle-aged and
2 older US adults

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24 **ABSTRACT**

25 It is important to distinguish between apprehensions that lead to vaccine rejection and those
26 that do not. In this study, we 1) identified latent classes of individuals by vaccination attitudes,
27 and 2) compared classes of individuals by sociodemographic characteristics COVID-19
28 vaccination, and risk reduction behaviors. The COVID-19 Coping Study is a longitudinal cohort
29 of US adults aged ≥ 55 years (n=2,358). We categorized individuals into three classes based on
30 the adult Vaccine Hesitancy Scale using latent class analysis (LCA). The associations between
31 class membership and sociodemographic characteristics, COVID-19 vaccination, and other
32 behaviors were assessed using chi-square tests. In total, 88.9% were Vaccine Acceptors, 8.6%
33 were Vaccine Ambivalent, and 2.5% Vaccine Rejectors. At the end, 90.7% of Acceptors, 62.4%
34 of the Ambivalent, and 30.7% of the Rejectors had been vaccinated. The Ambivalent were more
35 likely to be Black or Hispanic, and adopted social distancing and mask wearing behaviors
36 intermediate to that of the Acceptors and Rejectors. Targeting the Vaccine Ambivalent may be
37 an efficient way of increasing vaccination coverage. Controlling the spread of disease during a
38 pandemic requires tailoring vaccine messaging to their concerns, e.g., through working with
39 trusted community leaders, while promoting other risk reduction behaviors.

40

41 **Keywords:** COVID-19, vaccination, older people

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46 **INTRODUCTION**

47

48 The World Health Organization (WHO) Strategic Advisory Group of Experts on Immunization
49 (SAGE) defines vaccine hesitancy as “the reluctance or refusal to vaccinate despite the
50 availability of vaccines”.^[1, 2] The SAGE working group acknowledges that vaccine hesitancy
51 represents a spectrum of behaviors.^[1, 2] There is a large body of research describing specific
52 vaccine concerns, including safety,^[3] scheduling,^[4, 5] and beliefs about natural versus
53 vaccine-derived immunity.^[6]

54

55 By identifying vaccine hesitancy as one of ten threats to global health in 2019,^[7] the WHO
56 foreshadowed current challenges in COVID-19 vaccination. Within the US, vaccine supply has
57 surpassed demand since around May 2021.^[8, 9] As of mid-October 2021, only about 57% of
58 the population (and 66% of those ≥ 12 years old) have been fully vaccinated.^[10]

59

60 The current COVID-19 pandemic has unleashed an “infodemic” related to COVID-19 vaccine
61 development and vaccine safety.^[11, 12] At the same time, concerns about new pharmaceutical
62 products like COVID-19 vaccines are normal and expected, and Black and Hispanic individuals’
63 attitudes towards pharmaceuticals may be shaped by experiences with medical
64 discrimination.^[13] Under the paradigm of shared decision-making, individuals should feel
65 empowered to express their concerns about vaccines with health care providers.^[14, 15]
66 Moreover, individuals could theoretically mitigate their risk through other risk-reduction
67 behaviors, like social distancing^[16] and mask wearing.^[17]

68

69 There is a need for more research on what concerns individuals have about vaccines among
70 both those who accept and those who refuse vaccination. Within a longitudinal study of middle-
71 aged and older adults in the US, we assessed vaccination attitudes at the start of 2021, and

72 followed up for 4 months to determine when and if individuals were vaccinated against COVID-
73 19. The aims of this study were to 1) identify latent classes of individuals based on their
74 attitudes towards vaccination, and 2) compare classes of individuals by sociodemographic
75 characteristics, COVID-19 vaccination, and other risk reduction behaviors. This research
76 acknowledges that individuals could have a variety of concerns about vaccines, but it is
77 necessary to separate out apprehensions that lead to rejecting vaccines versus issues with no
78 such impact.

79

80 **METHODS**

81 **Study sample**

82 Data were from the COVID-19 Coping Study, which longitudinally followed adults aged ≥ 55
83 years living in the United States on a monthly basis from April/May 2020 through April/May
84 2021.[18] A non-probability, online recruitment strategy was used to identify and enroll
85 participants through social media (Facebook, Instagram), organizational mailing lists, the NIH
86 ResearchMatch database, and the University of Michigan Health Research database. At
87 enrollment, participants completed a baseline online survey and were asked to complete follow-
88 up online surveys each month for a year. Details on the study design and methodology are
89 available elsewhere.[18] All study surveys are publicly available at:
90 <https://sph.umich.edu/covid19copingstudy/>.

91

92 Participants were eligible for the present analysis if they responded to the questions regarding
93 vaccine attitudes during the Jan/Feb 2021 wave and were followed up monthly for vaccination
94 uptake until April/May 2021.

95

96 **Measures**

97 During the Jan/Feb 2021 wave, participants responded to the adult Vaccine Hesitancy Scale
98 (aVHS), a list of ten statements about vaccines in general.[19] A list of the statements can be
99 found in Figure 1.

100

101 Vaccination status was collected each month beginning with the Jan/Feb 2021 wave. At this
102 wave, participants were asked whether they had ever received a COVID-19 vaccine. For
103 subsequent waves, they were asked whether they had received a new dose of vaccine in the
104 past month.

105

106 We measured changes to risk reduction behaviors by comparing responses during the May/Jun
107 2020 and Dec 2020/Jan 2021 waves. At both waves, participants were asked to report the
108 number of days in the past week (0 days, 1-3, 4-6, 7) they engaged in specific risk reduction
109 behaviors: self-isolating, washing hands or using hand sanitizer more than normal, wearing a
110 face mask, engaging in in-person face-to-face contact for 15 or more minutes. Constructed
111 compliance variables comprised four categories: consistent complier (engaged in the activity 4-7
112 days in the past week at both the May/Jun 2020 and Dec 2020/Jan 2021 waves, consistent non-
113 complier (engaged in the activity 0-3 days in the past week at both waves), rejuvenator
114 (increased frequency of the activity from 0-3 days to 4-7 days between the waves), and fatiguer
115 (decreased frequency of the activity from 4-7 days to 0-3 days between the waves).

116

117 Demographic covariates were assessed at the baseline (April/May 2020), and included sex
118 (male, female), age (<65 years old, \geq 65 years old), race (Black, white, other), ethnicity
119 (Hispanic, not), education (some high school or high school diploma, some college or two-year
120 associate degree, four-year college or university degree, postgraduate or professional degree),
121 pre-COVID-19 employment status (employed, not employed, retired), relationship status

122 (married or in a relationship, single), self-reported health (poor, fair, good, very good, excellent),
123 and multi-morbidity (fewer than two chronic conditions, two or more chronic conditions).

124

125 **Statistical analysis**

126 All analyses were weighted to account for sampling and participant attrition.[18] The final
127 weights used in this analysis were the product of the sampling weight and the 9-month (Jan/Feb
128 2021 wave) attrition weight, as the vaccine hesitancy questions were asked at that wave.

129

130 Latent class analysis (LCA) was used to identify underlying groups of participants using their
131 responses to the vaccine hesitancy questions. We ran three sets of LCA models with five-,
132 three-, and two-level categorization of the survey questions (Supplemental Table 1). The first
133 set of models operationalized the vaccine hesitancy statements as five-level variables (Strongly
134 agree, Agree, Neither agree nor disagree, Disagree, Strongly Disagree). We ran four models
135 within this set:

136 1) Only vaccine hesitancy variables were included, treated as categorical variables.

137 2) Vaccine hesitancy and other vaccine-related variables were included ("How often do
138 you get vaccinated during the flu season?" And, "In deciding whether to get the COVID-
139 19 vaccine, how important is ____?:" (with responses: Other people in your community
140 getting vaccinated, its being available for free, convenience in where you can get it,
141 advice of your healthcare provider, advice of people you trust, your confidence in
142 vaccine's safety, and your confidence in vaccine's effectiveness). All variables were
143 treated categorically.

144 3) Only vaccine hesitancy variables were included, treated as ordinal variables.

145 4) Vaccine hesitancy variables and other vaccine-related questions were included, and
146 treated as ordinal variables.

147 The second set of LCA models operationalized the vaccine hesitancy variables as three-level
148 variables (Agree, Neither agree nor disagree, Disagree). The above four models were run in this
149 set. In the final set of LCA models, the vaccine hesitancy variables were dichotomized into
150 agree (Strongly agree, Agree) or do not agree (Neither agree nor disagree, Disagree, Strongly
151 disagree). For all models, an increasing number of latent classes was allowed until the model
152 failed to converge. AIC and BIC were used to assess model fit.

153

154 Within the optimal LCA model, participants were assigned to the latent class for which they had
155 the highest posterior probability. Then, distributions of vaccination status, COVID-19-relevant
156 behaviors, and sociodemographic characteristics across latent classes were compared. Rao-
157 Scott chi-square tests of independence, which allow survey weights, were used to investigate
158 associations between latent class assignment and the above factors. Holm-Bonferroni
159 corrections were made to p-values to account for multiple testing. Figures were created to show
160 participants' vaccine attitudes among the entire eligible sample and within each latent class.
161 Stata version 17.0 (College Station, TX, USA) was used for all analyses. The alpha level was
162 0.05 for significance.

163

164 **Ethical approval**

165 The University of Michigan Health Sciences and Behavioral Sciences Institutional Review Board
166 (IRB # HUM00179632) provided ethical approval to the COVID-19 Coping Study. In this
167 internet-based survey, participants read an informed consent form and had to click "agree"
168 before seeing the questionnaire.

169

170 **RESULTS**

171 The original baseline sample included 4,401 individuals. Participants were excluded for the
172 following reasons: did not respond to the Jan/Feb 2021 follow-up survey (n=1,954) or did not

173 respond to all aVHS items (n=89). The final analytic sample contained 2,358 participants. The
174 demographic distribution of respondents is shown in Table 1.

175

176 For the LCA, we chose the three-level model with three latent classes as the optimal model for
177 interpretability and which had relatively low AIC/BIC compared to most other models. Model fit
178 statistics are shown in Supplemental Table 1.

179

180 Overall, most participants expressed pro-vaccine attitudes, agreeing that vaccines are effective,
181 beneficial, and important to their own health and that of others in their community (Figure 1).

182 Upon examination of the vaccine opinions by latent class, we determined that one class held
183 largely pro-vaccine attitudes (Vaccine Acceptors, 88.9% of participants), one class held more
184 varied attitudes (Vaccine Ambivalent, 8.6% of participants), and one class held largely negative
185 attitudes about vaccines (Vaccine Rejectors, 2.5% of participants) (Figure 1). Proportions of
186 vaccine attitudes by latent class membership can be found in Supplemental Table 2. For
187 Vaccine Acceptors, there was still substantial hesitancy about newer vaccines carrying more
188 risks (22.1% agreed), and concern of serious adverse effects (19.2%). Among the Vaccine
189 Ambivalent, there were substantive concerns about whether all vaccines were beneficial (only
190 14.2% agreed), and whether information about vaccines was trustworthy (19.3% agreed).

191 Compared to Vaccine Acceptors, the Vaccine Ambivalent expressed greater concerns about
192 serious adverse effects and newer vaccines carrying more risks. Across all ten items, Vaccine
193 Rejectors expressed hesitancy to a great degree.

194

195 There were significant associations between latent class membership and vaccination status at
196 each wave of follow-up (Table 2). During Jan/Feb 2021, 27.3% of Acceptors, 9.1% of the
197 Ambivalent, and 12.2% of Rejectors were vaccinated. By Apr/May 2021, these numbers were
198 90.7%, 62.4%, and 30.7%, respectively.

199

200 The relationships between latent class membership for vaccination attitudes and risk reduction
201 behavior varied over time (Table 3 and Supplementary Table 3). There was a significant
202 relationship by risk reduction behavior except for the measure of having face-to-face contact. In
203 general, the Vaccine Ambivalent had behaviors intermediate to Acceptors and Rejectors at
204 baseline in spring 2020, but that they also had a high degree of fatigue in these behaviors over
205 time, trending towards Vaccine Rejectors by the end of 2020. For example, in May/Jun 2020,
206 46.6% of the Ambivalent self-isolated for 7 days (compared to 48.9% of Vaccine Rejectors and
207 64.5% of Vaccine Acceptors). By Dec 2020/Jan 2021, these proportions dropped among all
208 groups (31.6% of the Vaccine Ambivalent self-isolated for 7 days, compared to 20.3% of
209 Vaccine Rejectors and 46.3% of Vaccine Acceptors, see Supplementary Table 3).

210

211 Among latent classes there were statistically significant differences in the distributions of age,
212 race, education, pre-COVID-19 employment status, and relationship status (Table 1). Compared
213 to Vaccine Acceptors, a higher proportion of Vaccine Ambivalent and Vaccine Rejectors were
214 younger than 65 years old (36.0%, 51.5%, 54.4%, respectively). There were higher proportions
215 of Black (12.1%) and other race (19.0%) participants among the Ambivalent compared to both
216 Acceptors (5.2% Black, 5.5% other) and Rejectors (2.6% Black, 2.7% other). Among Acceptors,
217 the highest proportion of participants had a postgraduate or professional degree (35.7%),
218 whereas some college or two-year associate degrees were the most common level of education
219 among the Ambivalent (34.3%) and Rejectors (37.7%). Most Rejectors were employed before
220 the pandemic (64.2%) compared to less than half of the Ambivalent (46.3%) and approximately
221 one-third of Acceptors (34.2%). Additionally, more Acceptors were in a relationship (68.8%) than
222 either the Ambivalent (50.7%) or Rejectors (57.0%).

223

224 **DISCUSSION**

225 Low acceptance of a COVID-19 vaccine by segments of the population could foster continued
226 outbreaks and amplify challenges to controlling the spread of SARS-CoV-2. In the US, where
227 supply of COVID-19 vaccine currently exceeds demand, it is important to identify what vaccine-
228 related beliefs are associated with actual vaccination. In a longitudinal study of middle-aged and
229 older adults in the US, we found a large majority were Vaccine Acceptors (for vaccines in
230 general) and had received a COVID-19 vaccine by April/May 2021. The Vaccine Ambivalent will
231 be important targets in the identification of strategies to increase population vaccine uptake,
232 especially as COVID-19 vaccination booster programs roll out.

233

234 As measured through a latent class analysis of an adult Vaccine Hesitancy Scale,[19] almost 9
235 in 10 adults fell into the Vaccine Acceptor class, and were among the first to receive a COVID-
236 19 vaccine when it was introduced in the United States. The adult Vaccine Hesitancy Scale
237 measures hesitancy about vaccines in general, not for COVID-19 vaccines, but a previous study
238 also found high overlap between patterns of vaccine hesitancy in general and rejection for
239 COVID-19 vaccine specifically.[20] Another study of adults in Tennessee found that many
240 individuals believe they have not changed their attitudes towards vaccines because of the
241 pandemic,[21] which suggests that many vaccine beliefs are deeply entrenched.

242

243 We also want to highlight the sociodemographic differences across these classes. A previous
244 survey found younger adults, women, non-Hispanic Black persons, adults not in cities, and
245 adults with lower educational attainment, with lower income, and without health insurance were
246 the most likely to report not wanting to receive a COVID-19 vaccine.[22] In our study, the
247 Vaccine Ambivalent were more likely to be Black or Hispanic than the Vaccine Acceptors or
248 Rejectors. Prior to the COVID-19 pandemic, adult influenza vaccination rates in the US were
249 about 10 percentage points lower in Hispanic and Black Americans compared to their white
250 counterparts,[23] which could be due to vaccine hesitancy, but also issues of access,

251 affordability,[24] and racism experienced within the healthcare system.[24] To mitigate
252 disparities in who contracts SARS-CoV-2, it will be important to increase vaccination uptake in
253 Black and Hispanic Americans, for instance by involving trusted community leaders in delivering
254 pro-vaccine messaging.[25]

255

256 We found that a greater share of the middle-aged and older population was Vaccine Ambivalent
257 than Vaccine Rejectors, indicating they would be a more responsive target for strategies to
258 increase population vaccine uptake. Past research into pediatric vaccines has introduced the
259 concept of “fence-sitters”,[26] who are those parents who have concerns about vaccines and
260 may delay or selectively choose certain vaccines based on their own research. A response to
261 these individuals should target their particular concerns[27] and not assume that the individual
262 has a knowledge deficit.[26] The present study adds several pieces of information about the
263 Vaccine Ambivalent, to distinguish them from Acceptors or Rejectors. First, this study showed
264 that unlike Rejectors and like Acceptors, the Vaccine Ambivalent believe that being vaccinated
265 could be important for the health of others. Tailoring to the individual will be important here.

266 According to the “protector” schema, whom the individual is protecting matters; vaccine
267 promotional materials can highlight protection against a concrete person, like a close relative,
268 instead of a generic “other”. [28] Second, we found that many in the Vaccine Ambivalent group
269 do not trust doctors, and so these individuals may not always be the best delivery mechanism.

270

271 The Vaccine Ambivalent had other concerns, such as the riskiness of newer vaccines, that has
272 been echoed in previous studies. In a review of vaccine hesitancy studies during the COVID-19
273 pandemic, Troiano found many studies revealed substantial concerns about the speed of
274 vaccine development.[29] A survey of adults in December 2020 found that among those not
275 intending to be vaccinated, the main reasons included concerns about side effects and safety
276 (29.8%) and that the vaccine was developed rapidly (10.4%).[22] In a study by Nguyen et

277 al.[22] 14.5% of adults mentioned wanting to wait and see if the vaccine is safe and effective
278 prior to receiving it. The slower uptake of COVID-19 vaccination among the Vaccine Ambivalent
279 in our study points to this “wait-and-see” approach, and is in line with the importance of positive
280 experiences (such as personally knowing individuals safely vaccinated) in vaccine decision-
281 making.[30]

282

283 Beyond vaccination, the Vaccine Acceptors also adopted more risk reduction behaviors,
284 including washing hands, wearing masks, and social distancing. The Vaccine Ambivalent were
285 more likely to engage in behaviors to reduce risk of viral spread than Vaccine Refusers, which
286 could be a way to partially compensate for not receiving a vaccine by reducing risks through
287 other behaviors. Yet, other papers have also shown a correlation between vaccination intent
288 and social distancing and mask usage.[31] These findings may speak to a more general
289 “COVID-19 social identity”.[31] in showing outward behaviors congruent with groups believing
290 that the pandemic is real. Overall, more research is needed on how to encourage behaviors that
291 can limit spread of disease among those who want to “wait and see” prior to obtaining a
292 vaccine.

293

294 **Strengths and limitations**

295 Non-probability sampling strategy means that our sample is not population-representative.
296 Reassuringly, the proportion of vaccinated adults in our sample by the end of May 2021 is
297 similar to that of the general US population of this age range at the same point in time (85% of
298 our sample, compared to 88% of those aged 65-74 and 84% of those aged ≥ 75 in the general
299 population[10]). The study sample was weighted to the general US population aged ≥ 55 , but the
300 sample may not represent individuals who were too sick to participate, or who could not access
301 the Internet. The population sampling weight decreases selection and other sampling biases, so
302 while our results may not be representative of the general population, the estimated

303 relationships should be minimally biased. Individuals may have responded in a way they felt
304 was socially desirable for vaccine opinions, vaccination status, and risk reduction behaviors. A
305 strength of the study was the large sample size and broad geographic scope, with
306 representation from all 50 US states and the District of Columbia. Data collection began early in
307 the pandemic and continued longitudinally, meaning we were able to capture changes in
308 behaviors throughout course of the pandemic.

309

310 **Conclusions**

311 Most middle-aged and older Americans have positive attitudes about vaccines. Vaccine
312 Ambivalent adults appear more similar to Vaccine Rejectors than Acceptors in terms of their
313 demographic characteristics and in their initial vaccination behaviors. As the pandemic
314 continued through 2020 and into 2021, the Vaccine Ambivalent maintained their engagement in
315 risk reduction behaviors more than Rejectors. Although descriptive, these findings have
316 important implications for public health messaging and planning. Notably, we observed that,
317 over time, Vaccine Ambivalent middle-aged and older adults seemed to move towards the
318 vaccination behaviors of Vaccine Acceptors. This finding suggests that, with appropriate
319 messaging and engagement of trusted leaders (not necessarily physicians) in conversations
320 about preventive measures, many, or at least some, Vaccine Ambivalent individuals may be
321 convinced to get vaccinated and engage in other preventive behaviors.

322

323

324 **Declarations**

325

326 **Competing Interests:**

327 We declare no competing interests.

328

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336 **Ethics approval**

337 The University of Michigan Health Sciences and Behavioral Sciences Institutional Review Board
338 (IRB # HUM00179632) provided ethical approval to the COVID-19 Coping Study. In this
339 internet-based survey, participants read an informed consent form and had to click “agree”
340 before seeing the questionnaire.

341

342

343 **Data availability**

344 Data are available at: <https://doi.org/10.3886/E131022V1>.

345

346 **Author contributions**

347 Conceptualization: Abram L. Wagner, Jessica M. Finlay, Lindsay C. Kobayashi; Formal analysis
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349 Wagner, Julia M. Porth; Writing – review and editing: Zhenke Wu, Matthew L. Boulton, Jessica
350 M. Finlay, Lindsay C. Kobayashi; Funding acquisition: Jessica M. Finlay, Lindsay C. Kobayashi

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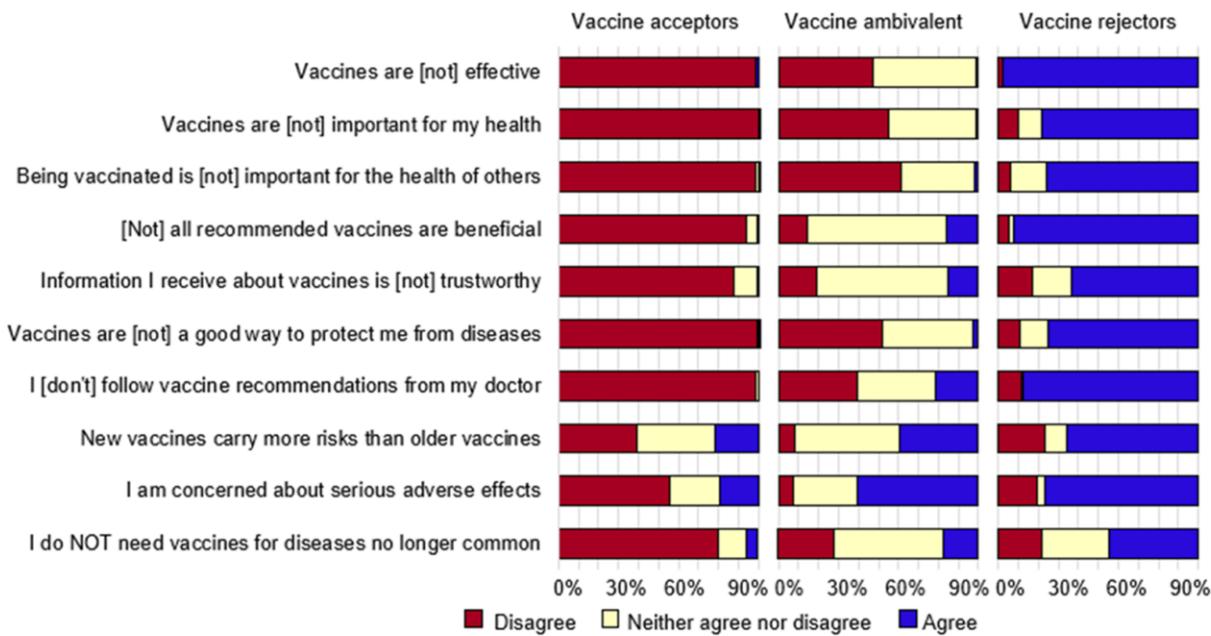
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459 **Figure legends**
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Fig. 1. Attitudes about vaccines stratified by latent class.
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Table 1. Distributions of demographic characteristics in entire sample and within each Latent Class¹

Sociodemographic factor	Total sample (N=2,358)	Vaccine Acceptors	Vaccine Ambivalent	Vaccine Rejectors	Adjusted p-value ²
Latent class membership	---	88.9%	8.6%	2.5%	---
Sex					1
Male	40.4%	41.6%	35.1%	29.3%	
Female	59.6%	58.4%	64.9%	70.7%	
Age					0.030
<65 years old	38.4%	36.0%	51.5%	54.4%	
≥65 years old	61.6%	64.0%	48.5%	45.6%	
Race					<0.008
Black	5.9%	5.2%	12.1%	2.6%	
White	87.2%	89.3%	68.9%	94.7%	
Other(s)	6.9%	5.5%	19.0%	2.7%	
Ethnicity					0.300
Hispanic or Latin(x)	4.4%	3.4%	9.8%	10.3%	
Not Hispanic or Latin(x)	95.6%	96.6%	90.2%	89.7%	
Education					0.008
≤High school	12.8%	11.2%	23.3%	20.3%	
Some college or associate's degree	26.2%	24.6%	34.3%	37.7%	
Bachelor's degree	28.3%	28.5%	27.0%	27.3%	
Graduate degree	32.7%	35.7%	15.4%	14.7%	
Pre-COVID-19 employment status					<0.008
Employed	36.6%	34.2%	46.3%	64.2%	
Not Employed	10.2%	8.7%	20.8%	11.9%	
Retired	53.2%	57.1%	32.9%	23.9%	
Relationship Status					0.020
Married or in a relationship	66.4%	68.8%	50.7%	57.0%	
Not married or in a relationship	33.6%	31.2%	49.3%	43.0%	
Self-reported health					1
Poor	1.8%	1.6%	3.6%	1.2%	
Fair	11.3%	10.8%	16.8%	5.4%	
Good	31.3%	31.5%	29.2%	33.5%	
Very good	37.4%	37.8%	34.9%	36.4%	
Excellent	18.2%	18.3%	15.5%	23.5%	
Multi-morbidity					1
Fewer than 2 chronic conditions	85.7%	85.0%	87.9%	94.1%	
2 or more chronic conditions	14.3%	15.0%	12.1%	5.9%	

¹Weighted by 9-month sample weight × attrition weight²Holm-Bonferroni-adjusted p-value of Rao-Scott Chi-square, which takes sampling and attrition weighting into account

Table 2. Vaccination status at 9-, 10-, 11-, and 12-month follow-up in entire sample and within each Latent Class¹

	Total sample	Vaccine Acceptors	Vaccine Ambivalent	Vaccine Rejectors	Adjusted p-value ²
Vaccination status Jan/Feb 2021					<0.004
Vaccinated	24.7%	27.3%	9.1%	12.2%	
Not vaccinated	75.3%	72.7%	90.9%	87.8%	
Vaccination status Feb/Mar 2021					<0.004
Vaccinated	50.2%	55.1%	22.9%	18.9%	
Not vaccinated	49.8%	44.9%	77.1%	81.1%	
Vaccination status Mar/Apr 2021					<0.004
Vaccinated	73.0%	78.3%	47.3%	28.1%	
Not vaccinated	27.0%	21.7%	52.7%	71.9%	
Vaccination status Apr/May 2021					<0.004
Vaccinated	85.3%	90.7%	62.4%	30.7%	
Not vaccinated	14.7%	9.3%	37.6%	69.3%	

¹Weighted by 9-month sample weight × attrition weight

²Holm-Bonferroni-adjusted p-value of Rao-Scott Chi-square, which takes sampling and attrition weighting into account

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Table 3. COVID-19 behaviors in entire sample and within each Latent Class¹

	Total sample	Vaccine Acceptors	Vaccine Ambivalent	Vaccine Rejectors	Adjusted p-value ²
Days in the past week spent self-isolating					0.008
Consistent complier	64.9%	67.7%	51.6%	32.1%	
Consistent non-complier	9.7%	8.1%	18.9%	22.5%	
Rejuvenator	8.1%	7.8%	11.6%	2.5%	
Fatiguer	17.3%	16.4%	17.9%	42.9%	
Days in the past week spent washing hands or using hand sanitizer more than normal					0.027
Consistent complier	72.2%	74.4%	62.0%	40.1%	
Consistent non-complier	10.2%	10.2%	7.6%	23.9%	
Rejuvenator	5.2%	4.4%	11.4%	5.3%	
Fatiguer	12.4%	11.0%	19.0%	30.7%	
Days in the past week participant has worn a face mask					0.040
Consistent complier	72.2%	74.4%	62.0%	40.1%	
Consistent non-complier	10.2%	10.2%	7.6%	23.9%	
Rejuvenator	5.2%	4.4%	11.4%	5.3%	
Fatiguer	12.4%	11.0%	19.0%	30.7%	
Days in the past week with in-person face-to-face contact for 15+ minutes					1
Consistent complier	32.0%	31.5%	34.2%	38.8%	
Consistent non-complier	23.4%	23.3%	23.3%	27.5%	
Rejuvenator	4.6%	4.7%	4.0%	3.1%	
Fatiguer	40.0%	40.5%	38.5%	30.6%	

¹Weighted by 9-month sample weight × attrition weight²Holm-Bonferroni-adjusted p-value of Rao-Scott Chi-square, which takes sampling and attrition weighting into account

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Supplemental Table 1. Convergence, AIC, and BIC for different vaccine opinion models

Model	Converges?	AIC	BIC
5-levels			
5-level categorical - only hesitancy variables			
One class	Yes	1.41E+09	1.41E+09
Two class	No		
5-level categorical - hesitancy variables + other vaccine opinions ¹			
One class	Yes	2.73E+09	2.73E+09
Two class	No	---	---
5-level ordinal - only hesitancy variables			
One class	Yes	1.41E+09	1.41E+09
Two class	No	---	---
5-level ordinal - hesitancy variables + other vaccine opinions ¹			
One class	Yes	2.73E+09	2.73E+09
Two class	No	---	---
3-levels			
3-level categorical - only hesitancy variables			
One class	Yes	7.53E+08	7.53E+08
Two class	Yes	6.24E+08	6.24E+08
Three class	Yes	5.97E+08	5.97E+08
Four class	Yes	5.84E+08	5.84E+08
Five class	No	---	---
3-level categorical - hesitancy variables + other vaccine opinions ¹			
One class	Yes	2.07E+09	2.07E+09
Two class	Yes	1.90E+09	1.90E+09
Three class	Yes	1.83E+09	1.83E+09
Four class	No	---	---
3-level ordinal - only hesitancy variables			
One class	Yes	7.53E+08	7.53E+08
Two class	Yes	6.24E+08	6.24E+08
Three class	No	---	---

3-level ordinal - hesitancy variables + other vaccine opinions ¹			
One class	Yes	2.07E+09	2.07E+09
Two class	Yes	1.90E+09	1.90E+09
Three class	No	---	---
Binary			
Binary- only hesitancy variables			
One class	Yes	5.01E+08	5.01E+08
Two class	Yes	3.84E+08	3.84E+08
Three class	Yes	3.74E+08	3.74E+08
Four class	No	---	---
Binary - hesitancy variables + other vaccine opinions ¹			
One class	Yes	1.09E+09	1.09E+09
Two class	Yes	9.50E+08	9.50E+08
Three class	Yes	9.09E+08	9.09E+08
Four class	No	---	---

¹Other vaccine opinion questions include: How often do you get vaccinated during the flu season? And In deciding whether to get the COVID-19 vaccine, how important is ____?

Other people in your community getting vaccinated, its being available for free, convenience in where you can get it, advice of your healthcare provider, advice of people you trust, your confidence in vaccine's safety, and your confidence in vaccine's effectiveness

Supplemental Table 2. Participants' opinions about vaccinations¹

Conditional probability	Total sample	Vaccine Acceptors	Vaccine Ambivalent	Vaccine Refusers
<i>Positive vaccine attitudes</i>				
Vaccines are effective				
Agree	89.6%	99.0%	47.3%	1.8%
Neither agree nor disagree	5.8%	0.0%	51.2%	0.0%
Disagree	4.6%	1.0%	1.5%	98.2%
Vaccines are important for my health				
Agree	91.5%	99.8%	54.9%	9.8%
Neither agree nor disagree	5.4%	0.0%	43.9%	11.7%
Disagree	3.1%	0.2%	1.2%	78.5%
Being vaccinated is important for the health of others in my community				
Agree	91.2%	98.9%	61.1%	5.7%
Neither agree nor disagree	5.7%	1.0%	37.3%	18.0%
Disagree	3.1%	0.1%	1.6%	76.3%
All recommended vaccines are beneficial				
Agree	81.5%	93.6%	14.2%	5.1%
Neither agree nor disagree	12.8%	5.8%	69.5%	2.7%
Disagree	5.7%	0.6%	16.3%	92.2%
Information I receive about vaccines from official sources is reliable and trustworthy				
Agree	77.6%	87.9%	19.3%	16.7%
Neither agree nor disagree	17.6%	11.2%	65.6%	19.6%
Disagree	4.8%	0.9%	15.1%	63.7%
Getting vaccines is a good way to protect me from diseases				
Agree	91.0%	99.6%	51.7%	10.8%
Neither agree nor disagree	5.8%	0.2%	45.5%	13.9%
Disagree	3.2%	0.2%	2.8%	75.3%
Generally, I follow vaccine recommendations from my doctor or healthcare provider				
Agree	88.6%	98.4%	39.1%	11.9%
Neither agree nor disagree	5.8%	1.6%	39.6%	0.5%
Disagree	5.6%	0.0%	21.3%	87.6%

<i>Negative vaccine attitudes</i>				
New vaccines carry more risks than older vaccines				
Agree	25.6%	22.1%	39.2%	65.8%
Neither agree nor disagree	39.5%	38.9%	52.7%	11.1%
Disagree	34.9%	39.0%	8.1%	23.1%
I am concerned about serious adverse effects of vaccines				
Agree	25.9%	19.2%	60.3%	76.8%
Neither agree nor disagree	25.1%	25.1%	32.4%	3.5%
Disagree	49.0%	55.7%	7.3%	19.7%
I do NOT need vaccines for diseases that are no longer common				
Agree	8.4%	5.8%	16.8%	43.9%
Neither agree nor disagree	19.2%	13.8%	55.0%	34.1%
Disagree	72.4%	80.4%	28.2%	22.0%

¹Weighted by 9-month sample weight × attrition weight

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Supplementary Table 3. COVID-19 behaviors in entire sample and within each Latent Class¹

	Total sample	Vaccine Acceptors	Vaccine Ambivalent	Vaccine Refusers	Adjusted p-value ²
Days in the past week spent self isolating					
May/Jun 2020					
0 days	7.9%	6.4%	20.0%	4.0%	
1-3 days	10.3%	10.3%	9.0%	19.3%	
4-6 days	19.7%	18.8%	24.4%	27.8%	
7 days	62.1%	64.5%	46.6%	48.9%	
Dec 2020 / Jan 2021					
0 days	12.7%	10.3%	24.2%	33.7%	
1-3 days	15.4%	15.0%	16.6%	21.5%	
4-6 days	28.2%	28.4%	27.6%	24.5%	
7 days	43.7%	46.3%	31.6%	20.3%	
Pattern of compliance					
Consistent complier	64.9%	67.7%	51.6%	32.1%	
Consistent non-complier	9.7%	8.1%	18.9%	22.5%	
Rejuvenator	8.1%	7.8%	11.6%	2.5%	
Fatiguer	17.3%	16.4%	17.9%	42.9%	
Days in the past week spent washing hands or using hand sanitizer more than normal					
May/Jun 2021					
0 days	4.4%	4.1%	2.9%	19.2%	
1-3 days	10.9%	9.8%	20.0%	8.0%	
4-6 days	8.1%	8.2%	8.7%	1.8%	
7 days	76.6%	77.9%	68.4%	71.0%	
Dec 2020 / Jan 2021					
0 days	12.3%	11.2%	16.8%	25.9%	
1-3 days	10.1%	10.0%	9.2%	16.3%	
4-6 days	11.9%	12.5%	10.9%	0.9%	
7 days	65.7%	66.3%	63.1%	56.9%	
Pattern of compliance					
Consistent complier	72.2%	74.4%	62.0%	40.1%	
Consistent non-complier	10.2%	10.2%	7.6%	23.9%	
Rejuvenator	5.2%	4.4%	11.4%	5.3%	
Fatiguer	12.4%	11.0%	19.0%	30.7%	
Days in the past week participant has worn a face mask					
May/Jun 2021					
0 days	5.6%	4.1%	16.0%	11.9%	
1-3 days	42.4%	41.9%	40.9%	66.0%	

4-6 days	21.5%	21.4%	24.4%	10.7%	
7 days	30.5%	32.6%	18.7%	11.4%	
Dec 2020 / Jan 2021					
0 days	2.8%	1.3%	10.9%	11.7%	
1-3 days	21.3%	20.4%	27.1%	26.3%	
4-6 days	18.1%	18.6%	14.1%	17.8%	
7 days	57.8%	59.7%	47.9%	44.2%	
Pattern of compliance					0.040
Consistent complier	72.2%	74.4%	62.0%	40.1%	
Consistent non-complier	10.2%	10.2%	7.6%	23.9%	
Rejuvenator	5.2%	4.4%	11.4%	5.3%	
Fatiguer	12.4%	11.0%	19.0%	30.7%	
Days in the past week with in-person face-to-face contact for 15+ minutes					
May/Jun 2021					
0 days	11.3%	11.7%	7.8%	14.0%	
1-3 days	15.7%	15.4%	18.5%	14.1%	
4-6 days	8.7%	7.1%	20.1%	12.4%	
7 days	64.3%	65.8%	53.6%	59.5%	
Dec 2020 / Jan 2021					
0 days	29.0%	30.4%	21.9%	17.8%	
1-3 days	35.5%	34.5%	41.5%	40.1%	
4-6 days	11.9%	11.7%	15.5%	5.2%	
7 days	23.6%	23.4%	21.1%	36.9%	
Pattern of compliance					1
Consistent complier	32.0%	31.5%	34.2%	38.8%	
Consistent non-complier	23.4%	23.3%	23.3%	27.5%	
Rejuvenator	4.6%	4.7%	4.0%	3.1%	
Fatiguer	40.0%	40.5%	38.5%	30.6%	

¹Weighted by 9-month sample weight × attrition weight

²Holm-Bonferroni-adjusted p-value of Rao-Scott Chi-square, which takes sampling and attrition weighting into account