

1 Detecting and describing stability and change in COVID-19 vaccine receptibility in the  
2 United Kingdom and Ireland

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4 Short title: COVID-19 vaccine receptibility in the UK and Ireland

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24

## 25 **Abstract**

26 COVID-19 continues to pose a threat to global public health. Multiple safe and effective  
27 vaccines against COVID-19 are available with one-third of the global population now  
28 vaccinated. Achieving a sufficient level of vaccine coverage to suppress COVID-19 requires,  
29 in part, sufficient acceptance among the public. However, relatively high rates of hesitance  
30 and resistance to COVID-19 vaccination persists, threatening public health efforts to achieve  
31 vaccine-induced population protection. In this study, we examined longitudinal changes in  
32 COVID-19 vaccine acceptance, hesitance, and resistance in two nations (the United Kingdom  
33 and the Republic of Ireland) during the first nine months of the pandemic, and identified  
34 individual and psychological factors associated with consistent non-acceptance of COVID-19  
35 vaccination. Using nationally representative, longitudinal data from the United Kingdom  
36 (UK; N = 2025) and Ireland (N = 1041), we found that (1) COVID-19 vaccine acceptance  
37 declined in the UK and remained unchanged in Ireland following the emergence of approved  
38 vaccines; (2) multiple subgroups existed reflecting people who were consistently willing to  
39 be vaccinated ('Accepters': 68% in the UK and 61% in Ireland), consistently unwilling to be  
40 vaccinated ('Deniers': 12% in the UK and 16% in Ireland), and who fluctuated over time  
41 ('Moveable Middle': 20% in the UK and 23% in Ireland); and (3) the 'deniers' and  
42 'moveable middle' were distinguishable from the 'accepters' on a range of individual (e.g.,  
43 younger, low income, living alone) and psychological (e.g., distrust of scientists and doctors,  
44 conspiracy mindedness) factors. The use of two high-income, Western European nations  
45 limits the generalizability of these findings. Nevertheless, understanding how receptibility to  
46 COVID-19 vaccination changes as the pandemic unfolds, and the factors that distinguish and  
47 characterise those that are hesitant and resistant to vaccination is helpful for public health  
48 efforts to achieve vaccine-induced population protection against COVID-19.

49 **Key words:** COVID-19; COVID-19 vaccination; vaccine hesitance; vaccine resistance.

## 50 **Highlights**

- 51 • Following the emergence of approved vaccines for COVID-19 there was a significant  
52 decrease in vaccine acceptance in the UK and no change in Ireland.
- 53 • Three distinct groups were identified in the UK and Irish populations: consistent  
54 vaccine accepters, consistent vaccine deniers, and those with changing willingness to  
55 be vaccinated against COVID-19.
- 56 • 61% and 68% of the Irish and UK populations were consistently willing to receive a  
57 COVID-19 vaccine, with a further 23% and 20% of these populations holding  
58 fluctuating levels of acceptance.
- 59 • Higher levels of conspiracy mindedness and distrust of doctors and scientists were  
60 consistently associated with vaccine hesitancy and resistance in the Irish and UK  
61 populations.

62

## 63 Introduction

64 The rapid development of safe and effective vaccines against Coronavirus Disease  
65 (COVID-19) represents one of the greatest collaborative scientific achievements of our  
66 lifetime. As of August 2021, four vaccines have been authorised by the European Medicines  
67 Agency, three have been authorized for emergency use by the United States Food and Drug  
68 Administration, and 99 are undergoing clinical trials on humans [1]. Just under five billion  
69 vaccines doses have been administered, globally, meaning that 31% of the world's population  
70 have been vaccinated and it is estimated that 75% of the world's population will be  
71 vaccinated by February 2021 [2]. Sufficient uptake of COVID-19 vaccines not only requires  
72 the coordinated action of governments, communities, and individuals alike to ensure adequate  
73 vaccine *delivery* (e.g., via production, logistics, procurement, financing, and service delivery  
74 components of the health system), but also to ensure vaccine *receptibility*.

75 COVID-19 vaccine acceptance rates across the world range from lows of 24% in  
76 Kuwait and 44% in Lebanon to highs of 88% in China and 91% in India [3-5]. Concurrently,  
77 rising rates of vaccine hesitancy, whereby an individual delays or refuses vaccination despite  
78 the availability of inoculation services [6], remains one of the greatest global health threats  
79 listed by the World Health Organization [7]. As the term implies, however, vaccine hesitancy  
80 is not immutable, and individual attitudes towards a specific vaccine can change over time as  
81 a function of a wide-range of interdependent individual, social, and vaccination-specific  
82 factors [8, 9] including, but not limited to, perceptions of susceptibility to pathogen exposure  
83 [10], severity of illness [11], perceived vaccine safety and efficacy [11, 12], and recency of  
84 vaccine development [13]. Accordingly, some have suggested that vaccine hesitancy is better  
85 conceptualised as existing on a continuum and bookended by 'decliners' and 'accepters', or  
86 those who completely reject or accept all vaccines, respectively [14]. Levels of COVID-19  
87 vaccine acceptability have fluctuated considerably throughout the pandemic. Most recent data

88 from the global survey of knowledge, attitudes, and practices around COVID-19 (KAP  
89 COVID-19) - which has reached over 1.7 million people in 67 countries across as many as 19  
90 waves of data collection in some contexts - indicates that only 63% of individuals would  
91 accept a COVID-19 vaccine as of the 31<sup>st</sup> of January 2021 [15]. Encouragingly, however,  
92 these same data suggest that willingness to be vaccinated has increased in nations that have  
93 successfully launched COVID-19 vaccination programmes (e.g., the United Kingdom [UK]).

94 Previous work carried out by our group, the COVID-19 Psychological Research  
95 Consortium, found that resistance to COVID-19 vaccination in the UK and the Republic of  
96 Ireland is associated with distrust of experts and authority figures (i.e., scientists, health care  
97 professionals, and government), stronger religious, conspiratorial, and paranoid beliefs, a  
98 higher internal locus of control, preference for hierarchically structured and authoritarian  
99 societies, anti-migrant views, lower levels of agreeableness, conscientiousness, and emotional  
100 stability [16]. Similarly, the ‘attitude roots’ model of science rejection proposes that  
101 conspiratorial beliefs, disgust sensitivity, trait reactance – as a motivational state that arises  
102 when people feel that their behavioural freedom has been threatened or taken away [17] - and  
103 hierarchical worldviews are central to understanding individual differences in vaccine  
104 resistant attitudes [18-21]. Thus, understanding the individual factors, including  
105 psychological dispositions, that predict whether vaccine hesitant individuals change their  
106 minds about COVID-19 vaccination, as well as the factors that might predict a move towards  
107 acceptance or resistance over time is paramount, albeit currently less well understood [9].

108 In light of these existing gaps, the current study was planned with three primary  
109 objectives. The first was to examine changes in COVID-19 vaccine acceptance, hesitance,  
110 and resistance in the Irish and UK adult populations across four time periods (Waves) during  
111 the first nine months of the global pandemic. We have previously reported on the changes in  
112 these populations across the first three waves of the survey (i.e., March-April, April-May, and

113 July-August 2020) [22]; however, as these data were obtained prior to the development of  
114 safe and effective vaccines for COVID-19, our focus in this study is on *changes* from Wave 3  
115 (July/August 2020) to Wave 4 (November/December 2020) when populations transitioned  
116 from having to contemplate a hypothetical vaccine to considering an actual, available  
117 vaccine.

118         Understanding that people’s willingness to accept a COVID-19 vaccine may fluctuate  
119 over time, our second objective was to determine if there were multiple groups in each  
120 sample with distinct probabilities of accepting a COVID-19 vaccine over time. We  
121 hypothesised that there would be two stable groups in each sample: one representing people  
122 with consistently high probabilities of accepting a COVID-19 vaccine (‘Accepters’), and the  
123 other representing people with consistently low probabilities of accepting a COVID-19  
124 vaccine (‘Deniers’). Additionally, we expected to identify a group (or groups) in each sample  
125 with fluctuating probabilities of accepting a COVID-19 vaccine; a group that have often been  
126 termed the movable middle.

127         Finally, we sought to identify key sociodemographic and psychological factors that  
128 were associated with belonging to any group that was not consistent in their acceptance of a  
129 COVID-19 vaccine. Our intention with the second and third objectives was to develop a  
130 comprehensive understanding of the people who were *not consistent* in their willingness to  
131 accept a COVID-19 vaccine so that targeted and effective public health strategies could be  
132 developed to reach those who can still change their minds.

## 133 **Material and methods**

### 134 **Participants and procedures**

135         This study is based on data from the Irish and UK strands of the COVID-19  
136 Psychological Research Consortium (C19PRC) study. The C19PRC study was established to  
137 track the social, political, economic, and mental health effects of the COVID-19 pandemic on

138 society. Data for this study were collected at four assessment points during the first nine  
139 months of the COVID-19 pandemic. Wave 1 data were collected in the UK between March  
140 23<sup>rd</sup> and 28<sup>th</sup>, 2020, and in Ireland between March 30<sup>th</sup> and April 5<sup>th</sup>, 2020. These dates  
141 coincided with the initial public health lockdown measures in the respective countries. Wave  
142 2 data were collected in the UK from April 22<sup>nd</sup> to May 1<sup>st</sup>, 2020, and in Ireland from April  
143 30<sup>th</sup> to May 19<sup>th</sup>, 2020. Wave 3 data were collected in the UK from July 9<sup>th</sup> to July 23<sup>rd</sup>, 2020,  
144 and in Ireland from July 16<sup>th</sup> to August 8<sup>th</sup>, 2020. Finally, Wave 4 data were collected in the  
145 UK from November 25<sup>th</sup> to December 22<sup>nd</sup>, 2020, and in Ireland from December 2<sup>nd</sup> to  
146 December 22<sup>nd</sup>, 2020.

147         The UK and Irish samples were collected using a non-probability Internet panel  
148 survey design. The survey research company Qualtrics was employed to recruit participants  
149 from traditional, actively managed, double-opt-in research panels via email, SMS, or in-app  
150 notifications. Inclusion criteria for both samples were that respondents were aged 18 years or  
151 older, residing in the UK or Ireland, respectively, and capable of completing the survey in  
152 English. Ethical approval was granted by the research ethics committees at the University of  
153 Sheffield (Reference number: 033759), Ulster University (Reference number: 230320), and  
154 Maynooth University (Reference number: SRESC-2020-2402202). Participants were  
155 remunerated by Qualtrics, and informed electronic consent was obtained from all  
156 participants. Quota sampling methods were used at Wave 1 to generate samples that  
157 represented the general adult populations of both nations. In the UK, the sample was recruited  
158 to match known population quotas for sex, age, and income distributions. In Ireland, the  
159 sample was recruited to match known population quotas for sex, age, and regional  
160 distribution. Further details regarding the UK and Irish samples, including evidence of their  
161 representativeness, are presented elsewhere [23-25].

162 As described in an earlier study [16], power analyses to determine optimal sample  
163 sizes were calculated to detect common mental health disorders such as Major Depressive  
164 Disorder and Posttraumatic Stress Disorder. Sample size calculations were performed to  
165 detect a disorder with a 4% prevalence rate, with a precision of 1%, and 95% confidence  
166 levels. This resulted in a required sample size of 1,476. As Qualtrics could only guarantee a  
167 sample size of 1,000 participants in Ireland, this was set as the target sample size in Ireland.  
168 Holding all other parameters in the sample size calculation equal, this sample size resulted in  
169 a precision of 1.21%. Given the substantially larger population of the UK and thus the  
170 availability of a larger pool of potential participants, we set a target sample size of 2,000  
171 people.

172 At Wave 1, the sample size in the UK was 2,025 and 1,041 in Ireland. The  
173 sociodemographic characteristics for both samples at Wave 1 are reported in Table 1. In the  
174 UK, the recontact rate was 69% ( $n = 1406$ ) at Wave 2, 58% ( $n = 1166$ ) at Wave 3, and 63%  
175 ( $n = 1271$ ) at Wave 4. Those who responded at each wave significantly differed ( $p < .05$ )  
176 from non-responders on a range of sociodemographic variables including being older, male,  
177 living with fewer adults, higher income earners, born in the UK, not living in a city, having a  
178 post-secondary education, and not having a suspected or confirmed COVID-19 infection.

179 In Ireland, the recontact rate was 49% ( $n = 506$ ) at Wave 2, 51% ( $n = 534$ ) at Wave 3,  
180 and 40% ( $n = 416$ ) at Wave 4. Respondents significantly differed ( $p < .05$ ) from non-  
181 responders by being older, more likely to have been born in Ireland, not living in a city, to  
182 have a pre-existing health condition, and not having a suspected or confirmed COVID-19  
183 infection. Management of missing data is outlined in the data analysis section.

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187 **Table 1. Sociodemographic characteristics of the Irish and UK samples.**

Ireland (N = 1041)	%	UK (N = 2025)	%
<b>Sex</b>		<b>Sex</b>	
Female	51.5	Female	51.7
Male	48.2	Male	48.3
<b>Age</b>		<b>Age</b>	
18-24	11.1	18-24	12.1
25-34	19.2	25-34	18.8
35-44	20.6	35-44	17.4
45-54	15.9	45-54	20.2
55-64	21.0	55-64	17.2
65+	12.2	65+	14.2
<b>Born in Ireland</b>	70.7	<b>Born in UK</b>	90.6
<b>Region of Ireland</b>		<b>Region of UK</b>	
Leinster	55.3	England	86.9
Munster	27.3	Scotland	7.8
Connacht	12.0	Wales	3.1
Ulster	5.4	Northern Ireland	2.3
<b>Ethnicity</b>		<b>Ethnicity</b>	
Irish	74.8	White British/Irish	85.5
Irish Traveller	0.3	White non-British/Irish	5.7
Other White background	17.3	Indian	2.0
African	1.9	Pakistani	1.3
Other Black background	0.3	Chinese	0.9
Chinese	0.4	Afro-Caribbean	0.6
Other Asian	3.2	African	1.3
Mixed Background	1.8	Arab	0.1
		Bangladeshi	0.3
		Other Asian	0.5
<b>Living location</b>		<b>Living location</b>	
City	24.5	City	24.6
Suburb	18.1	Suburb	28.2
Town	26.8	Town	30.6
Rural	28.8	Rural	16.5
<b>Highest Education</b>		<b>Highest Education</b>	
No qualification	1.2	No qualifications	2.9
Finished mandatory schooling	6.4	O-level/GCSE or similar	19.0
Finished secondary school	22.4	A-level or similar	18.1
Undergraduate degree	22.5	Diploma	5.6
Postgraduate degree	19.8	Undergraduate degree	28.2
Other technical qualification	27.9	Postgraduate degree	15.6
		Technical qualification	9.3
		Other	1.3

<b>2019 income</b>		<b>2019 income</b>	
0-€19,999	24.6	£0-£15490	20.2
€20,000-€29,999	21.3	£15,491-£25,340	20.2
€30,000-€39,999	19.5	£25,341-£38,740	19.0
€40,000-€49,999	12.7	£38,741-£57,930	20.2
€50,000+	21.9	£57,931+	20.2
<b>Employment status</b>		<b>Employment status</b>	
Full-time (self)/employed	43.3	Full-time (self)/employed	48.8
Part-time (self)/employed	15.7	Part-time (self)/employed	15.0
Retired	15.0	Retired	16.5
Unemployed	8.4	Unemployed	11.7
Student	6.3	Student	4.7
Unemployed (disability or illness)	5.6	Unemployed (disability or illness)	3.4
Unemployed due to COVID-19	5.7		
<b>Religious identification</b>		<b>Religious identification</b>	
Christian	69.8	Christian	50.4
Muslim	1.6	Muslim	3.0
Jewish	0.2	Jewish	0.8
Hindu	1.1	Hindu	0.6
Buddhist	0.6	Buddhist	0.8
Sikh	0.1	Sikh	0.5
Other religion	3.8	Other	6.0
Atheist	15.3	Atheist	25.4
Agnostic	7.5	Agnostic	12.5
<b>Lone adult in household</b>		<b>Lone adult in household</b>	
Yes	18.4	Yes	22.4
<b>Children in the household</b>		<b>Children in the household</b>	
Yes	39.7	Yes	29.2
<b>Physical health problem</b>	16.7	<b>Physical health problem</b>	15.4
<b>Pregnant</b>	4.0	<b>Pregnant</b>	3.8
<b>COVID-19 infection - self</b>	2.3	<b>COVID-19 infection - self</b>	2.4
<b>COVID-19 infection – other</b>	6.7	<b>COVID-19 infection – other</b>	5.5
<b>Mental health treatment</b>	33.0	<b>Mental health treatment</b>	32.0
<b>Voting behaviour</b>		<b>Voting behaviour</b>	
Fine Gael	17.4	Conservative Party	42.0
Fianna Fail	11.9	Labour Party	28.4
Sinn Fein	22.8	Liberal Democrats	10.3
Green Party	5.4	Green Party	5.0
Labour Party	3.8	Other nationalist parties	5.1
Other left-wing parties	6.1	Other unionist parties	3.3
Independent	8.1	Other party	2.8
Did not vote	24.5	Did not vote	4.2

## 189 **Materials**

### 190 *COVID-19 vaccination status*

191 In the UK and Irish samples, participants were asked the following question at Waves  
192 1, 2, and 3: *'If a new vaccine were to be developed that could prevent COVID-19, would you*  
193 *accept it for yourself?'* At Wave 4, participants in both samples were asked: *'Multiple*  
194 *vaccines for COVID-19 have now been developed. Will you take a vaccine for COVID-19*  
195 *when it becomes available to you?'* The response options at all times were 'Yes', 'Maybe',  
196 and 'No'. Those who answered 'Yes' were classified as 'vaccine accepting', those who  
197 responded 'Maybe' were classified as 'vaccine hesitant', and those who responded 'No' were  
198 classified as 'vaccine resistant'.

### 199 *Sociodemographic, political, and health indicators (Measured at Wave 1)*

200 The sociodemographic, political, and health indicator variables used in this study  
201 were identical to those utilized in our previous study [16], and all are listed in Table 1. For  
202 analytical purposes, several of these variables were recoded. Living location was recoded to  
203 represent city dwelling vs. non-city dwelling; education status was recoded to represent post-  
204 secondary education vs. non-post-secondary education; employment status was recoded to  
205 represent unemployed vs. all other options; and religion was recoded to represent any  
206 religious identification vs. atheist or agnostic. Additionally, due to limited numbers in various  
207 subgroups, ethnicity was recoded to represent self-identified Irish ethnicity vs. non-Irish  
208 ethnicity in the Irish sample.

### 209 *Psychological indicators (Measured at Wave 1)*

210 Personality traits: The Big-Five Inventory (BFI-10) [26] measures the traits of  
211 openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism.  
212 Each trait is measured by two items using a five-point Likert scale that ranges from 'strongly  
213 disagree' (1) to 'strongly agree' (5). Higher scores reflect higher levels of each personality

214 trait, and Rammstedt and John [26] reported good reliability and validity for the BFI-10 scale  
215 scores. Internal reliability coefficients are not provided as this scale measures each trait using  
216 only two items, and it is well documented that coefficient alpha is inappropriate and  
217 meaningless for two-item scales [27].

218       Locus of control: The Locus of Control Scale (LoC) [28] measures internal (e.g., ‘My  
219 life is determined by my own actions’) and external locus of control. The latter has two  
220 components, ‘Chance’ (e.g., ‘To a great extent, my life is controlled by accidental  
221 happenings’) and ‘Powerful Others’ (e.g., ‘Getting what I want requires pleasing those people  
222 above me’). Each subscale was measured using three questions and a seven-point Likert scale  
223 that ranges from ‘strongly disagree’ (1) to ‘strongly agree’ (7). Higher scores reflect higher  
224 levels of each construct. The internal reliabilities of the Internal and Chance subscale scores  
225 in the Irish sample were slightly lower than desirable ( $\alpha = .67$  &  $.63$ , respectively) but  
226 somewhat stronger for the UK sample ( $\alpha = .71$  &  $.70$ , respectively), while those for the  
227 Powerful Others subscale scores were good in both samples (Ireland:  $\alpha = .78$ ; UK:  $\alpha = .85$ ).

228       Analytical/reflective reasoning: The Cognitive Reflection Task (CRT) [29] is a three-  
229 item measure of analytical reasoning where respondents are asked to solve logical problems  
230 designed to hint at intuitively appealing but incorrect responses. The response format was  
231 multiple choice with three foil answers (including the hinted incorrect answer), as  
232 recommended by Sirota and Juanchich [30]. The internal reliabilities of the CRT scores in the  
233 Irish and UK samples were  $\alpha = .67$  and  $\alpha = .69$ , respectively.

234       Altruism: The Identification with all Humanity scale (IWAH) [31] is a nine-item  
235 scale. Respondents are asked to respond to three statements with reference to three groups;  
236 people in my community, people from Ireland/ the UK, and all humans everywhere. The  
237 three statements were presented to respondents separately for each of the three groups, as  
238 follows: (1) How much do you identify with (feel a part of, feel love toward, have concern

239 for) ...? (2) How much would you say you care (feel upset, want to help) when bad things  
240 happen to ...? And, (3) When they are in need, how much do you want to help...? Response  
241 scale ranged from 1 'not at all' to 5 'very much'. Higher scores reflect greater identification  
242 with others, care for others, and a desire to help others. The internal reliabilities of each  
243 subscale of the IWAH in both the Irish and UK samples were excellent (identification with  
244 others  $\alpha = .79$  &  $.81$ ; care for others  $\alpha = .88$  &  $.89$ ; desire to help others  $\alpha = .86$  &  $.88$ ,  
245 respectively).

246 Conspiracy beliefs: The Conspiracy Mentality Scale (CMS) [32] measures conspiracy  
247 mindedness using five items with each scored on an 11-point scale (1 = 'Certainly not 0%' to  
248 11 = 'Certainly 100%'). Items include, 'I think that many very important things happen in the  
249 world, which the public is never informed about', and 'I think that there are secret  
250 organizations that greatly influence political decisions'. The internal reliability of the CMS in  
251 both the Irish and UK samples was good ( $\alpha = .84$  &  $.85$ , respectively).

252 Paranoia: The five-item persecution subscale from the Persecution and Deservedness  
253 Scale was used [33]. Participants rate their agreement with statements such as "I'm often  
254 suspicious of other people's intentions towards me" and "You should only trust yourself."  
255 Response options ranged from 'strongly disagree' (1) to 'strongly agree' (5) with higher  
256 scores reflecting higher levels of paranoia. The psychometric properties of the scale scores  
257 have been previously supported [34], and the internal reliability in both the Irish and UK  
258 samples was good ( $\alpha = .83$  &  $.86$ , respectively).

259 Trust: Respondents were asked to indicate the level of trust they have in political  
260 parties, Parliament, the government, the police, the legal system, scientists, and doctors and  
261 other health professionals. Responses were scored on a five-point Likert scale ranging from  
262 'do not trust at all' (1) to 'completely trust' (5). For this study, responses to the first five  
263 institutions were summed to generate a total score for 'trust in the state'. Responses to the

264 final two questions were summed to generate a total score for ‘trust in scientists and  
265 doctors/health professionals’.

266       Authoritarianism: The Very Short Authoritarianism Scale [35] includes six items  
267 assessing agreement with statements such as: ‘It’s great that many young people today are  
268 prepared to defy authority’ and ‘What our country needs most is discipline, with everyone  
269 following our leaders in unity’. All items were scored on a five-point Likert scale ranging  
270 from ‘strongly disagree’ (1) to ‘strongly agree’ (5), with higher scores reflecting higher levels  
271 of authoritarianism. The internal reliability of the scale scores in the Irish sample was lower  
272 than desirable ( $\alpha = .58$ ) but somewhat stronger for the UK sample ( $\alpha = .65$ ).

273       Social Dominance: Respondents’ levels of social dominance orientation were  
274 assessed using the eight-item Social Dominance Scale [36]. Respondents were asked the  
275 extent to which they opposed/favoured statements such as: ‘An ideal society requires some  
276 groups to be on top and others to be on the bottom’; ‘Some groups of people are simply  
277 inferior to other groups’; and ‘We should do what we can to equalize conditions for different  
278 groups’. Responses were scored using a 5-point Likert scale ranging from 1 ‘Strongly  
279 oppose’ to 5 ‘Strongly Favour’. Ho and colleagues demonstrated that the scale had good  
280 criterion and construct validity [36]. The internal reliability of the scale scores in both the  
281 Irish and UK samples was good ( $\alpha = .79$  &  $.82$ , respectively).

282       Attitude towards migrants: Two items assessing respondents’ attitudes towards  
283 migrants were taken from the British Social Attitudes Survey 2015 [37]. These were, (1)  
284 ‘Would you say it is generally bad or good for the UK’s economy that migrants come to the  
285 UK from other countries?’ (scored on a 10-point scale ranging from 1 ‘extremely bad’ to 10  
286 ‘extremely good’), and (2) ‘Would you say that the UK’s cultural life is generally  
287 undermined or enriched by migrants coming to live here from other countries?’ (scored on a

288 10-point scale ranging from 1 ‘undermined’ to 10 ‘enriched’). These items were phrased  
289 appropriately for use with the Irish sample.

## 290 **Data analysis**

291 The first objective was assessed by means of structural equation modelling (SEM). A  
292 SEM approach was used so that missing data could be most effectively managed using full  
293 information robust maximum likelihood estimation (MLR) [38]. This approach is helpful  
294 because it means that all available information at Wave 1 is used to estimate missingness at  
295 future waves, thus ensuring minimal loss of statistical power or sample representativeness.  
296 This method of estimation can also handle non-normally distributed variables [39]. This  
297 analytic process involved three steps. First, a ‘null’ model was specified where the  
298 proportions (e.g., in vaccine acceptance, hesitance, and resistance – all are estimated  
299 individually) at Waves 1-4 were constrained to be equal. Second, an ‘alternative’ model was  
300 specified where the proportions were freely estimated at each wave. These models differed by  
301 three degrees of freedom and significant differences in model fit were tested using a  
302 loglikelihood ratio test (LRT), which follows a chi-square ( $\chi^2$ ) distribution. Third, post-hoc  
303 pairwise comparisons were tested using a Wald  $\chi^2$  test.

304 The second objective was assessed using latent class analysis (LCA). Responses to  
305 the question about willingness to accept a COVID-19 vaccine (0 = Yes, 1 = Maybe, 2 = No)  
306 at Waves 1-4 were used as the observed indicators in the model. To understand the  
307 probability of consistent acceptance of a COVID-19 vaccine across time, we focused our  
308 interpretations on the probability of the first response (i.e., ‘Yes’) within each class. Models  
309 with one to six classes were estimated in the Irish and UK samples using MLR. To avoid  
310 solutions based on local maxima, 500 random starting values and 50 final stage optimizations  
311 were used. The relative fit of these models was compared using three information theory  
312 based fit statistics: the Akaike Information Criterion (AIC) [40], the Bayesian Information

313 Criterion (BIC) [41] and the sample size adjusted Bayesian Information Criterion (ssaBIC)  
314 [42]. The solution with the lowest value of these statistics is deemed superior, or if no  
315 minimum is found then the ‘diminishing gains in model fit’ for additional classes can be  
316 examined [43]. Simulation studies suggest that the BIC is optimal for identifying the correct  
317 number of classes [44]. Additionally, the Lo-Mendell-Rubin adjusted likelihood ratio test  
318 (LMR-A) [45] was used to compare models with increasing numbers of latent classes. When  
319 a non-significant value occurs, the model with one fewer class should be accepted. Model  
320 convergence, replication of the log-likelihood, entropy values, the plausibility of the model  
321 estimates, and the interpretability of the model solutions were also used to determine the  
322 optimal solution.

323         The third objective was assessed by adding the demographic and psychological  
324 predictor variables to the best fitting LCA models in the Irish and UK samples, respectively.  
325 A 3-step approach was used so that the inclusion of the predictor variables did not influence  
326 the formation of the classes [46].

## 327 **Results**

### 328 **Objective 1: Vaccine Acceptance, Hesitance, and Resistance**

329         From March/April 2020 (Wave 1) to December 2020 (Wave 4) in Ireland, there was  
330 evidence of significant change in rates of vaccine acceptance ( $\chi^2(3, 1030) = 40.12, p < .001$ )  
331 and resistance ( $\chi^2(3, 1030) = 45.34, p < .001$ ), but not vaccine hesitance ( $\chi^2(3, 1030) = 4.41,$   
332  $p = .220$ ). From March 2020 (Wave 1) to November/December 2020 in the UK, there was  
333 evidence of significant change in rates of vaccine acceptance ( $\chi^2(3, 2020) = 26.82, p < .001$ ),  
334 hesitance ( $\chi^2(3, 2020) = 39.96, p < .001$ ), and resistance ( $\chi^2(3, 2020) = 110.78, p < .001$ ).  
335 The nature of these changes in both samples are presented in Fig 1, and the pairwise  
336 comparisons are presented in Table 2.

337

338 **Table 2. Pairwise Comparisons for the Irish (N = 1,030) and UK (N = 2,020) Samples.**

	Ireland		UK	
	Wald $\chi^2$	<i>p</i>	Wald $\chi^2$	<i>p</i>
<b>COVID-19 Vaccine Acceptance</b>				
Wave 1 vs. Wave 2	0.07	.786	3.40	.065
Wave 1 vs. Wave 3	25.23	<.001	3.14	.077
Wave 1 vs. Wave 4	15.82	<.001	5.67	.017
Wave 2 vs. Wave 3	22.74	<.001	14.66	<.001
Wave 2 vs. Wave 4	12.40	<.001	0.59	.444
Wave 3 vs. Wave 4	0.07	.793	20.06	<.001
<b>COVID-19 Vaccine Hesitance</b>				
Wave 1 vs. Wave 2	1.99	.158	0.95	.330
Wave 1 vs. Wave 3	0.28	.595	29.52	<.001
Wave 1 vs. Wave 4	0.68	.411	21.41	<.001
Wave 2 vs. Wave 3	3.24	.072	22.65	<.001
Wave 2 vs. Wave 4	3.30	.069	13.50	<.001
Wave 3 vs. Wave 4	0.12	.726	0.41	.520
<b>COVID-19 Vaccine Resistance</b>				
Wave 1 vs. Wave 2	6.04	.014	18.91	<.001
Wave 1 vs. Wave 3	30.63	<.001	26.53	<.001
Wave 1 vs. Wave 4	20.01	<.001	92.23	<.001
Wave 2 vs. Wave 3	11.50	<.001	1.51	.220
Wave 2 vs. Wave 4	5.61	.018	35.32	<.001
Wave 3 vs. Wave 4	0.29	.589	25.28	<.001

339 Note:  $\chi^2$  = chi-square; all Wald  $\chi^2$  tests have one degree of freedom.

340

341

Fig 1 here

342 **Fig 1. COVID-19 Vaccine Acceptance, Hesitance, and Resistance in the Irish and UK**  
343 **Samples.**344 Data are presented as the proportion of the Irish (n = 1030) and United Kingdom (n = 2000)  
345 samples indicating COVID-19 acceptance (blue line), hesitance (orange line), and resistance  
346 (red line) across four waves of data collection (Wave 1, March-April 2020, Wave 2 is April-  
347 May 2020, Wave 3 is July-August 2020, and Wave 4 is November-December 2020).  
348

349 In the Irish sample, there were no significant changes in vaccine acceptance ( $\chi^2$  (1,  
350 1030) = 0.07,  $p = .793$ ), hesitance ( $\chi^2$  (1, 1030) = 0.12,  $p = .726$ ), or resistance ( $\chi^2$  (1, 1030) =  
351 0.29,  $p = .589$ ) between Wave 3 and Wave 4. In the UK sample, there was a significant  
352 decrease in vaccine acceptance ( $\chi^2$  (1, 2020) = 20.06,  $p < .001$ ), no significant change in  
353 vaccine hesitance ( $\chi^2$  (1, 2020) = 0.41,  $p = .520$ ), and a significant increase in vaccine  
354 resistance ( $\chi^2$  (1, 2020) = 25.28,  $p < .001$ ) between Wave 3 and Wave 4.

355

## 356 **Objective 2: Changing Probabilities of Vaccine Acceptance Over Time**

357 The full set of latent class analysis (LCA) results for the Irish and UK samples are  
358 presented in Table 3. In both samples, iterative models with one to four classes terminated  
359 normally, and the loglikelihood values were replicated. Models with more than four classes  
360 failed to converge or terminate normally in both samples suggesting that models with more  
361 than four classes were not viable representations of the sample data. Overall, the results were  
362 similar in the two samples in that the Bayesian Information Criteria (BIC) and sample size  
363 adjusted BIC (ssaBIC) values were lowest for the three-class models. The Lo-Mendell-Rubin  
364 adjusted likelihood-ratio test (LMR-A) values become non-significant at five classes, which  
365 suggests that a four-class model may be optimal; however, the  $p$ -values for the four-class  
366 model were also elevated (Ireland:  $p = .022$ ; UK:  $p = .027$ ), suggesting a better fit for the  
367 three-class model. Comparing the profiles of the three- and four-class models, a relatively  
368 large group of people with high probabilities of accepting a COVID-19 vaccine in the three-  
369 class model was differentiated in the four-class model to represent groups with high and  
370 moderate-to-high probabilities of vaccine acceptance. Thus, the addition of another class in  
371 the four-class model was not qualitatively different from the classes identified in the more  
372 parsimonious three-class model. Consequently, based on parsimony, model interpretability,

373 and recognition that BIC is an optimal index for model selection, the three-class model was  
 374 selected as the best fitting model of the Irish and UK sample data.

375

376 **Table 3. Fit Indices for Latent Class Models in the Irish and UK Samples.**

	Log likelihood	AIC	BIC	ssaBIC	LMR-A (p)	Entropy
<b>Ireland</b>						
1	-2250.26	4516	4556	4530	--	--
2	-1959.16	3952	4036	3982	573.02 (<.001)	.67
3	-1889.46	3830	3959	3876	137.22 (<.001)	.67
4	-1880.67	3831	4004	3892	17.30 (.022)	.64
5	-1873.07*	3834	4051	3911	15.08 (.883)	.56
6	-1867.68	3841	4103	3934	14.72 (.522)	.60
<b>UK</b>						
1	-4690.03	9396	9440	9415	--	--
2	-4098.31	8230	8325	8271	1166.41 (<.001)	.72
3	-3978.96	8009	8155	8073	234.84 (<.001)	.74
4	-3963.45	7996	8193	8082	30.57 (.027)	.63
5	-3959.39*	8006	8253	8113	8.01 (1.00)	.66
6 <sup>^</sup>	--	--	--	--	--	--

377 Note: \* models were not identified; AIC = Akaike Information Criterion; BIC = Bayesian  
 378 Information Criterion; ssaBIC = sample size adjusted Bayesian Information Criterion; LMR-  
 379 A = Lo-Mendell-Rubin adjusted likelihood ratio test.

380

381 The probabilities of accepting a COVID-19 vaccine over time in the Irish and UK  
 382 samples are represented in Figs 2 and 3, respectively. In the Irish sample, class 1 included  
 383 16% of people and was characterised by extremely low probabilities of accepting a COVID-  
 384 19 vaccine over time. Notably, there was a drop-off from an already low probability at Wave

385 1 (.15) to near zero probabilities of accepting a vaccine through Waves 2-4. This class was  
 386 labelled 'Deniers'. Class 2 included 61% of the sample and was characterised by high  
 387 probabilities of accepting a COVID-19 vaccine over time. Yet, it is noteworthy that the  
 388 probability of acceptance steadily declined from Wave 2 (.93) to Wave 4 (.82), despite  
 389 remaining high. This class was labelled 'Accepters'. Finally, class 3 included 23% of the  
 390 sample and was characterised by fluctuating probabilities of accepting a COVID-19 vaccine.  
 391 This class had a low-to-moderate probability of vaccine acceptance at Wave 1 (.34) that  
 392 declined markedly by Wave 3 (.05) before increasing again at Wave 4 (.26). This class was  
 393 labelled 'Movable Middle'.

394 Figs 2 and 3 here

395

396 **Fig 2. Latent Class Probabilities of COVID-19 Vaccine Acceptance in the Irish Sample.**

397 Data are presented as the latent class probabilities of COVID-19 acceptance in the Irish  
 398 sample (n = 1030) across four waves of data collection.

399

400 **Fig 3. Latent Class Probabilities of COVID-19 Vaccine Acceptance in the UK Sample.**

401 Data are presented as the latent class probabilities of COVID-19 acceptance in the UK  
 402 sample (N = 2000) across four waves of data collection.

403

404 In the UK sample, class 1 included 12% of people and was characterised by declining  
 405 probabilities of accepting a COVID-19 vaccine over time. This class had a low-to-moderate  
 406 probability of vaccine acceptance at Wave 1 (.32) that declined through Wave 2 (.17) and  
 407 Wave 3 (.09) and remained low at Wave 4 (.10), even after the introduction of an approved  
 408 vaccine. This class was labelled 'Deniers'. Class 2 included 68% of the sample and was  
 409 characterised by consistently high probabilities of vaccine acceptance. Notably, the  
 410 probability of vaccine acceptance rose steadily from Wave 1 (.86) to Wave 3 (.97) before  
 411 decreasing at Wave 4 (.88). This class was labelled 'Accepters'. Finally, class 3 included  
 412 20% of the sample and, like class 1, demonstrated declining probabilities of vaccine  
 413 acceptance from Wave 1 (.33) to Wave 2 (.12) but then diverged from class 1 as the

414 probability of vaccine acceptance increased steadily through Wave 3 (.19) and Wave 4 (.24).

415 This class was labelled ‘Movable Middle’.

### 416 **Objective 3: Correlates of Class Membership**

417 Based on our desire to understand why individuals were *not consistent* in their

418 willingness to accept a COVID-19 vaccine, the class of ‘Accepters’ in the Irish and UK

419 samples were set as the reference categories for analyses to determine the correlates of

420 membership in the ‘Deniers’ and ‘Movable Middle’ classes. These findings for the Irish and

421 UK samples are presented in Tables 4 and 5, respectively.

422

423 **Table 4. Correlates of Class Membership in the Irish sample (N = 1,030).**

	Deniers			Movable Middle		
	B	<i>p</i>	AOR	B	<i>p</i>	AOR
Females	0.34	.341	1.41	<b>0.76</b>	<b>.032</b>	<b>2.15</b>
18-24 years	1.45	.156	4.26	0.38	.667	1.47
25-34 years	1.49	.101	4.45	0.56	.393	1.74
35-44 years	1.35	.119	3.85	1.08	.069	2.96
45-54 years	1.27	.158	3.56	1.01	.093	2.73
<sup>a</sup> 55-64 years	0.25	.796	1.28	0.61	.263	1.84
Not born in Ireland	-0.16	.794	0.85	0.27	.615	1.31
Non-Irish ethnicity	1.10	.077	3.01	-0.68	.292	0.51
City dwelling	0.38	.297	1.46	0.15	.686	1.16
Post-secondary education	-0.24	.560	0.79	-0.09	.818	0.91
Unemployed	0.42	.299	1.53	-0.08	.856	0.93
Religious identification	-0.29	.475	0.75	0.35	.449	1.42
Living with another adult	<b>-0.91</b>	<b>.046</b>	<b>0.40</b>	-0.15	.727	0.86
Living with children	0.50	.209	1.65	-0.37	.306	0.69
Less than €20,000 per year income	<b>1.38</b>	<b>.026</b>	<b>3.96</b>	0.51	.359	1.66
€20,000 - €29,999 per year income	0.89	.138	2.43	0.56	.285	1.75
€30,000 - €39,999 per year income	1.01	.075	2.76	0.40	.412	1.49
<sup>b</sup> €40,000 - €49,999 per year income	0.92	.183	2.51	-0.16	.792	0.85

Physical health problem	-0.46	.391	0.63	-0.49	.223	0.61
Pregnant	0.49	.592	1.63	-0.20	.810	0.82
COVID-19 infection – self*	--	--	--	--	--	--
COVID-19 infection – other	0.13	.851	1.14	0.31	.546	1.37
Mental health treatment	0.08	.839	1.08	-0.75	.057	0.48
Chose not to vote in GE	0.34	.497	1.40	0.05	.913	1.05
Voted Sinn Fein in GE	0.19	.711	1.21	0.01	.989	1.01
Voted Independent in GE	0.72	.270	2.05	0.44	.493	1.56
<sup>c</sup> Voted ‘Other’ in GE	0.17	.771	1.19	-0.28	.566	0.76
Openness	0.18	.146	1.19	0.03	.728	1.03
Conscientiousness	0.16	.210	1.18	-0.03	.734	0.97
Extraversion	0.12	.230	1.12	0.15	.078	1.17
Agreeableness	-0.15	.221	0.86	-0.17	.216	0.84
Neuroticism	-0.15	.172	0.86	-0.04	.674	0.96
Locus of control - chance	-0.10	.169	0.91	0.05	.350	1.05
Locus of control - powerful others	-0.05	.363	0.95	<b>-0.11</b>	<b>.033</b>	<b>0.90</b>
Locus of control - internal	0.01	.875	1.01	0.08	.105	1.08
Empathy	-0.02	.408	0.98	-0.01	.755	0.99
Conspiracy mindedness	<b>0.04</b>	<b>.050</b>	<b>1.04</b>	<b>0.04</b>	<b>.038</b>	<b>1.04</b>
Paranoia	0.03	.537	1.03	0.02	.665	1.02
Cognitive reflection	-0.02	.899	0.98	-0.04	.780	0.96
Trust in Irish state institutions	0.01	.856	1.01	-0.01	.833	0.99
Trust in scientists and doctors	<b>-0.57</b>	<b>&lt;.001</b>	<b>0.57</b>	<b>-0.26</b>	<b>.013</b>	<b>0.77</b>
Authoritarianism	-0.03	.611	0.97	0.06	.166	1.06
Social dominance	0.03	.497	1.03	-0.00	.975	1.00
Attitudes toward migrants	<b>-0.14</b>	<b>.004</b>	<b>0.87</b>	-0.04	.360	0.96

424 Multinomial logistic regression analyses were performed to identify the key variables  
425 associated with belonging to the ‘Deniers’ and ‘Movable Middle’ classes. All predictors are  
426 adjusted for all other covariates in the model. Note: B = unstandardized beta value; p =  
427 statistical significance value; AOR = adjusted odds ratio; <sup>a</sup> = reference category is 65 year  
428 and older; <sup>b</sup> reference category is €50,000 or more income; <sup>c</sup> = reference category is voted for  
429 the incumbent government parties of Fine Gael or Fianna Fail; \* variable was not included in  
430 the model due to insufficient cases in each class; statistically significant associations (p < .05)  
431 are highlighted in bold.  
432

433 In the Irish sample, membership of the ‘Deniers’ class was significantly associated  
 434 with not living with any other adults (OR = 0.40), earning less than €20,000 per year (OR =  
 435 3.96), higher levels of conspiracy mindedness (OR = 1.04), lower levels of trust in scientists  
 436 and doctors (OR = 0.57), and stronger negative attitudes towards migrants in Irish society  
 437 (OR = 0.87).

438 Membership of the ‘Movable Middle’ class was significantly associated with being  
 439 female (OR = 2.15), lower levels of locus of control regarding the role of powerful others  
 440 (OR = 0.90), higher levels of conspiracy mindedness (OR = 1.04), and lower levels of trust in  
 441 scientists and doctors (OR = 0.77).

442

443 **Table 5. Correlates of Class Membership in the UK sample (N = 2,000).**

	Deniers			Movable Middle		
	B	<i>p</i>	AOR	B	<i>p</i>	AOR
Females	0.32	.209	1.38	<b>0.49</b>	<b>.011</b>	<b>1.64</b>
18-24 years	<b>2.79</b>	<b>.017</b>	<b>16.29</b>	<b>1.36</b>	<b>.003</b>	<b>3.90</b>
25-34 years	<b>2.97</b>	<b>.008</b>	<b>19.57</b>	<b>1.35</b>	<b>.002</b>	<b>3.84</b>
35-44 years	<b>2.78</b>	<b>.012</b>	<b>16.16</b>	<b>1.47</b>	<b>.000</b>	<b>4.35</b>
45-54 years	2.09	.065	8.08	<b>1.12</b>	<b>.004</b>	<b>3.08</b>
<sup>a</sup> 55-64 years	1.75	.129	5.78	<b>1.30</b>	<b>.000</b>	<b>3.69</b>
Not born in the UK	-0.72	.270	0.49	0.23	.643	1.25
Ethnicity – White Non-UK/Irish	0.88	.188	2.40	0.32	.579	1.38
Ethnicity – Afro-Caribbean	0.72	.321	2.05	0.03	.977	1.03
Ethnicity – Chinese/Asian	-0.31	.838	0.73	<b>1.20</b>	<b>.031</b>	<b>3.33</b>
<sup>b</sup> Ethnicity – Indian/Pakistani/Bangladeshi	0.76	.090	2.13	0.54	.279	1.72
City dwelling	0.29	.290	1.33	0.09	.681	1.09
Post-secondary education	0.25	.334	1.29	-0.09	.652	0.92
Unemployed	-0.61	.167	0.54	0.34	.164	1.41
Religious identification	0.30	.303	1.35	-0.02	.907	0.98
Living with another adult	<b>-0.63</b>	<b>.041</b>	<b>0.53</b>	-0.24	.306	0.79
Living with children	<b>0.52</b>	<b>.028</b>	<b>1.69</b>	0.06	.791	1.06

Less than £300 per week income	<b>1.11</b>	<b>.023</b>	<b>3.03</b>	<b>0.82</b>	<b>.026</b>	<b>2.28</b>
£301 - £490 per week income	0.71	.104	2.03	<b>0.73</b>	<b>.035</b>	<b>2.08</b>
£491 - £740 per week income	0.75	.077	2.12	0.56	.108	1.75
°£741 - £1,111 per week income	0.22	.579	1.24	0.32	.312	1.37
Physical health problem	-0.29	.379	0.75	-0.33	.186	0.72
Pregnant	0.46	.309	1.58	-0.43	.488	0.65
COVID-19 infection – self	1.14	.078	3.11	0.03	.953	1.03
COVID-19 infection - other	-1.15	.138	0.32	-0.06	.875	0.95
Mental health treatment	0.23	.378	1.25	0.09	.660	1.09
Chose not to vote in GE	<b>0.70</b>	<b>.040</b>	<b>2.01</b>	-0.08	.812	0.93
Voted Labour in GE	0.19	.530	1.21	-0.19	.459	0.83
Voted Liberal Democrats in GE	-0.07	.914	0.93	-0.14	.705	0.87
Voted Greens in GE	-0.54	.497	0.58	-0.06	.884	0.94
Voted ‘Nationalist’ in GE	-0.13	.867	0.88	-0.24	.638	0.79
Voted ‘Unionist’ in GE	0.52	.290	1.68	-0.09	.842	0.91
<sup>d</sup> Voted ‘Other’ in GE	0.77	.220	2.16	<b>1.18</b>	<b>.010</b>	<b>3.25</b>
Openness	0.04	.611	1.04	<b>0.15</b>	<b>.006</b>	<b>1.16</b>
Conscientiousness	-0.11	.151	0.90	-0.08	.128	0.92
Extraversion	0.01	.847	1.01	<b>-0.11</b>	<b>.036</b>	<b>0.90</b>
Agreeableness	<b>-0.20</b>	<b>.012</b>	<b>0.82</b>	-0.10	.103	0.91
Neuroticism	<b>-0.19</b>	<b>.029</b>	<b>0.82</b>	-0.06	.289	0.94
Locus of control - chance	0.02	.636	1.02	0.00	.959	1.00
Locus of control - powerful others	-0.02	.763	0.99	-0.01	.869	1.00
Locus of control - internal	-0.03	.524	0.97	-0.01	.752	0.99
Empathy	-0.02	.463	0.98	0.00	.922	1.00
Conspiracy mindedness	<b>0.04</b>	<b>.028</b>	<b>1.04</b>	0.01	.349	1.01
Paranoia	0.00	.983	1.00	-0.02	.373	0.98
Cognitive reflection	-0.12	.408	0.89	-0.08	.404	0.92
Trust in UK state institutions	0.00	.909	1.00	-0.01	.811	0.99
Trust in scientists and doctors	<b>-0.33</b>	<b>.001</b>	<b>0.72</b>	<b>-0.26</b>	<b>&lt;.001</b>	<b>0.78</b>
Authoritarianism	0.05	.265	1.05	0.01	.682	1.01
Social dominance	0.04	.150	1.04	0.01	.440	1.01
Attitudes toward migrants	-0.05	.220	0.96	-0.04	.127	0.96

444 Multinomial logistic regression analyses were performed to identify the key variables  
445 associated with belonging to the ‘Deniers’ and ‘Movable Middle’ classes. All predictors are  
446 adjusted for all other covariates in the model. Note: B = unstandardized beta value; p =  
447 statistical significance value; AOR = adjusted odds ratio; <sup>a</sup> = reference category is 65 year  
448 and older; <sup>b</sup> = reference category is ‘White British or Irish’; <sup>c</sup> = reference category is £1,112  
449 per week or more; <sup>d</sup> = reference category is voted for the incumbent Conservative  
450 government party; statistically significant associations ( $p < .05$ ) are highlighted  
451 in bold.

452

453

454 In the UK sample, membership of the ‘Deniers’ class was significantly associated  
455 with younger respondents (aged 18-24: OR = 16.29; 25-34: OR = 19.57; 35-44: OR = 16.16),  
456 not living with another adult (OR = 0.53), living with children under the age of 18 (OR =  
457 1.69), abstaining from voting in the previous UK general election (OR = 2.01), lower levels  
458 of trait agreeableness (OR = 0.82), lower levels of trait neuroticism (OR = 0.82), higher  
459 levels of conspiracy mindedness (OR = 1.04), and lower levels of trust in scientists and  
460 doctors (OR = 0.72).

461 Membership of the ‘Movable Middle’ class was significantly associated with being  
462 female (OR = 1.64), being younger than 65 (aged 18-24: OR = 3.90; 25-34: OR = 3.84; 35-  
463 44: OR = 4.35; 45-54: OR = 3.08; 55-64, OR = 3.69), being of Chinese or Asian ethnicity  
464 (OR = 3.33), low weekly incomes (earning less than £300 per week: OR = 2.28; earning  
465 between £301 and £490 per week: OR = 2.08), having voted for an ‘Other’ party in the  
466 previous UK general election (OR = 3.25), lower levels of trait extraversion (OR = 0.90),  
467 higher levels of trait openness (OR = 1.16), and lower levels of trust in scientists and doctors  
468 (OR = 0.78).

## 469 **Discussion**

470 Three important findings emerged from the analyses. First, the arrival of vaccines  
471 against COVID-19 coincided with a significant change in vaccine receptibility, but in only  
472 one of the two countries sampled. Second, within both samples, vaccine receptibility over

473 time was most parsimoniously represented by three distinct groups. In Ireland and the UK,  
474 the majority of respondents belonged to a group characterised by stable acceptance that  
475 accounted for 61% and 68% of each sample, respectively. Conversely, the fewest respondents  
476 in both samples belonged to a group characterised by stable non-acceptance (Ireland: 16%) or  
477 decreasing acceptance (UK: 12%). A final group characterised by fluctuating probabilities of  
478 accepting a COVID-19 vaccine over time was also identified within each sample (Ireland:  
479 23%; UK: 20%). Third, compared to those characterised by stable acceptance over time,  
480 individuals characterised by changing or decreasing acceptance of a COVID-19 vaccine were  
481 distinguishable, and also comparable, in relation to several individual, socio-economic, and  
482 psychological variables. The significance of these findings is described in turn below.

483         Compared to data that had been collected at a time when vaccine receptibility could  
484 only be considered in relation to a hypothetical vaccine (i.e., July/August 2020), data from a  
485 period when approved vaccines for COVID-19 had been introduced in both countries  
486 (December 2020) showed a significant increase in vaccine resistance in the UK, and a  
487 significant decrease in vaccine acceptance. No change in vaccine acceptance, resistance, or  
488 hesitance was identified in the Irish sample between these timepoints. The proportion of UK  
489 respondents in November/December 2020 who indicated that they would be receptive to one  
490 of the approved vaccines for COVID-19 when it became available to them (65.5%) was  
491 slightly lower than the proportion of the sample who indicated acceptance of a hypothetical  
492 vaccine in July of the same year (71.1%). Moreover, the proportion of the sample in  
493 November/December 2020 who indicated that they would be resistant to accepting one of the  
494 approved vaccines when made available to them (15.6%) was markedly higher than the  
495 proportion who indicated resistance to a hypothetical vaccine in July 2020 (10.6%). While  
496 this trend may have been attributable to factors other than the arrival of approved vaccines  
497 (i.e., our analyses clearly indicated that fluctuation in vaccine receptibility has been at play in

498 both countries for some time), recency of vaccine development and distribution has been  
499 identified as one of many factors that can influence vaccine hesitancy [13]. In relation to the  
500 COVID-19 pandemic specifically, a study of 1,941 Israeli healthcare workers and members  
501 of the general Israeli population has shown that the vast majority of responders' concerns  
502 were due to the assumed speed of vaccine development and related concerns surrounding  
503 quality controls [10]. It is notable that while the extant literature covers vaccine efficacy and  
504 safety extensively, and the rigorous quality controls that precede, dictate, and follow  
505 approvals [47, 48], members of the general population still identify speed, safety, efficacy,  
506 and quality control as key reasons for hesitation/concern about receiving a vaccine. It is  
507 imperative therefore that public health authorities do more to educate, inform, and intervene  
508 to challenge vaccine hesitancy on these grounds.

509         The current study revealed important vaccine receptibility subgroups and trends in  
510 both countries. Mixture modelling of our longitudinal data afforded a valuable opportunity to  
511 investigate (i) the proportion of each population that displayed a sustained high probability of  
512 vaccine acceptance throughout the pandemic, (ii) the proportion that displayed a sustained  
513 low probability of vaccine acceptance, and importantly, (iii) whether a 'moveable middle'  
514 group – or groups – existed, and what their receptibility profiles looked like. Overall, 61%  
515 and 68% of the Irish and UK samples, respectively, exhibited stable vaccine acceptance with  
516 acceptance probabilities in both samples above 80% across all four timepoints. However,  
517 somewhat concerningly, the trajectories for both groups ended in a downward trend. It will be  
518 important, therefore, to monitor these stable acceptance groups at later survey waves to  
519 determine what effect, if any, national vaccination programmes and communication strategies  
520 are having on acceptance levels for those who seem committed to vaccination. Notably,  
521 however, the size of these groups also reveals significant differences between countries

522 regarding rates of acceptance and highlights the importance of country-specific approaches to  
523 understanding and tackling vaccine hesitancy and promoting vaccine receptibility.

524         While we expected to identify distinct subgroups in both populations characterised by  
525 low probabilities of vaccine acceptance over time, the profiles for these groups differed in  
526 important ways. While the Irish sample included a group characterised by sustained low-to-  
527 near zero probabilities of acceptance at each survey wave (16%), the UK's most resistant  
528 group (12%) began with a 32% probability of acceptance that steadily declined to 10% by  
529 Wave 4. The Irish non-acceptance group, therefore, reflected more extreme and stable  
530 resistance compared to those who were most resistant in the UK. Several studies have shown  
531 that upwards of approximately 10% of study populations appear to be opposed to  
532 vaccinations in whatever form they take [49, 50]; therefore, these findings were not entirely  
533 surprising. It was notable, however, that resistance was lowest in both countries at the  
534 beginning of the pandemic (~6-10% in March/April 2020), and that this resistance steadily  
535 rose (significantly between some survey waves) to ~16-18% by Waves 3 (July/August 2020)  
536 and 4 (November/December 2020). Resistance to actual approved vaccines in December  
537 2020, therefore, was concerningly high. If resistance remains at this level or continues to rise,  
538 public health officials will likely need to consider how to reach and persuade a now  
539 substantial subpopulation that has traditionally been shown to be extremely resistant to  
540 vaccine promotional campaigns and public health messaging regarding inoculation generally  
541 [51, 52].

542         A third group was also identified in both countries. This group was considered to  
543 represent a 'moveable middle' or 'changing' group that may hold important significance for  
544 future public health initiatives that seek to achieve herd-protection against SARS-CoV-2. In  
545 the Irish sample, this group was characterised by a 26% probability of accepting a vaccine in  
546 December 2020 when approved vaccines had been developed. However, in the months

547 preceding vaccine development (July/August 2020), this same group of respondents exhibited  
548 only a 5% probability of acceptance, while at the beginning of the pandemic, acceptance  
549 probability was at its highest (34%). Comparatively, the ‘moveable middle’ group in the UK  
550 sample exhibited a similar probability of acceptance in November/December 2020 (24%),  
551 and at the beginning of the pandemic (33%) but had its lowest level of acceptance in  
552 April/May 2020 (12%). These groups have fluctuated in their positions over the duration of  
553 the pandemic, and while there may be cause for optimism in the upward trends identified at  
554 the most recent data collection timepoints, it must be noted that neither of these groups  
555 displayed a probability of acceptance above 34% at any time since the beginning of the  
556 pandemic.

557         While the extant research literature details many distinct socio-demographic and  
558 psychological indicators of vaccine hesitancy generally [6, 53, 54], and a burgeoning  
559 literature has begun to list those common to COVID-19 vaccines specifically [10, 16, 55],  
560 studies describing characteristics associated with stability or change in vaccine receptibility  
561 over time are lacking. Our findings revealed important similarities and distinctions in vaccine  
562 receptibility between those in the ‘movable middle’ and those characterised by stable  
563 resistance in both countries.

564         First, those who fluctuated in their receptiveness to a COVID-19 vaccine in Ireland  
565 and the UK were more likely to be female and to lack trust in scientists and health care  
566 professionals. Evidence suggests that, in relation to COVID-19 vaccination specifically,  
567 females may have concerns surrounding issues such as fertility and pregnancy [56, 57]. As  
568 has been highlighted earlier, trust in scientists and health care professionals (particularly  
569 regarding the speed of vaccine development and distribution) seems also to be of particular  
570 concern for many who are hesitant about a COVID-19 vaccine specifically [10]. Public health  
571 messaging, therefore, tailored specifically to allay concerns and/or fears that may be specific

572 to women, and/or to educate and reassure the public about quality controls and standards  
573 relating to the development, distribution, administration, and review of COVID-19 vaccines  
574 may prove useful. Notable distinctions were also evident for the moveable middle groups  
575 across samples. In Ireland, those who fluctuated over time were more likely than accepters to  
576 believe that powerful others were responsible for their experiences and to hold conspiratorial  
577 beliefs, while those in the UK were more likely than accepters to be younger, of  
578 Chinese/Asian ethnicity, have a lower level of income, have voted 'other' in the last general  
579 election, be lower in extraversion, and higher in openness. These distinct country specific  
580 characteristics may help to further inform and refine public health messaging in ways that are  
581 contextually sensitive to each population.

582         Second, those who remained resistant over time in Ireland and the UK tended not to  
583 live with any other adults, to hold conspiratorial beliefs, and to lack trust in scientists and  
584 health care professionals. While those who remained resistant over time may be more  
585 challenging to reach or persuade than those who fluctuate in their receptibility, these common  
586 indicators of resistance may prove useful in informing our understanding of who these people  
587 are and why they are susceptible and committed to the beliefs they hold. Individuals living  
588 alone have been shown to lack important opportunities to explore/discuss their concerns or to  
589 reality test their assumptions about the world in which they live [58, 59], while those who are  
590 open/receptive to conspiratorial interpretations of world events often dismiss information  
591 sourced from or disseminated by traditional, scientific and/or authoritative sources [60, 61].  
592 Notably, as was also evident for the change groups, stable resisters in both countries also  
593 differed in specific ways. In Ireland, these individuals were uniquely characterised by low  
594 income and negative views towards migrants, while in the UK, those most resistant to a  
595 COVID-19 vaccine were more likely to have children, not to have voted in the last general  
596 election, and to be lower in the personality traits of agreeableness and neuroticism. Each of

597 these indicators has previously been shown to be associated with vaccine hesitancy/resistance  
598 [6, 62]. That they do not predict resistance in the same way within different populations and  
599 in relation to common vaccines likely reflects the context specific complexity of vaccine  
600 hesitancy as a phenomenon and the challenging terrain that must be navigated by those  
601 seeking to tackle it.

602         These findings should be interpreted considering several limitations. First, non-  
603 probability quota-based sampling methods were used to recruit samples via the Internet. This  
604 opt-in mode of recruitment employed by the survey company who facilitated the data  
605 collection (Qualtrics), albeit being a cost-effective method for gaining fast access to a large  
606 and diverse sample (and the most feasible method of recruitment during the pandemic),  
607 inevitably meant that it was not possible to know if participants in these panels differed in  
608 important ways from members of the public that do not belong to the panels. Second, the  
609 current study was also limited to two western, European countries whose populations had  
610 many social, cultural, economic, and political similarities. However, while these populations  
611 may have been similar in many respects, our findings highlight notable differences between  
612 countries in relation to (i) the proportions of each population that were receptive, hesitant,  
613 and resistant over time, (ii) the profiles and trajectories of these groups, and (iii) the specific  
614 indicators that predicted fluctuation and stable resistance over time. Now that vaccination  
615 programmes are underway in many countries, our findings highlight the importance of  
616 population-specific analyses of vaccine hesitancy and the continued monitoring of this  
617 phenomenon as vaccination programmes advance. Relatedly, the extent to which these results  
618 will generalise to other nations is unknown. It is essential that other (low, middle, and high  
619 income) countries obtain estimates of change in hesitancy/resistance to COVID-19  
620 vaccination in their general populations, given that vaccination efforts will only succeed if  
621 sufficiently undertaken globally. Third, while the use of nationally representative samples

622 from two countries is a key strength, these samples are representative of general adult  
623 populations and do not include members of the public that are institutionalised (e.g., hospital  
624 care, prisons, refugee centres) or difficult to reach (e.g., those not online, the homeless, etc.).  
625 The inability to survey these members of society also limits the generalisability of our results.

## 626 **Conclusion**

627 Our findings suggest that approximately two-thirds of adults in the general  
628 populations of the UK and Ireland had consistently high probabilities of accepting a COVID-  
629 19 vaccine during the first nine months of the global pandemic. To achieve wider vaccine  
630 coverage, it will be important to reach the 20-25% of people in society who belong to the so-  
631 called ‘moveable middle’. In both samples, these individuals were more likely to be women,  
632 and to have lower levels of trust in scientists, doctors, and other healthcare professionals.  
633 Furthermore, context-specific identifiers were also evident such as younger age, Asian  
634 ethnicity, and lower income in the UK, and conspiracy mindedness and external locus of  
635 control in Ireland. These findings can be used to aid public health efforts in both countries to  
636 reach those in society whose minds can be changed with regards to COVID-19 vaccination.

637

638

639 **Data Availability**

640 Datasets for this study are available on the open science framework at

641 <https://osf.io/ugwdz/files/>

642

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