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Resolving the small-pockets problem helps clarify the role of education and political ideology in shaping vaccine scepticism

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Understanding the factors associated with vaccine scepticism is challenging because of the 'small-pockets' problem: The number of highly vaccine-sceptical people is low, and small subsamples such as these can be missed using traditional regression approaches. To overcome this problem, the current study (N = 5,200) used latent profile analysis to uncover six profiles, including two micro-communities of vaccine-sceptical people who have the potential to jeopardize vaccine-led herd immunity. The most vaccine-sceptical group (1.14%) was highly educated and expressed strong liberal tendencies. This group was also the most sceptical about genetically modified crops and nuclear energy, and most likely to receive news about science from the Internet. The second-most vaccine-sceptical group (3.4%) was young, poorly educated, and politically extreme (both left and right). In resolving the small-pockets problem, the current analyses also help reconcile competing theoretical perspectives about the role of education and political ideology in shaping anti-vaccination views.

Vaccines are one of the most effective population health interventions in history (Ehreth, 2003; Plotkin, 2014). Unsurprisingly, then, the majority of the public views vaccines positively (Larson, de Figueiredo, Karafillakis, & Rawal, 2018). However, it only takes a small proportion of the population to not vaccinate to undermine herd immunity and trigger public health crises. This is why anti-vaccination movements arouse so much concern, even though there are relatively few anti-vaccination advocates. Indeed, in 2019 the World Health Organization listed vaccine hesitancy as one of the top 10 threats to global health in 2019 (WHO, 2019). This urgency has intensified since, as evidence mounts of fear and resistance towards COVID-19 vaccines (Rigby, 2020; Roozenbeek et al., 2020).

Gaining a nuanced, quantitative understanding of the factors associated with anti-vaccination attitudes is challenging because of what we refer to here as the 'small-pockets' problem: The number of people with strong anti-vaccination attitudes represents a small

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minority of the population. Yet, regression approaches – which are by far the most common method of quantitatively identifying predictors of anti-vaccination attitudes – model the central tendencies of the whole sample. As such, scholars are typically calculating variation in levels of *pro*-vaccination attitudes. Although this approach is valuable, it means that niche groups with intense anti-vaccination attitudes – who may have their own unique psychological profile – might be obscured. As an example, imagine a hypothetical situation in which there are a very small group of people on the political far left who are very anti-vaccination, and a much larger group of people on the centre left who are very pro-vaccination. If one were to use traditional regression techniques, the small group of people on the far left would be swamped by the larger group of centre left individuals, leading to the simplistic conclusion that left-wing people are relatively pro-vaccination (this is indeed the conclusion of many recent population-based surveys conducted using regression; Baumgaertner, Carlisle, & Justwan, 2018; Hornsey, Finlayson, Chatwood, & Begeny, 2020; Hornsey, Lobera, & Díaz-Catalán, 2020; Joslyn & Sylvester, 2019).

The current study: Approach and theoretical frame

In the current study, we take a person-centred approach to analysis, identifying several profiles of the population in relation to their views on vaccination. This technique enables us to identify pockets of the population with highly anti-vaccination views, even if those groups are a small proportion of the overall sample. Person-centred analyses also provide a sensitive way of testing the complex patterns of relationships among several variables at once. Of course, we do not mean to imply that traditional regression analyses will always be suboptimal when examining the predictors of anti-vaccination views: Some of its limitations can partly be resolved through techniques such as curvilinear regression (combined with testing for interactions). Nor do we suggest that person-centred analyses are the only way to resolve the small-pockets problem. However, it remains the case that person-centred analyses such as latent profile analysis (LPA) are well equipped to test the complex interplay between a *range* of variables in tandem, even when these relationships do not obey a predictable line or curve. Most importantly for the current analysis, LPA can model complex patterns of relationships even in small and heterogenous pockets of the population.

The theoretical frame for the current study is a debate between two perspectives on what causes people to hold views that lie outside the scientific consensus. When grappling with the question of why people would lose confidence in vaccines – despite official reassurances that they are safe and effective – it is reasonable to consider whether it is a result of poor education (i.e., early exit from the education system) and/or poor science literacy (i.e., weak knowledge and understanding of scientific concepts and processes). This perspective corresponds to the so-called 'deficit model' of science communication; that failure to come on board with the scientific consensus on vaccination is caused by a lack of exposure to information, or a failure to understand information when it is presented. Consistent with this idea, general knowledge about vaccinations and health tends to be associated with more positive attitudes towards vaccinations (Larson, Jarrett, Eckersberger, Smith, & Paterson, 2014; Schmid, Rauber, Betsch, Lidolt, & Denker, 2017). Furthermore, a European Commission Survey (Larson et al., 2018) found that, in a number of countries, the highest levels of vaccine scepticism were found among respondents who had no more than a primary school education.

However, evidence for a link between education and vaccine scepticism is mixed; for example, a systematic review concluded that the relationship between health literacy and vaccination is unclear (Lorini et al., 2018). Although several studies have found education to be a facilitator of vaccine acceptance, several others have identified high education as a potential *barrier* to vaccine acceptance (Larson et al., 2014). One recent study found no reliable relationship between education and vaccine scepticism in a sample of 5,323 participants in 24 countries (Hornsey, Harris, & Fielding, 2018). Finally, vaccination interventions that have relied on presenting information – or refuting myths about vaccinations – have had limited success. Although some have had small positive effects (Schmid & Betsch, 2019), others have had no reliable effects on vaccine-hesitant individuals (Horne et al., 2015; Nyhan, Reifler, Richey, & Freed, 2014) and some have had negative (backfire) effects (Betsch & Sachse, 2013). Thus, the role of education in shaping vaccine scepticism appears to be complex and requires a nuanced exploration.

As a counterpoint to the deficit model of science communication, some theorists have pointed to the role of motivated reasoning (Browne, Thomson, Rockloff, & Pennycook, 2015; Hornsey & Fielding, 2017; Kahan, 2013; Kunda, 1990). According to this perspective, people often operate more like 'cognitive lawyers' than 'cognitive scientists': Rather than weighing up information in an open-minded fashion, they selectively attend to, critique, and remember information in a way that reinforces a preferred conclusion. This perspective might help to explain why vaccine-hesitant people spend a relatively large amount of time seeking information on the Internet about vaccinations (Jones et al., 2012) but still reach factually dubious conclusions.

One prominent theory that incorporates ideas around motivated reasoning is the theory of cultural cognition. Proponents of this theory argue that people interpret scientific evidence through the lens of their ideologies and worldviews (Kahan, 2010; Kahan, Jenkins-Smith, & Braman, 2011). For example, people might selectively attend to risks of a public health intervention if that intervention threatens their worldviews about how society should be structured. In line with this argument, it has been shown that people who ideologically endorse power hierarchies as a normal and acceptable part of life are more likely to perceive human papillomavirus (HPV) vaccine risk (Kahan, Braman, Cohen, Gastil, & Slovic, 2010). The authors interpreted this finding as being due to the perception that, by preparing girls for sexual activity, HPV vaccines threaten traditional gender norms around sexuality, a particularly threatening state of affairs for people who are ideologically wedded to the status quo.

An implication of these ideas is that it can be misleading to examine effects of education independently of ideological factors. For example, Republicans report less accurate beliefs about the link between vaccinations and autism, but the effect of political preference is largest among the more educated participants (Joslyn & Sylvester, 2019). A similar pattern has been found between levels of climate change scepticism and levels of education/science literacy in the United States (Drummond & Fischhoff, 2017; Hamilton, 2011; Kahan et al., 2012). On politically contentious scientific attitudes, political polarization appears to be greatest among those who are most educated and scientifically literate. These initially counter-intuitive relationships can be accounted for by what has been called identity-protective cognition (Drummond & Fischhoff, 2017; Kahan, 2013; Kahan et al., 2012): Higher levels of education give people the skills to find information that aligns with their political identities and worldviews, and to critique information that threatens them. In short, education gives people the ability to curate their sense of reality in a way that is sympathetic to what they want to believe.

What these ideas suggest is that the interplay between ideology, education, and vaccine scepticism is complex and requires careful unpicking. To do this, the current paper takes a person-centred approach to identifying the extent to which political ideology, education, and science literacy are implicated in vaccine scepticism. Our analysis has the potential to resolve empirical contradictions in the literature, as well as speaking to ongoing theoretical debates about the role of education and ideology in facilitating (or hindering) support for vaccinations. On a pragmatic level, this research helps guide policymakers and science communicators in terms of identifying and describing the audiences that are most in need of interventions.

In addition to education and ideology, we also included age in our profile analysis. One reason for doing this is evidence that the effects of health literacy on vaccination take-up tend to be age-dependent (Lorini et al., 2018). We also reasoned that different ages would potentially have different avenues through which they would consume information about vaccinations (e.g., through social media versus through traditional media such as television and written press; Nord, Espinosa, Paliszkiewicz, & Madra-Sawicka, 2020). Experimental work (Betsch, Renkewitz, Betsch, & Ulshöfer, 2010), survey work (Jones et al., 2012), qualitative analysis of anti-vaccination communities (Smith & Graham, 2019), and computational analyses (Johnson et al., 2020) have all highlighted the role of social media in nourishing and distributing anti-vaccination views.

In sum, our profile analysis incorporates the following six variables: education, objective science literacy, subjective science literacy, political ideology, age, and vaccine scepticism. We chose to look at both *objective* and *subjective* science literacy (the extent to which people have a self-image as science-literate) for two reasons. First, there is evidence from the climate change literature that the two are only modestly correlated, and that the former shares a stronger relationship with climate scepticism than does the latter (Hornsey, Harris, Bain, & Fielding, 2016). Second, there is emerging evidence that the mismatch between objective and subjective science literacy might be particularly consequential for vaccination beliefs (i.e., the belief that one 'knows more than the experts' is particularly high among people with particularly low levels of objective knowledge; Motta, Callaghan, & Sylvester, 2018).

After uncovering profiles, we then used these profiles to explore differences in related attitudes and behaviours: (1) perceptions of the risks versus benefits of vaccination, (2) media through which participants obtain information about science and technology, and (3) perceived risks versus benefits of four scientific practices that are not related to vaccines. The inclusion of the dichotomous measure of risks versus benefits of vaccination was designed to offer an easy-to-digest heuristic about vaccine hesitancy, one that can be used to triangulate the results of the profile analyses.

The latter two measures – media consumption and perceptions of the four scientific practices – were included as outcome measures (rather than being included in the profile analyses themselves) for both theoretical and pragmatic reasons. In terms of theory, the media and scientific practice variables do not speak to the debate about identity-protective cognition, and so for reasons of parsimony and interpretability, we excluded them from the profile analyses. However, they do speak to questions of interest in the broader research domains of science perceptions and science communication. Note that we had no a priori predictions around these analyses; they were exploratory. With respect to pragmatics, we note that the media data are frequency data, as opposed to the continuous/ordinal variables that are used in LPA. In sum, our analytic strategy offers the best balance between comprehensiveness, comprehensibility, and theoretical coherence.

Method

Sampling and participants

We analysed data collected as part of the 9th Survey on the Social Perception of Science and Technology, conducted by the Spanish Foundation for Science and Technology and the Ministry of Science. A total of 5,200 personal interviews (51.4% female) were conducted face-to-face with people who had been residents in Spain for five or more years and were 15 years of age or older between 14 May and 2 July 2018 (M = 43.95 years, SD = 17.95). This approach enables a truly representative sample when it comes to education, including people who have limited literacy. Overall, 0.2% self-described as illiterate, 2.7% as literate but without any formal education, 3.0% as having an incomplete primary education, 8.9% as having primary school education, 29.2% as having lower secondary education, 35% as having upper secondary education and post-secondary non-tertiary, 8% as having short-cycle tertiary education, 12.4% as having a bachelor's or master's degree, and 0.5% as having a doctorate.

Interviews were conducted in the house of the respondent either on the spot or at a scheduled date. No incentives were offered to encourage participation. Informed consent was obtained after the nature, and possible consequences of the studies had been fully explained.

The sampling procedure was multi-staged and stratified, with selection of primary units (municipality) and secondary units (census tracts) conducted through proportional random sampling and the last units (individuals) by random routes and quotas for gender and age. The sampling error for the total sample is $\pm$1.25% for a confidence level of 95.5%, with the assumption of simple random sampling, calculated considering non-proportional samples.

Measures: Latent profile indicators

To measure vaccine scepticism, we combined responses to four items. Two items asked people to rate the costs and benefits of childhood vaccines. Participants were told 'Now I'm going to ask you about childhood vaccines like measles, mumps and rubella'. They were then asked 'How would you rate their benefit in preventing disease?' and 'How would you rate their risk of serious side-effects?' (1 = very high, 5 = very low). Participants also rated their level of trust in 'childhood vaccines' (1 = none, 5 = very high) and how 'scientific' they found vaccines (1 = not scientific at all, 5 = totally scientific). The three positively worded items were reversed – such that high scores indicated high vaccine scepticism – and the four items were then combined into a single scale of vaccine scepticism (α = .64). A fifth item was dichotomous and so was analysed separately as a triangulation exercise, to see whether responses differed reliably between the uncovered profiles: 'As a whole, when it comes to evaluating childhood vaccines, I would say that . . .' (options: 'The benefits outweigh the risks' or 'The risks outweigh the benefits').

Objective science literacy was measured using questions adapted from various national surveys that traditionally measure scientific literacy, such as the General Social Survey and the U.K. Public Attitudes to Science Survey. However, some have argued that a traditional format – in which a single statement is presented and participants respond true or false – can lead to measurement error linked to satisficing (the tendency to offer a satisfactory answer, the first considered acceptable after a superficial analysis of the information). To reduce this type of error, the current

survey measured scientific knowledge as pairs of responses instead of a single true–false sentence. This way, an interviewee with low motivation has to choose between two sentences instead of quickly responding as true or false. We presented six pairs of statements, organized such that one statement was correct and the other statement was false. Example items are as follows (with incorrect responses in brackets): *The Earth revolves around the Sun (The Sun revolves around the Earth)* and *Antibiotics cure infections caused by bacteria (Antibiotics cure infections caused by both viruses and bacteria)*.

Subjective science literacy was measured using five items. Participants rated the level of knowledge they perceived themselves to have on four domains, including "medicine and health" and "science and technology" (1 = very low, 5 = very high). A fifth item asked 'Would you say that the level of scientific and technical education you have received is...?' (1 = very high, 5 = very low). After reversing the last item, the scale showed acceptable reliability (α = .76).

Finally, we measured the following demographic variables: sex, age, political ideology (1 = far left, 10 = far right), and education (1 = illiterate, 9 = doctorate).

Outcome measures: Media consumption

Participants were presented with seven types of media – Internet, books, written press, radio, scientific/technical journals, general information magazines, and television – and were asked to rank from first to third the media through which they are informed about science and technology issues. The 3,302 respondents who indicated that they used the Internet were further asked about the *type* of Internet media that they relied on. They rated 'yes' or 'no' to whether they used blogs/forums; social media (Facebook, twitter, etc); general digital media; digital media specializing in science and technology; Internet radio; videos (YouTube or similar sites); and Wikipedia.

Outcome measures: Risks versus benefits of other scientific practices

Participants rated the risks (1 = no risk, 5 = many risks) and benefits (1 = no benefit, 5 = many benefits) of four potentially controversial scientific practices: cultivation of genetically modified (GM) crops, nuclear energy, fracking, and wind turbines. Difference scores were calculated to produce a single index for each scientific practice ranging from −4 (benefits far outweigh the risks) to +4 (risks far outweigh the benefits).

Ethics statement

This study was carried out in accordance with the International Ethical Guidelines and Declaration of Helsinki. For the collection of data and its treatment, we observed the recommendations of the European Commission on Ethics for Researchers (version of 2013), with special emphasis on obtaining informed consent from key informants, as well as the protocol for conducting interviews developed by the College of Arts of the University of Glasgow, which establishes good practices in relation to procedures, the place of the interviews, and the security, confidentiality and consent of informants. We guaranteed the voluntary, free and informed participation of the interviewees, and their anonymity and confidentiality of their information, both in conducting the interviews and in the processing of the data and its publication.

Results

Means, standard deviations, and intercorrelations among our key variables are summarized in Table 1. Note that the mean anti-vaccination score for the sample was 1.71 (SD = 0.60) reflecting support for vaccination overall.

Identification of profiles

All respondents were included in analysis (there were no deletions). The rate of missing data was low (<1%) on every variable except for political ideology, for which a significant portion of people did not offer a response. Given this, we used the full information maximum likelihood (FIML) missing at random approach to deal with missing data, but to ensure robustness we cross-validated our solutions on the 3,812 respondents with a full (listwise deletion) data set.

Mplus was used to identify the fit indices and characteristics of latent profile analyses for 2–10 class models. Each test was run using 500 random starting values. As discussed in the literature focusing on latent profile analyses (Collins & Lanza, 2010; Geiser, 2012), there is no one indicator that researchers can draw on to determine the number of classes that best fit the data: decisions are made as a function of fit indices, parsimony, and interpretability (Bauer & Curran, 2003; Jung & Wickrama, 2008; Muthén, 2003; Rindskopf, 2003). The three main fit indices are set out in Table 2. Inspection of the Lo–Mendell–Rubin-adjusted LRT shows that the addition of one extra class significantly improved ($p < .05$) the classification up to and including a six-class solution. However, the 7th class did not add empirical value over and above the six-class solution ($p = .45$) and this analysis did not identify an additional vaccine-hesitant group. Importantly, by adding a 7th or 8th class to the profile analyses, no additional vaccine-hesitant groups were identified beyond the three identified in the six-class solution (which identified the small pocket of ideologically left vaccine-hesitant respondents). Therefore, the six-class solution remains a more parsimonious solution. We also checked the six-class full sample model against profiles produced with a six-class solution using only the smaller, less representative listwise deletion subsample. Interpretation of the six-class solution profiles was the same regardless of whether we analysed the full sample (using FIML) or this more restricted subsample. In sum, the six-class solution provided the best balance between fit, parsimony, robustness, and interpretability.

Table 1. Means, standard deviations, and bivariate correlations among variables in the profiles

Measure	*M*	*SD*	2	3	4	5	6
1. Vaccine scepticism	1.71	0.60	−.05**	−.12***	−.03*	−.13***	−.04**
2. Political ideology	4.81	1.84	–	−.09***	−.07***	−.07***	.11***
3. Obj. science literacy	4.24	1.22		–	.19***	.27***	−.14***
4. Subj. science literacy	3.03	0.70			–	.36***	−.22***
5. Education	5.66	1.39				–	−.31***
6. Age	43.97	17.97					–

*$p < .05$, **$p < .01$, ***$p < .001$.

Table 2. Fit statistics for the varying latent profile solutions with different numbers (1–10) of classes (using MAR assumptions)

No. of classes	Log-Lik	No. of free parameters	AIC	BIC	SSABIC	Entropy	Lo–Mendell–Rubin adjusted	*p*	Parametric bootstrapped likelihood	*p*	No. of vaccine-sceptical classes > mean
1	−57,849	20	115,723	115,802	115,763						
2	−56,870	27	113,779	113,903	113,843	0.76	1,926	<.001	1,958	<.001	1
3	−56,523	34	113,098	113,269	113,186	0.78	683	<.001	694	<.001	1
4	−56,247	41	112,561	112,777	112,672	0.77	542	<.001	551	<.001	2
5	−56,026	47	112,133	112,395	112,268	0.77	435	.005	442	<.001	2
6	−55,907	20	111,906	112,214	112,064	0.79	237	.028	241	<.001	3
7	−55,780	27	111,668	112,022	111,850	0.80	248	.449	252	<.001	3
8	−55,686	34	111,494	111,894	111,700	0.81	185	.007	188	<.001	3
9	−55,598	41	111,333	111,779	111,563	0.79	172	.001	175	<.001	4
10	−55,517	75	111,185	111,676	111,438	0.80	159	.004	162	<.001	5

Description of profiles

Six profiles emerged. The features of the six profiles are summarized in Figure 1, which plots the standard deviations above or below the sample means for each variable. Profiles are discussed below in order of the most vaccine-sceptical to the least.

Profile 1: Educated, strong left

The group with the highest level of vaccine scepticism (3.41 *SD* above average) was a relatively small group (1.14%, $N = 59$). They were easily the most left wing of the six profiles – 0.90 *SD* below the mean – with nobody self-identifying as right wing. This group had the second highest education levels of the six profiles (0.68 *SD*): 39.0% had a university degree. This group was within 0.1 *SD* of the overall sample average on objective science literacy, subjective science literacy, and age.

Profile 2: Young, poorly educated, politically polarized

The second highest levels of vaccine scepticism (1.79 standard deviations above the mean) were found in a profile comprising 3.4% of the sample ($N = 179$). On average,

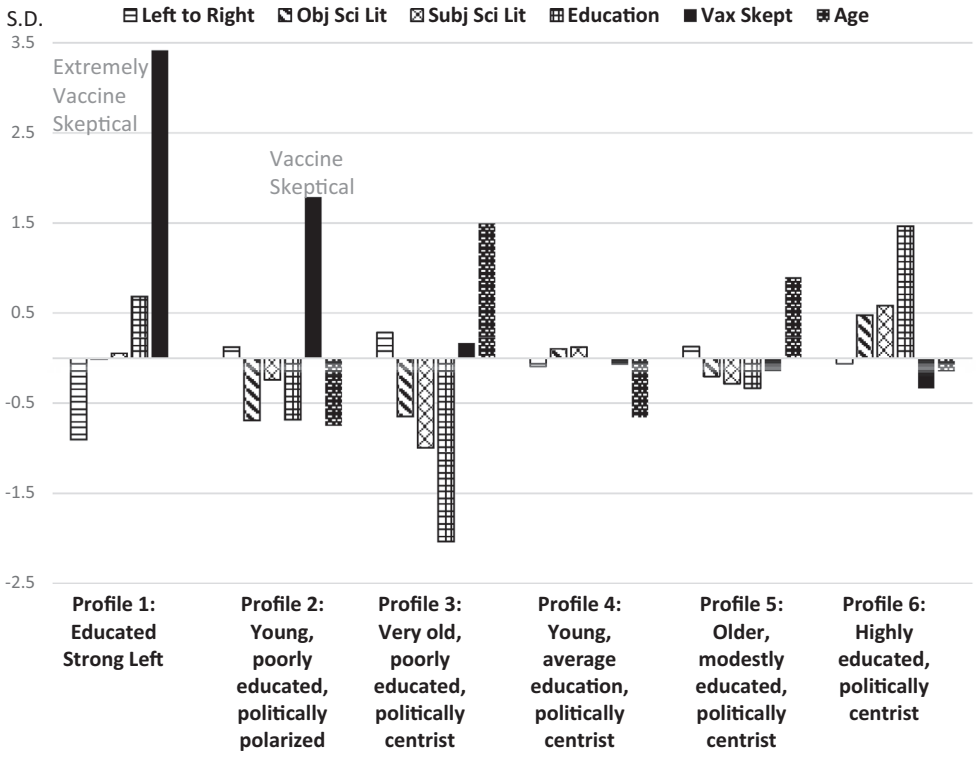

Figure 1. Profile plots for six-class solution. Vertical bars indicate how many standard deviations above or below the sample each profile scores across the six variables of interest. *Obj Sci Lit* and *Subj Sci Lit* refer to objective and subjective science literacy, respectively. *Vax Skept* refers to vaccine scepticism. Low scores on the left to right variable indicate the profile was more left-wing on average than the mean for the sample.

members of this profile leaned slightly to the right of average for the sample (0.12 *SD* above the mean). But this disguises the fact that this group was by far the most politically polarized of the sample. Only 38.7% of the sample scored on the middle four points of the scale, with the rest distributed relatively evenly between the outer regions of the left and right ends of the spectrum. This group had a lower-than-average level of education (−0.68 *SD*; none were university educated). Objective levels of science literacy were low (−0.65 *SD*). Subjective levels of science literacy were also low (−0.24 *SD*), but less so than on the objective index. The members of this group were, on average, considerably younger than the rest of the sample (M = 30 years, −0.75 *SD*).

Profile 3: Very old, poorly educated, politically centrist

Comprising 6.5% of the sample, this group had slightly higher-than-average vaccine scepticism (0.17 *SD*), although in the context of a predominantly pro-vaccination sample, this could be construed as unproblematic. This group was centrist politically (0.28 *SD* on political ideology, with 51% of the sample scoring on the middle four points of the scale). It was the oldest of the profiles (M = 70.84 years; 1.50 *SD*) and by far the most poorly educated (−2.04 *SD*). Objective science literacy (−0.65 *SD*) and subjective science literacy (−0.99 *SD*) were also low.

Profile 4: Young, average education, politically centrist

This was the largest group in our analysis, comprising 45.3% of the sample. This group was relatively young on average (M = 32.20; −0.66 *SD*) and politically centrist (−0.09 *SD*, with 58.2% of the sample scoring on the middle four points of the scale). They had average levels of vaccination scepticism (−0.08 *SD*) and average education (0.00 *SD*). This group was slightly above average on objective (0.11 *SD*) and subjective literacy (0.12 *SD*).

Profile 5: Older, modestly educated, politically centrist

Comprising 26.6% of the sample, this was the second-most pro-vaccination profile (−0.14 *SD*). These were older respondents (M = 60 years, 0.89 *SD*) who had relatively low levels of education (−0.34 *SD*) and lower objective (−0.20 *SD*) and subjective science literacy (−0.28 *SD*). This group was centrist politically (0.13 *SD*, with 53.0% of the sample scoring on the middle four points of the scale).

Profile 6: Highly educated, politically centrist

The profile with the most pro-vaccination tendencies (−0.33 *SD*) comprised 17.06% of the respondents. This group was highly educated (1.46 *SD*), with all of its members university educated. They were the most politically centrist group (−0.06 *SD*, with 59.9% of the sample scoring on the middle four points of the scale). They had high levels of objective and subjective scientific literacy (0.48 and 0.58 *SD*, respectively) and were just below the average age of the sample (M = 41.36, −0.15 *SD*).

We compared the profiles with respect to responses to the dichotomous measure of whether respondents thought the risks of vaccines outweigh the benefits or whether the benefits outweigh the risks. As can be seen in Figure 2, results reinforce the utility of the six profiles. The most vaccine-sceptical class – Profile 1 – predominantly reported that the risks outweigh the benefits. The second-most vaccine-sceptical class – Profile 2 – was

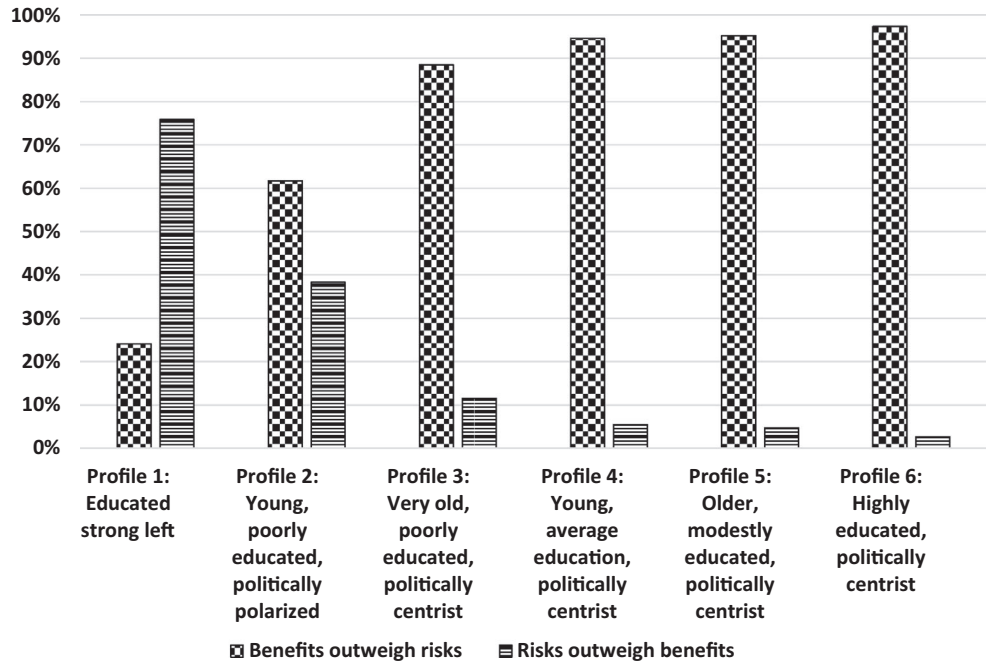

Figure 2. Perceived risk versus benefits of vaccines across the profiles. Vertical bars indicate the percentage of people who say the benefits of vaccines outweigh the risks, or the risks outweigh the benefits, in a dichotomous, forced-choice measure.

divided, with only a small majority saying that the benefits outweighed the risks. In the other four profiles, the vast majority reported that the benefits outweighed the risks.

Media channels through which respondents seek information about science and technology

Participants ranked which media channel was their first-choice source of information about science and technology. We tested the degree to which participants' first choices were associated with their profile membership by using crosstabs combining profile membership with different first-choice media preferences. Different patterns of preferences were found depending upon the profile membership, $\chi^2(55) = 880.20, p < .001$. These first-choice preferences are plotted in Figure 3. Of note, the most vaccine-hesitant group (Profile 1) reported the highest level of reliance on the Internet for their scientific and technology information (64% ranked this first) and the least reliance on television of all of the groups (16%).

Among the 3,302 respondents who indicated that they used the Internet, we further asked about the *type* of Internet media that they relied on (see Figure 4). Participants could choose more than one option, and the dependent measure of interest was the percentage of people who indicated they drew on this particular online media to receive scientific and technical information. On all channels, there were clear preferences for different media across the six profiles: blogs and forums, $\chi^2(15) = 60.92, p < .001$; social media, $\chi^2(15) = 62.28$, $p < .001$; general digital media, $\chi^2(15) = 73.70$, $p < .001$; speciality science and technology digital media, $\chi^2(15) = 79.01$, $p < .001$; podcasts,

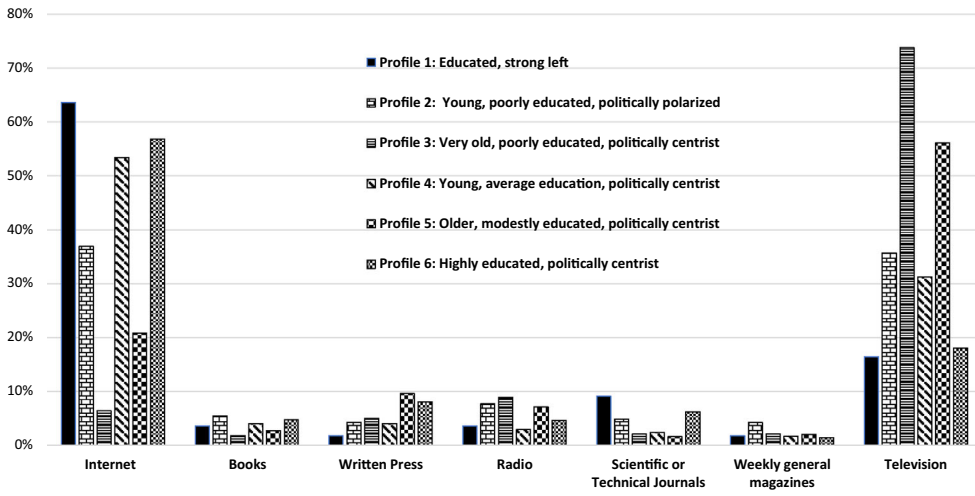

Figure 3. First-choice media preferences for scientific and technical information across the classes. Vertical bars indicate the percentage of people in each profile who indicated that the various media was their first choice for scientific and technical information.

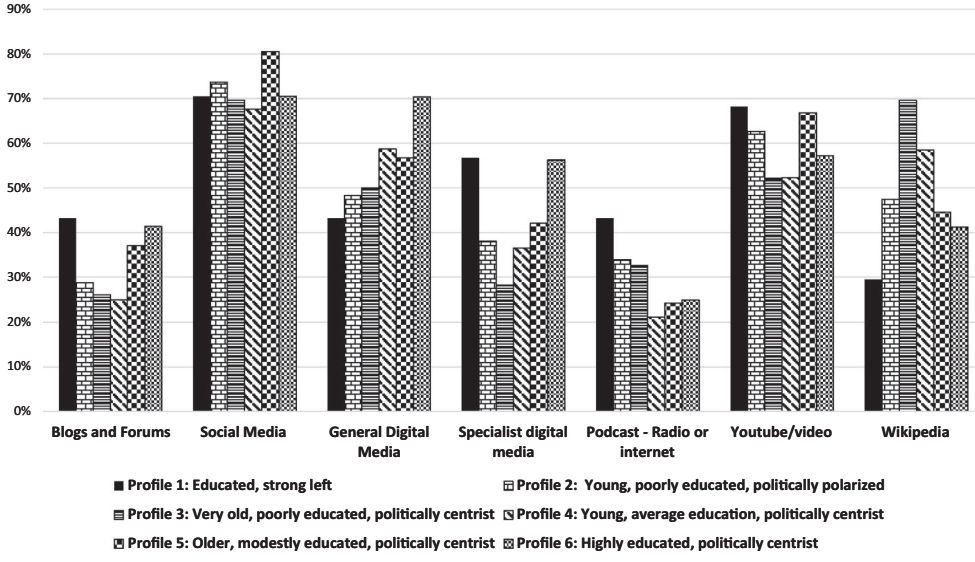

Figure 4. Internet media channel preferences of the different profiles. This summarizes data among people who indicate the Internet was their first choice for scientific and technical information (Figure 3). Vertical bars indicate the percentage of people in each profile who indicated through which online media in particular they received scientific and technical information. Participants could choose more than one option.

$\chi^2(15) = 39.70$, $p < .001$; videos (e.g., YouTube), $\chi^2(15) = 87.49$, $p < .001$; and Wikipedia, $\chi^2(15) = 88.00$, $p < .001$. Relative to the other profiles, the most vaccine-hesitant group was particularly unlikely to use Wikipedia and general digital media, but

Table 3. Perceived risk versus benefits of controversial scientific practices across the profiles: difference scores range from −4 (benefits far outweigh the risks) to +4 (risks far outweigh the benefits)

	Profile 1	Profile 2	Profile 3	Profile 4	Profile 5	Profile 6
GM crops	2.04_{b} (2.17)	0.60_{a} (1.85)	1.05_{a} (2.12)	0.30_{a} (2.15)	0.67_{a} (2.17)	0.59_{a} (2.26)
Nuclear energy	2.29_{b} (1.92)	0.75_{a} (1.56)	1.00_{a} (1.75)	0.89_{a} (1.84)	1.17_{a} (1.83)	1.00_{a} (1.85)
Fracking	2.48_{c} (1.72)	0.52_{a} (1.39)	0.70_{ab} (1.83)	0.79_{ab} (1.98)	1.11_{b} (2.01)	1.44_{b} (2.00)
Wind turbines	-1.91_{a} (2.15)	-0.88_{b} (2.14)	-1.85_{a} (2.03)	-2.31_{a} (1.70)	-2.35_{a} (1.69)	-2.41_{a} (1.60)

Note. Analysis of variance revealed that the differences across the profiles were significant for GM crops, $F(5, 4{,}663) = 14.29$, $p < .001$, $\eta^2 = .015$; nuclear energy, $F(5, 4{,}682) = 9.49$, $p < .001$, $\eta^2 = .010$; fracking, $F(5, 3{,}292) = 17.52$, $p < .001$, $\eta^2 = .026$; and wind turbines, $F(5, 4{,}829) = 26.09$, $p < .001$, $\eta^2 = .026$. Profiles are described in order of the most vaccine-hesitant (Profile 1) to the least (Profile 6). Means that do not share a subscript are significantly different according to the Tukey *post-hoc* tests ($p < .05$). Numbers in parentheses are standard deviations.

particularly likely to use blogs and forums, Internet radio, specialist digital media, and online videos.

Risks versus benefits of other (potentially controversial) scientific practices

Respondents rated the risks and benefits associated with GM crops, nuclear energy, fracking, and wind turbines. We included these measures in order to test whether there are patterns in terms of the attitudes towards scientific innovations held by people in the respective profiles. Table 3 summarizes the means across profiles. Of note, the most vaccine-hesitant subsample (Profile 1) was especially sceptical about GM crops, nuclear energy, and fracking. Interestingly, this quality was not shared by members of the second-most vaccine-hesitant group (Profile 2) who held attitudes towards these issues that were mostly indistinguishable (statistically) from Profiles 3–6. This pattern was reversed when it came to the issue of wind turbines. The sample generally saw more benefits than risks around wind turbines, but Profile 2 was the *least* supportive of the six profiles. On this issue, Profile 1 held attitudes that were statistically indistinguishable from Profiles 3–6. These patterns demonstrate that Profiles 1 and 2 do not just differ in the levels of vaccine scepticism they display; they also are qualitatively distinct in terms of their attitudes to a range of other (potentially controversial) scientific practices.

Discussion

Consistent with representative surveys internationally, the current sample was highly pro-vaccination. However, our novel analyses revealed two small pockets of the population who were outliers in terms of their high levels of vaccine scepticism; micro-communities that have the potential to jeopardize the goal of vaccine-led herd immunity. Describing these groups of people can help policymakers and science communicators anticipate and defuse vaccine scepticism in the community. It also helps lend nuance to the meta-debate about what leads people to reject scientific consensus: Is it caused by a lack of cognitive sophistication (as suggested by the deficit model), political ideology (as suggested by the theory of cultural cognition) or a combination of the two (as predicted by proponents of identity-protective cognition)?

The most vaccine-hesitant group was a highly educated group who expressed strong liberal tendencies. This was the only group to explicitly state that the risks of vaccines outweigh the benefits. Regression-based analyses – which examine central tendencies in a whole sample – have typically found that conservatives are slightly more anti-vaccination than are liberals (Baumgaertner et al., 2018; Hornsey, Finlayson, et al., 2020; Hornsey, Lobera, et al., 2020; Joslyn & Sylvester, 2019), apparently contradicting the stereotype that anti-vaccination communities trend to the left (Berezow & Campbell, 2012). However, the current data cast this issue in a different light, revealing a small group of extremely anti-vaccination liberals that would otherwise be (statistically) diluted by a much larger group of people who lean slightly left and are very pro-vaccination (e.g., Profile 6 in the current sample).

As a secondary analysis, we examined whether the profiles differed in terms of their media consumption habits and their attitudes towards (potentially controversial) scientific innovations. More so than the rest of the sample, the most vaccine-hesitant group had an especially weak preference for using Wikipedia, but an especially strong preference for using blogs, Internet radio, digital media specializing in science and technology, and online videos. This finding is consistent with qualitative research that has highlighted digital media as channels through which anti-science 'echo chambers' can emerge (Johnson et al., 2020; Smith & Graham, 2019). Table 3 demonstrates that Profile 1 was highly sceptical not just of vaccines, but also of GM crops, nuclear energy, and fracking. This suggests that their anti-vaccination attitudes form part of a suite of attitudes that align with traditional left-wing concerns around tampering with the natural world (Douglas & Wildavsky, 1982).

Overall, this pattern of results converges with what might be expected from the perspective of identity-protective cognition. Consistent with what we are seeing in Profile 1, rejection of science is strongest when it aligns with a worldview (in this case political ideology) and when the attitude holder has the cognitive skills to engage in motivated reasoning; that is, they have the education and critical skills to find attitudes sympathetic to their worldview and to critique information that is inconsistent with their worldviews.

The second-most vaccine-hesitant group was distinguished by being relatively young, poorly educated, and politically polarized. Whereas most of the current sample clustered towards the middle of the political spectrum, this group disproportionately gravitated to the ends of the political spectrum (both left and right). They had the second-lowest levels of education of all the profiles, and the equal-lowest levels of objective scientific literacy. However, their *subjective* science literacy was closer to the median for the sample, suggesting a level of confidence that seems disproportionate given how much they struggled to answer basic questions about science. This mismatch reinforces recent research suggesting that people high in anti-vaccination views might be liable to the Dunning–Kruger effect; the tendency for overconfidence to be especially high among people with the least objective knowledge. For example, objectively low knowledge about autism is associated with the belief that one knows more than experts, which in turn is associated with anti-vaccination beliefs (Motta et al., 2018).

The pattern displayed in Profile 2 cannot be easily reconciled with the notion of identity-protective cognition, given that it represents a convergence of political extremism and *low* cognitive sophistication. This pattern – which falls outside the traditional left-right divide – may reflect the emerging phenomenon of populism, characterized by a suspicion of 'elites' and 'the establishment' (as defined in opposition to ordinary citizens; Lasco & Curato, 2019; Lasco & Larson, 2020). Relatedly, Profile 2 corresponds closely to the profile of the conspiracy theorist that has emerged in social and

political psychology. Here, there is a convergence of evidence that people who are prone to the conspiracist worldview are relatively young (Essential Report, 2020), poorly educated (van Prooijen, 2017), and disproportionately located on both the far left and the far right (van Prooijen, Krouwel, & Pollet, 2015). Given that conspiracist thinking is a strong predictor of anti-vaccination views (Hornsey et al., 2018; Lewandowsky, Gignac, & Oberauer, 2013), it would seem plausible that propensity to believe conspiracies is a mechanism that might help explain why members of Profile 2 are relatively vaccine-sceptical. A conspiracist bent may also help explain why members of Profile 2 are most sceptical about wind turbines, given that turbines have been the target of numerous conspiracy theories in the past, including the notion – articulated by former US President Donald Trump among others (Worland, 2019) – that they can cause cancer.

Strengths and practical implications

The current data set has several strengths; it is a large, representative sample, capable of reaching people who are typically excluded from online samples. Most importantly, our analytic strategy was able to uncover a subsample of the population – not easily detected in traditional regression analyses – who are strongly anti-vaccination. Knowing that this group is highly educated but politically partisan is an important insight for those whose job it is to communicate with anti-vaccination communities. Because they are highly educated (and relatively science-literate), it is also likely that they are particularly prone to motivated reasoning; skilled in being able to find attitude-confirming information, and adept at critiquing or rebutting attitude-disconfirming information. For these people, it is typically assumed that the mere repeating of the scientific consensus may not be particularly effective. Instead, there is a growing convergence of scholars arguing that communication should be framed in ways that align with the audience's underlying ideologies and worldviews. In this case, messages could be framed using left-wing moral foundations of harm and justice, or focusing on mistrust of Big Pharma and Western medicine, rather than focusing on the science exclusively (Hornsey, 2020; Hornsey, Finlayson, et al., 2020).

Limitations and future directions

Of course, like any survey, the current data set carries limitations. First, it is a single-nation sample: Although there is no reason to believe that Spain would be dramatically different from other Western, industrialized nations in terms of its population attitudes towards vaccinations, this remains to be tested. The official or unofficial platform of political parties is likely to be different in different countries, which may cause nation-to-nation variability in profiles. This is particularly true in the post-Trump era in the United States, where anti-vaccination conspiracies have started to be adopted by populist political movements typically associated with the right (e.g., Baumgaertner et al., 2018; Hornsey, Finlayson, et al., 2020).

Second, the data were collected prior to the emergence of the COVID-19 pandemic. On the one hand, the emergence of the pandemic has underscored the importance of understanding the identities, backgrounds, and worldviews of anti-vaccination advocates. On the other hand, it is possible that COVID-19 has subtly changed the landscape of who is most likely to be vaccine-hesitant, as the vaccination issue gets caught in a new 'culture war' associated with the role of the state in regulating the lives of individuals.

Third, the face-to-face methodology used here has the potential to elicit more social desirability bias than other approaches such as self-administered online questionnaires. Research suggests that these biases are modest and occur only on very sensitive questions (Kim, Dubowitz, Hudson-Martin, & Lane, 2008), and this limitation is offset by the greater representativeness that the face-to-face methodology allows (Szolnoki & Hoffmann, 2013). However, we acknowledge that the face-to-face methodology may have resulted in some socially desirable responding, potentially reducing the extent to which people admitted to being anti-vaccination and/or at the extreme ends of politics. The time-intensive, face-to-face methodology also necessitated the use of relatively brief scales; future research could perhaps benefit from more sophisticated, multidimensional measures of the key constructs.

Finally, the focus of the study is anti-vaccination attitudes. Although these attitudes contribute to societal norms about vaccination – and are in themselves strongly predictive of vaccination behaviour – we can only speculate about whether the anti-vaccination views described by the people in Profiles 1 and 2 would translate to a refusal to vaccinate.

Summary and conclusions

Despite the limitations, the novel analyses reported here provide a fresh perspective on the question of who in the population is most likely to be vaccine-sceptical. Profile 1 reveals a niche community of educated, left-wing people with extreme anti-vaccination attitudes. Profile 2 reveals a coalition between people at all levels of the political spectrum, one that is united by youth, political extremism, and low education.

Given that the two profiles with the most vaccine-hesitant views were also the most politically extreme groups, the current data provide solid reinforcement of the theory of cultural cognition, which highlights how political views shape how people interpret and appraise science. However, one implication of the current data is that no single theoretical prescription can help illuminate all the nuance associated with vaccine scepticism. To exclusively take a deficit model approach – and to presume that anti-vaccination views are a simple result of poor education and a lack of cognitive sophistication – would help explain Profile 2. But it would leave one unable to anticipate the highly educated people in Profile 1 (with strong anti-vaccination views) or the poorly educated people in Profile 3 (with relatively benign views). To presume that the effects of political polarization are most apparent among the highly educated – consistent with the notion of identity-protective cognition – would leave one well positioned to predict Profile 1, but puzzled by Profile 2.

Common sense suggests that these 'competing' perspectives are likely to explain some of the people some of the time: They need not be in hydraulic competition with each other. Traditional, variable-centred techniques – that trade off perspectives and imply an ultimate winner – may have contributed to an unhelpful sense that the field is divided on what promotes 'anti-science' views such as vaccine scepticism. Profile analyses such as the ones reported here highlight that a diversity of theoretical perspectives might be necessary to explain the heterogeneous groups that hold anti-vaccination attitudes.

Conflicts of interest

All authors declare no conflict of interest.

Author contributions

Matthew J. Hornsey (Conceptualization; Writing – original draft) Martin Edwards (Formal analysis; Writing – review & editing) Josep Lobera (Data curation; Funding acquisition; Methodology; Project administration; Writing – review & editing) Celia Díaz-Catalán (Data curation; Funding acquisition; Project administration; Writing – review & editing) Fiona Barlow (Conceptualization; Writing – review & editing).

Data availability statement

Measures reported in the current manuscript were part of a broader survey examining social perceptions of science and technology. The full database is publicly available here: https://icono.fecyt.es/informes-y-publicaciones/percepcion-social-de-la-ciencia-y-la-tecnologia-en-espana

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