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

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Abstract

Understanding the factors associated with vaccine skepticism is challenging because of the "small pockets" problem: the number of highly vaccine-skeptical people is low, and small sub-samples such as these can be missed using traditional regression approaches. To overcome this problem, the current study (*N*=5200) used latent profile analysis to uncover six profiles, including two micro-communities of vaccine skeptical people that have the potential to jeopardise vaccine-led herd immunity. The most vaccine-skeptical group (1.14%) was highly educated and expressed strong liberal tendencies. This group were also the most skeptical about genetically modified crops and nuclear energy, and most likely to receive news about science from the internet. The second-most vaccine-skeptical 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.

Key words: vaccination hesitancy; political ideology; cultural cognition; rejection of science; identity-protective cognition

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 et al., 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 ten threats to global health in 2019 (WHO, 2019). This urgency has intensified since, as evidence mounts of fear and resistance toward 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 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 is 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 et al., 2018; Hornsey et al., 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 sub-optimal 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 like 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 et al. 2014; Schmid et al., 2017). Furthermore, a European Commission survey (Larson et al., 2018) found that, in a number of countries, the highest levels of vaccine skepticism were found among respondents who had no more than a primary school education.

However, evidence for a link between education and vaccine skepticism 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 skepticism in a sample of 5,323 participants in 24 countries (Hornsey et al., 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 et al., 2014) and some have had negative (backfire) effects (Betsch & Sachse, 2013). Thus, the role of education in shaping vaccine skepticism appears to be complex and requires a nuanced exploration.

As a counter-point to the deficit model of science communication, some theorists have pointed to the role of motivated reasoning (Browne et al., 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 et al., 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 skepticism and levels of education/science literacy in the U.S. (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 (Kahan, 2013; Drummond & Fischhoff, 2017; 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 skepticism 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 skepticism. 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 policy-makers 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 et al., 2020). Experimental work (Betsch et al., 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 skepticism. 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, evidence from the climate change literature that the two are only modestly correlated, and that the former shares a stronger relationship with climate skepticism than does the latter (Hornsey et al., 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 et al., 2018).

After uncovering profiles, we then used these profiles to explore differences in related attitudes and behaviors: (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 practices 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 May 14 and July 2, 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 or Masters 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 ±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 skepticism, 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 skepticism – and the four items were then combined into a single scale of vaccine skepticism ($\alpha = .64$). A fifth item was dichotomous and so was analyzed 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, organised 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. The first four items asked participants to rate the level of knowledge they possessed with regard to four domains, including "science and technology" and "medicine and health" (1 = very low, 5 = very high). The 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, as well as 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 summarised 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 to 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 6-class solution. However, the 7th class did not add

empirical value over and above the 6-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 6-class solution (which identified the small-pocket of ideologically left vaccine hesitant respondents). Therefore, the 6-class solution remains a more parsimonious solution. We also checked the 6-class full sample model against profiles produced with a 6-class solution using only the smaller, less representative listwise-deletion sub-sample. Interpretation of the 6-class solution profiles were the same regardless of whether we analysed the full sample (using FIML) or this more restricted sub-sample. In sum, the 6-class solution provided the best balance between fit, parsimony, robustness, and interpretability.

Description of profiles

Six profiles emerged. The features of the six profiles are summarised 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 skeptical to the least.

Profile 1: Educated, strong left. The group with the highest level of vaccine skepticism (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 skepticism (1.79 standard deviations above the mean) were found in a profile comprising 3.4% of the sample (N = 179). On average, 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 polarised 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 skepticism (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 (-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 skepticism (-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*) as well as 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-skeptical class – Profile 1 – predominantly reported that the risks outweigh the benefits. The second most vaccine-skeptical class – Profile 2 – was 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 indivated 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, $\chi^2(15) = 39.70$, $p < .001$; 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 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 toward scientific innovations held by people in the respective profiles. Table 3 summarises the means across profiles. Of note, the most vaccine-hesitant sub-sample (Profile 1) was especially skeptical 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 skepticism 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 skepticism; micro-communities that have the potential to jeopardise the goal of vaccine-led herd immunity. Describing these groups of people can help policy makers and science communicators anticipate and defuse vaccine skepticism 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 were 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 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 toward (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 skeptical 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 criticial 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 polarised. Whereas most of the current sample clustered toward 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 second-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 over-confidence 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, characterised 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 et al., 2015). Given that conspiracist thinking is a strong predictor of anti-vaccination views (Hornsey et al., 2018; Lewandowsky et al., 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 skeptical. A conspiracist bent may also help explain why members of Profile 2 are most skeptical 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 sub-sample 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-literatre) it is also likely that they are particularly prone to motivated reasoning; skilled in being able to find attitude-conforming 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 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, industrialised nations in terms of its population attitudes toward 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 U.S., 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 et al., 2020).

Second, the data were collected prior to the emergence of the COVID-19 pandemic. On 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 et al., 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 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 multi-dimensional 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 behavior – 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 skeptical. Profile 1 reveales 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 view 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 skepticism. 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 polarisation 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 skepticism. 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.

Data Availability

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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Table 1
Means, Standard Deviations and Bivariate Correlations Among Variables in the Profiles

Measure	*M*	*SD*	*2*	*3*	*4*	*5*	*6*
1. Vaccine skepticism	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					-

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

Table 2.

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

N of Classes	Log Lik'	*N* free Parameters	*AIC*	*BIC*	*SSABIC*	*Entropy*	Lo-Mendell Rubin Adjusted	*p*	Parametric Bootstrapped Likelihood	*p*	*N* of vaccine skeptical classes >mean
1	-57849	20	115723	115802	115763						
2	-56870	27	113779	113903	113843	0.76	1926	<.001	1958	<.001	1
3	-56523	34	113098	113269	113186	0.78	683	<.001	694	<.001	1
4	-56247	41	112561	112777	112672	0.77	542	<.001	551	<.001	2
5	-56026	47	112133	112395	112268	0.77	435	.005	442	<.001	2
6	-55907	20	111906	112214	112064	0.79	237	.028	241	<.001	3
7	-55780	27	111668	112022	111850	0.80	248	.449	252	<.001	3
8	-55686	34	111494	111894	111700	0.81	185	.007	188	<.001	3
9	-55598	41	111333	111779	111563	0.79	172	.001	175	<.001	4
10	-55517	75	111185	111676	111438	0.80	159	.004	162	<.001	5

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)

Notes. Analysis of variance revealed that the differences across the profiles were significant for GM crops, $F(5,4663)=14.29$, $p<.001$, $\eta^2=.015$; nuclear energy, $F(5,4682)=9.49$, $p<.001$, $\eta^2=.010$; fracking, $F(5,3292)=17.52$, $p<.001$, $\eta^2=.026$; and wind turbines, $F(5,4829)=26.09$, $p<.001$, $\eta^2=.026$. 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 Tukey posthoc tests ($p < .05$). Numbers in parentheses are standard deviations.

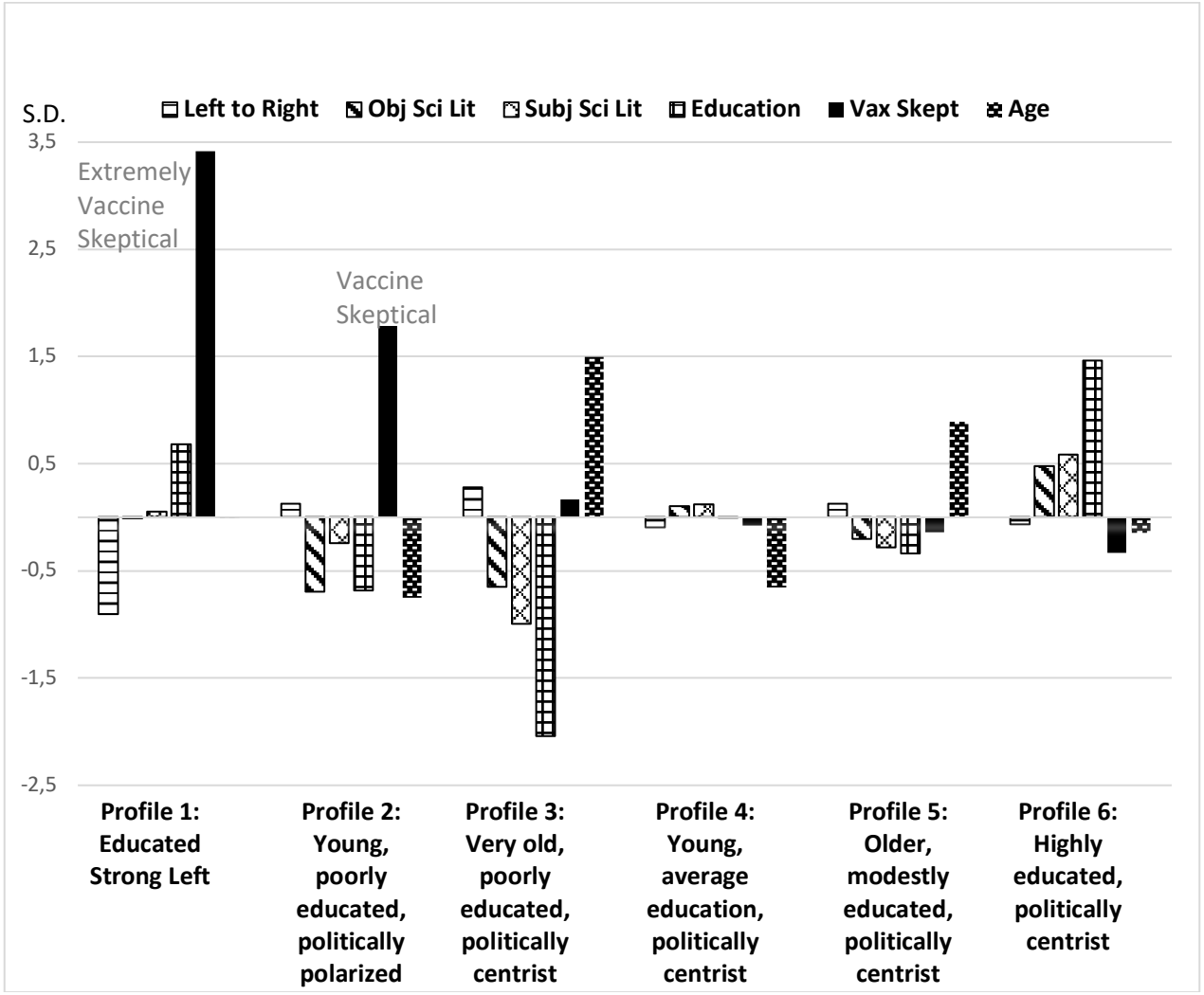
Figure Captions

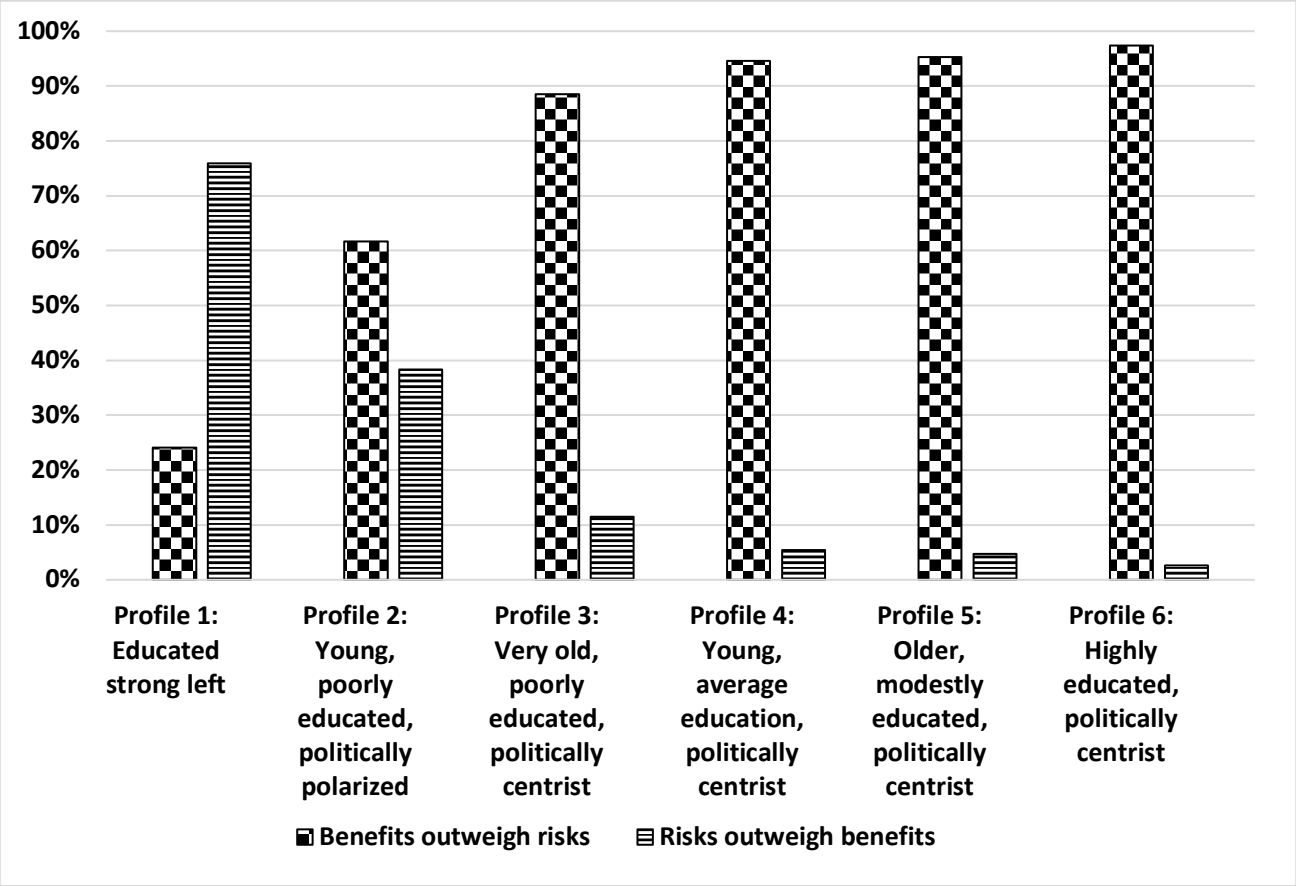
Figure 1. Profile plots for 6-class solution. Vertical bars indicate how many standard deviations above or below the sample each profile scores across the six variables of interest. *Obj Sci Lit* and *Subj Sci Lit* refer to objective and subjective science literacy respectively. *Vaxx Skept* refers to vaccine skepticism. Low scores on the left to right variable indicate the profile was more left-wing on average than the mean for the sample.

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.

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 summarises 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.


S.D.
Left to Right
Obj Sci Lit
Subj Sci Lit
Education
Vax Skept
Age
3,5
2,5
1,5
0,5
-0,5
-1,5
-2,5
Extremely Vaccine Skeptical
Vaccine Skeptical
Profile 1: Educated Strong Left
Profile 2: Young, poorly educated, politically polarized
Profile 3: Very old, poorly educated, politically centrist
Profile 4: Young, average education, politically centrist
Profile 5: Older, modestly educated, politically centrist
Profile 6: Highly educated, politically centrist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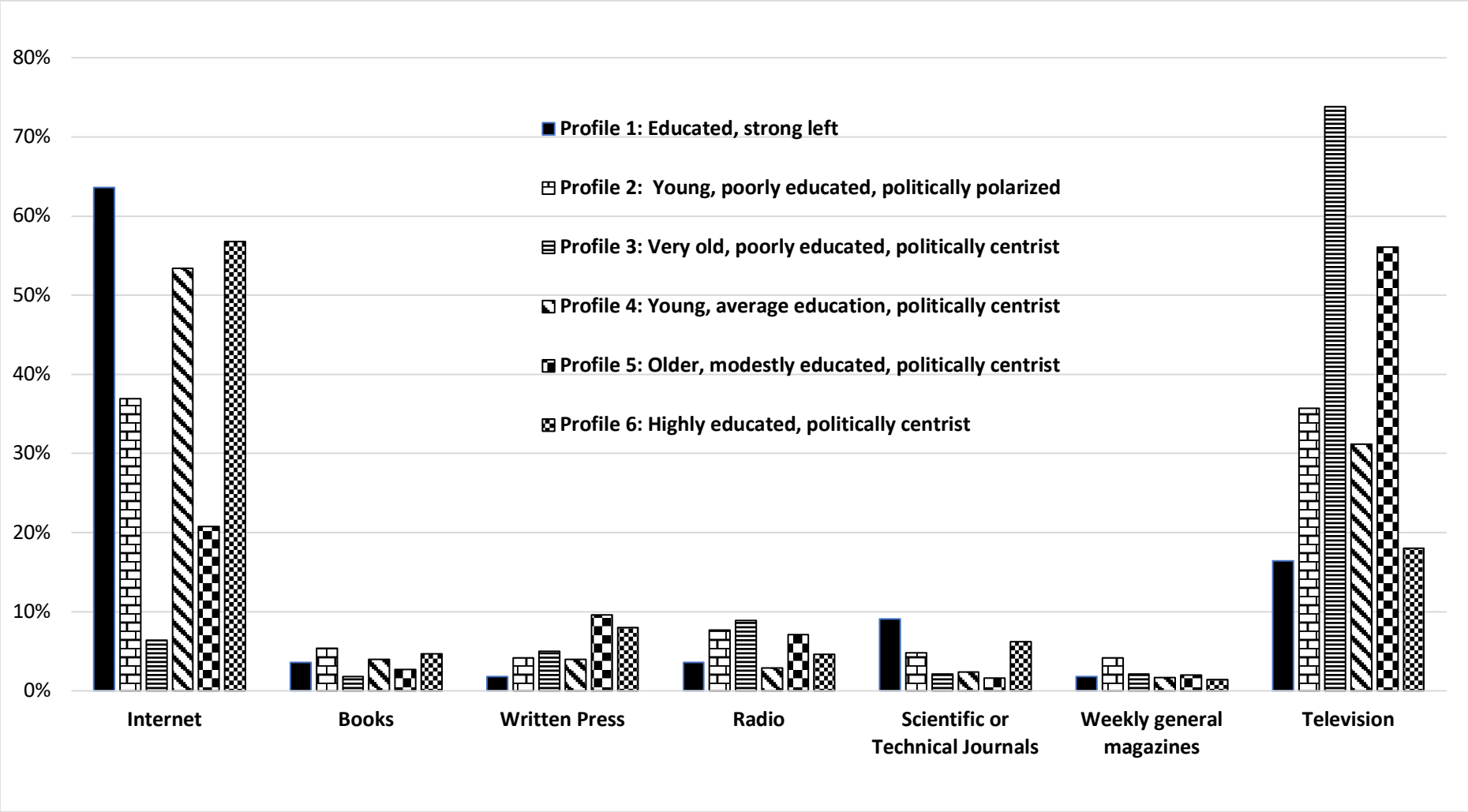
Profile 1: Educated strong left
Profile 2: Young, poorly educated, politically polarized
Profile 3: Very old, poorly educated, politically centrist
Profile 4: Young, average education, politically centrist
Profile 5: Older, modestly educated, politically centrist
Profile 6: Highly educated, politically centrist
Benefits outweigh risks
Risks outweigh benefits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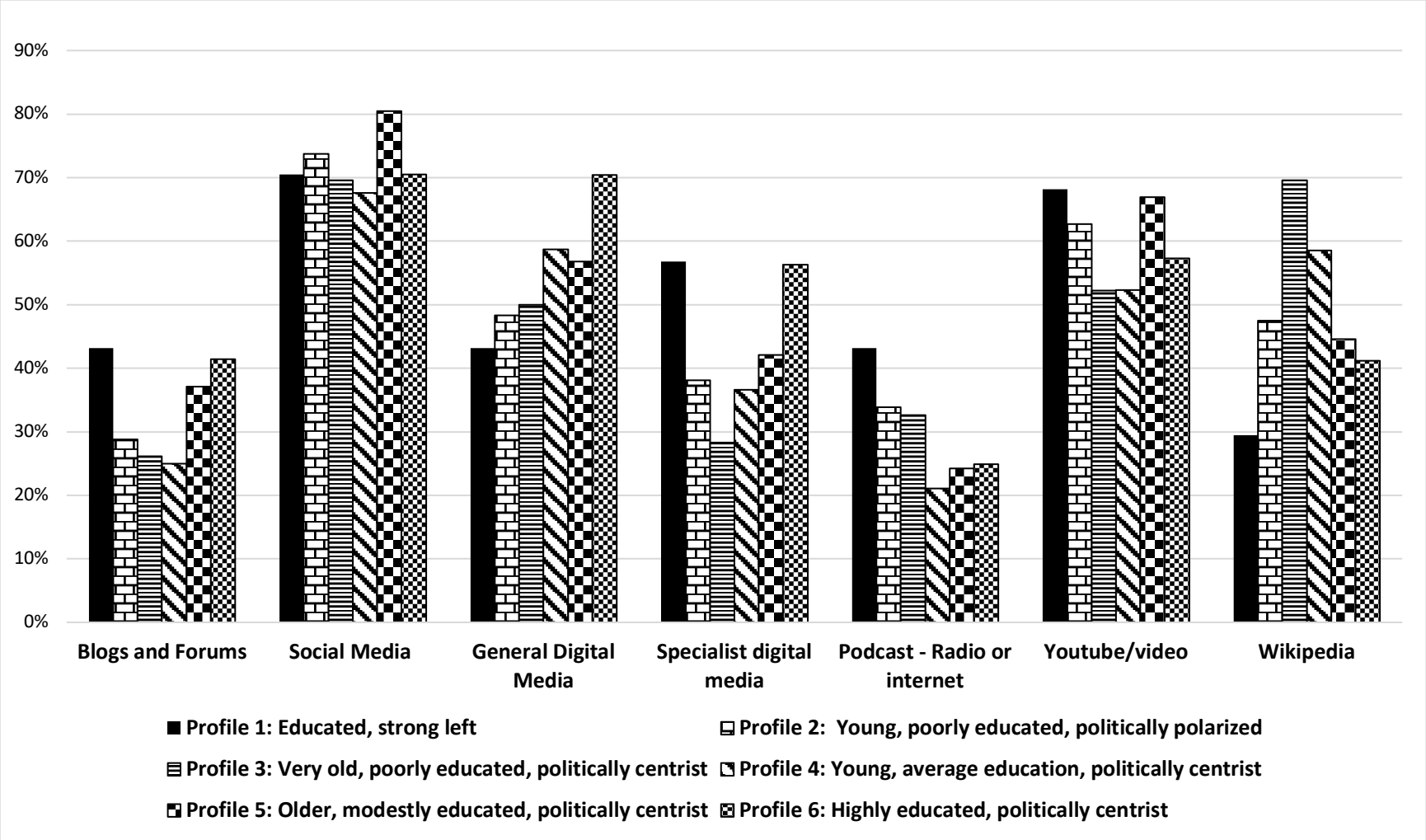
Profile 1: Educated, strong left
Profile 2: Young, poorly educated, politically polarized
Profile 3: Very old, poorly educated, politically centrist
Profile 4: Young, average education, politically centrist
Profile 5: Older, modestly educated, politically centrist
Profile 6: Highly educated, politically centrist
Internet
Books
Written Press
Radio
Scientific or Technical Journals
Weekly general magazines
Television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Blogs and Forums
Social Media
General Digital Media
Specialist digital media
Podcast - Radio or internet
Youtube/video
Wikipedia
Profile 1: Educated, strong left
Profile 2: Young, poorly educated, politically polarized
Profile 3: Very old, poorly educated, politically centrist
Profile 4: Young, average education, politically centrist
Profile 5: Older, modestly educated, politically centrist
Profile 6: Highly educated, politically centrist