



## HEALTH PROMOTION

# Political views and science literacy as indicators of vaccine confidence and COVID-19 concern

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## Keywords

Vaccine hesitancy • Science literacy • Political views • COVID-19 • Pandemic concern

## Summary

**Introduction.** *The distrust, delay and refusal of vaccinations represent serious threats to global public health. As demonstrated by the dramatic worldwide impact of the COVID-19 pandemic, adequate vaccine coverage against infectious diseases is essential towards the preservation and function of virtually every aspect of our society. While the determinants of vaccine hesitancy and pandemic concern have been widely investigated, conflicting evidence exists with regards to their association with education levels and political views.*

**Methods.** *This study aimed to investigate whether science literacy levels and standpoint on social and economic matters are associated with different levels of vaccine confidence and COVID-19 concern. An online survey was circulated amongst participants recruited via convenience sampling, and data were analysed using non-parametric statistical tests.*

**Results.** *The survey (n = 389) highlighted that participants who studied Science at General Certificate of Secondary Education level have a lower vaccine confidence than those with both lower and higher levels of science education. Participants with neutral/centrist political views expressed lower confidence than those with a libertarian social stance or a left-wing economic stance. A higher concern with the COVID-19 pandemic was associated with lower levels of science education, libertarian social views, and left-wing economic views.*

**Conclusions.** *The present study provides novel insight on the educational and political factors associated with vaccine hesitancy and pandemic concern within a British population sample.*

## Introduction

Vaccine hesitancy: definition, causes and consequences  
Vaccine hesitancy, defined as the delay, refusal, or distrust of vaccinations, had been classified by the World Health Organization (WHO) as one of the top ten threats to global health even before the COVID-19 pandemic brought the subject of immunisation to the frontpage of worldwide news outlets [1]. Far from being a recent phenomenon, scepticism and hostility have accompanied the practice of artificial immunisation even prior to the administration of the first vaccine in 1796 by Edward Jenner [2]. It is worth noting that vaccine hesitancy rarely presents itself as a dichotomy between full acceptance and full refusal. In most cases, hesitancy represents a continuum whereby hesitant individuals do not oppose all vaccinations unconditionally, but rather accept some vaccinations while refusing or delaying others [3]. The multifaceted nature of vaccine hesitancy is underpinned by an equally complex combination of causative factors. Understanding why individuals hesitate or refuse to vaccinate themselves and their children is crucial towards helping policymakers and healthcare workers (HCW) deploy mitigation strategies [4]. Towards this endeavour, the WHO Strategic Advisory Group of Experts (SAGE) developed two keystone theoretical frameworks, namely the Complacency, Convenience and Confidence (“3Cs”) model and the Determinants

of Vaccine Hesitancy Matrix [5]. In the 3Cs model, confidence is defined as trust in the effectiveness and safety of the vaccines, as well as the healthcare system and personnel that promote and deliver them. Complacency refers to the risks posed by specific vaccine-preventable diseases (VPD) being perceived as low and therefore not worth the risk/hassle associated with the vaccination. Convenience encompasses the factors relating to the availability, affordability, and accessibility of vaccinations. The Determinants of Vaccine Hesitancy Matrix provides a more complex framework to categorise the factors and influences that lead to vaccine hesitancy, arranging them into three broad categories: contextual influences, individual and group influences, and vaccine-specific issues. As high levels of vaccine coverage are crucial in maintaining herd immunity within a population, vaccine hesitancy and refusal have been linked to the re-emergence and diffusion of vaccine-preventable diseases (VPD). Historically, events leading to a decrease in vaccine confidence and uptake have resulted in VPD outbreaks in the following period. For example, a case report published in 1974 suggested a causative link between the DPT (diphtheria, pertussis, tetanus) vaccine and the onset of neurological damage in 36 children [6]. Although those findings were subsequently disproved due to inadequate experimental design and small sample size of the report, the controversy led to a decrease in DPT vaccination

uptake in several countries [7]. In the UK, DPT vaccine coverage decreased from 81% to 31% in the aftermath of the scandal, causing frequent pertussis outbreaks until vaccine uptake was restored to levels close to the herd immunity threshold [8]. Analysis of epidemiological data show that the incidence of pertussis was unaffected by the DPT controversy in countries where vaccine hesitancy was low and uptake high [9]. In comparison, pertussis incidence was 10-100 times higher in countries where the immunisation campaigns were disrupted by anti-vaccination movements. Similarly, the allegations of a causative link between the MMR (measles, mumps, rubella) vaccine and the onset of gastrointestinal and neurological symptoms proposed in 1998 by Andrew Wakefield in *The Lancet* led to a dramatic decrease in MMR coverage over the following years [10]. Despite the retraction of Wakefield's paper and his removal from the British medical register due to several counts of scientific malpractice and unethical conduct, the MMR controversy had a global detrimental impact on vaccine confidence, the consequences of which are still felt to this day [11]. Over the last decade, the affirmation of anti-vaccination movements in the aftermath of the MMR controversy has led to the re-emergence of measles outbreaks in several developed countries in which the disease had been nearly eradicated prior to the publication of Wakefield's fraudulent paper [12].

## Politics and vaccine hesitancy

The deployment of the COVID-19 vaccines has already had a significant impact on the number of cases, hospitalisations and fatalities, and the success of vaccination campaigns is crucial in the global efforts of overcoming the current pandemic. However, this endeavour will require vaccine coverage to reach sufficiently high levels: although the herd immunity threshold for SARS-CoV-2 has not been determined yet, it is clear that the circulation of the virus can only be stopped if the vast majority of the global population receives a complete immunisation course against it [13]. The acceptance of the COVID-19 vaccination campaigns depends heavily on the population's trust in their governing bodies, which is in turn a direct consequence of the popular perception of the government's handling of the current pandemic [14]. In the UK, the observation of eminent governmental figures such as Chief Adviser Dominic Cummings (and, more recently, Health Secretary Matt Hancock) caught breaching lockdown restrictions and social distancing that they had personally contributed to impose, had a detrimental effect on the public's confidence in the National Health Service (NHS) and on the vaccination campaigns they promote [15]. A survey carried out amongst the French population revealed that political views are a key determinant of people's attitudes towards COVID-19 vaccinations. Far-right and far-left voting individuals, as well as those who abstain from voting, are significantly more likely to refuse a vaccine than

those holding more moderate or centrist views [16]. The research also indicated that criticism of the government by opposing political parties caused distrust and uncertainty around vaccine campaigns. The problems that arise when political entities attempt to convince the public of vaccine safety are connected to the difficulty in assuring that the recommendations given are determined by scientific information, and not motivated by politics. These findings reinforce previous observations that individuals on the political fringes, far right and far left, tend to overestimate their own knowledge and have misplaced certainty in their views. This can make them resistant to change their views and beliefs, even when provided with evidence to the contrary, a metacognitive feature which may explain why anti-vaccine sentiment is more common in those with more radical political beliefs [17]. The last decade has seen the consolidation of populist worldviews in the global political panorama. Independently from their political colour, populist parties present themselves as standing for 'the people' against 'the elite', defining both categories by different (albeit frequently nebulous) criteria depending on where they fall in the political spectrum [18]. Both political populism and vaccine hesitancy are underpinned by a similar distrust in authority, and often accompanied by conspiratorial, anti-establishment, and anti-intellectual worldviews. A recent analysis of national-level data revealed a strong association between votes for populist parties in the 2014 European Parliament elections and vaccine hesitancy in the same country, highlighting that "Vaccine hesitancy and political populism are driven by similar dynamics: a profound distrust in elites and experts" [19].

## Educational levels, science literacy and vaccine hesitancy

The correlation between educational levels and vaccine hesitancy has been widely investigated, however there is contrasting evidence with regards to the nature, or arguably even existence, of any such correlation. For example, while higher levels of hesitancy were associated with lower education and income levels in the Canadian Childhood National Immunization Coverage Survey [20], the inverse trend had been found in a previous review of U.S. medical records [21]. On the other hand, no association between vaccine hesitancy and education levels was observed in a multi-national study carried out across five low- or middle-income countries [22]. These observations indicate that the analysis of the relationship between education and vaccine hesitancy is likely to be affected by other confounding variables of social, economic, cultural or religious nature. Another key factor complicating the elucidation of a relationship between education and vaccine hesitancy is that both variables themselves are defined and quantified differently across different studies, which frequently use dissimilar strategies for population sampling, survey design, and data analysis. Moreover, the majority of

studies investigating the demographic determinants of vaccine hesitancy mainly focus on the qualification level of participants or communities without taking into account the subject studied at each level [23]. As hesitancy is often underpinned by inadequate or incorrect information on the composition, mechanism of action, and safety of vaccines, it is reasonable to speculate that higher levels of literacy in biomedical subjects may be associated with increased levels of vaccine confidence. A recent systematic review highlighted that while there is a positive association between health literacy and vaccine acceptance, this relationship is influenced by confounding variables related to both the individual (country, age) and the nature of the vaccine [24].

## Aims

The primary aim of this study was to elucidate whether science literacy and political views are associated with vaccine confidence (or lack thereof) in a British population sample. The secondary aim was to investigate the association of the same two factors with different levels of concern about the COVID-19 pandemic. Science literacy (as opposed to health literacy) was chosen as an independent variable to account for the observation that vaccine hesitancy is caused not only

by a lack of understanding of the biological bases of vaccination, but in many instances by a lack of trust in scientists and in the scientific method itself. Regardless of the scientific discipline studied, individuals familiar with its rudiments are more likely to understand and accept its basic principles (replicability, falsifiability, difference between correlation and causality) and therefore less likely to reject empirical evidence and take on pseudo-scientific or anti-scientific views [25, 26]. To gain a broader understanding of the correlation between political views and vaccine confidence in the sample population, the participants' stances on social and economic matters were used as two distinct independent variables. This is a crucial distinction because, unlike the one-dimensional left/right political axis, it allows to decouple the participants' stance along the libertarian/authoritarian axis from their position with regards to economic issues [27].

## Methods

### ETHICAL APPROVAL

This study was carried out in accordance with the Helsinki declaration for research involving human subjects and with the University of Portsmouth Ethics Policy. Ethical approval (code BIOL-ETHICS #009-

**Tab. 1.** Questionnaire used in the survey. Answers to the questions highlighted with an asterisk were used in the calculation of the Vaccine Confidence Score.

<b>Section 1: about you</b>
1.1 What is your age?
1.2 What gender do you identify as?
1.3 What is your annual income?
1.4 How many children do you have?
1.5 What is your highest academic qualification?
1.6 What academic levels have you studied science at? (Tick all that apply)
1.7 What is your ethnic group?
1.8 What is your religion/spiritual belief?
1.9 How would you describe your stance on social matters?
1.10 How would you describe your stance on economic matters?
<b>Section 2: attitude on vaccinations</b>
*2.1 Vaccines are safe.
*2.2 I think vaccines should be a compulsory practice.
*2.3 I believe that vaccine-preventable diseases (like measles and mumps) can be serious.
*2.4 My healthcare provider (for example my GP) has mine and/or my child's best interests at heart.
2.5 I believe the government has my best health interests at heart
*2.6 Vaccines are beneficial for our health and wellbeing.
2.7 Are you opposed to any vaccinations?
2.7.1 If YES, which vaccinations are you opposed to and why?
<b>Section 3: COVID-19</b>
3.1 Do you agree or disagree with the following statement: "I am concerned with the current pandemic"?
3.2 How likely are you to get vaccinated against COVID-19 when a vaccine becomes available?
3.3 How likely are you to vaccinate your child/children against COVID-19? (Please leave blank if you do not currently have children or don't plan to have any)
3.4 With the ongoing pandemic, have you considered getting vaccinated against the common flu this year?
3.4.1 If NO, is there any specific reason?
3.4.2 If YES, is there any specific reason?

2020) was obtained by the investigators prior to the distribution of the survey. A disclaimer, provided at the beginning of the survey, described its voluntary and anonymous nature. Participants were informed of their right to omit any questions they did not feel comfortable answering, as well as their right to withdraw at any point by not clicking the “submit” button. No information that would allow the identification of individual participants was collected in the survey. All data were processed and stored in accordance with the General Data Protection Regulation (GDPR).

#### *Survey design and distribution*

The questionnaire used in this study (Tab. I) was structured in three sections. Section 1, titled “About you”, contained questions designed to determine the demographic features of the participants (age, gender, ethnicity, annual income, academic qualifications) as well as their religious beliefs and stance on social and economic matters. Section 2 was titled “Attitude on Vaccinations”, and required participants to respond

to statements about their perception of the safety and benefits of the practice of vaccination in general. Section 3, titled “COVID-19”, included questions to gather the public’s perspectives on the COVID-19 pandemic and intentions to get vaccinated against it. It is important to note that the survey was distributed before COVID-19 vaccinations were publicly available, but at a time when their development and upcoming administration were prevalent in national and international news. The questionnaire contained a mix of multiple choice (Likert-type, yes/no, and tick box questions) and open-ended questions designed to gather, respectively, quantitative and qualitative data on the public’s perception on the practice of vaccination. Some of the questions in sections 2 and 3 were adapted from the World Health Organisation survey “Determinants of vaccine hesitancy: sample survey questions” [28], while the remaining sections and questions were developed by the investigators specifically for this study. The survey was developed using Google Forms and distributed online between the 9<sup>th</sup> of November and the 11<sup>th</sup> of December 2020. A

**Tab. II.** Demographic characteristics of the study population.

<b>Age</b>	<b>Count</b>	<b>%</b>	<b>Highest academic qualification</b>	<b>Count</b>	<b>%</b>
18-24	207	53.2	GCSE/O-LEVEL/equivalent	41	10.5
25-30	13	3.3	A-level/BTEC/equivalent	188	48.3
31-45	41	10.5	Bachelor’s degree	98	25.2
46-60	96	24.7	Post-graduate degree	50	12.8
60+	32	8.2	Other	7	1.8
<b>Income</b>	<b>Count</b>	<b>%</b>	<b>Religion</b>	<b>Count</b>	<b>%</b>
Not currently in employment	129	33.3	Agnostic / Atheist	185	48.3
£0 - 20,000	113	29.2	Buddhist	4	1.0
£21,000 - 30,000	50	12.9	Christian	179	46.7
£31,000 - 40,000	39	10.1	Hindu	1	0.3
£41,000 - 50,000	20	5.2	Jewish	0	0.0
£51,000 - 60,000	10	2.6	Muslim	6	1.6
£61,000 - 70,000	13	3.4	Sikh	0	0.0
£71,000 or more	13	3.4	Other	7	1.8
<b>Ethnicity</b>	<b>Count</b>	<b>%</b>	<b>Number of children</b>	<b>Count</b>	<b>%</b>
Arab	3	0.8	0	239	61.4
Asian - Bangladeshi	0	0.0	1	12	3.0
Asian - Chinese	3	0.8	2	90	23.1
Asian - Indian	2	0.5	3	35	8.9
Asian - Other	3	0.8	4	9	2.3
Asian - Pakistani	2	0.5	5+	3	0.7
Black - African	0	0.0			
Black - Caribbean	2	0.5	Gender	Count	%
Black - Other	2	0.5	Female	286	73.5
Mixed - White and Asian	4	1.0	Male	103	26.5
Mixed - White and Black African	0	0.0			
Mixed - Other	7	1.8			
Mixed - White and Black Caribbean	5	1.3			
White - English/Welsh/Scottish/Northern Irish	305	78.8			
White - Irish	9	2.3			
White - Gypsy or traveller	0	0.0			
White - Other	38	9.8			
Other ethnicity	2	0.5			

convenience sampling strategy was used, whereby the survey link was distributed by the investigators using different social media platforms, namely Facebook, Instagram, and WhatsApp.

#### DATA ANALYSIS

Data were analysed using IBM SPSS Statistics 26. Given the ordinal nature of the data gathered in the survey, non-parametric tests were used to analyse the statistical significance of the findings. In particular, Kruskal-Wallis tests were used with a significance p-value cut-off of 0.05 to compare median answers between different groups of participants. When statistically significant differences were highlighted via Kruskal-Wallis tests, post-hoc pairwise Dunn's tests were carried out to pinpoint where the differences lay, and the significance threshold adjusted using Bonferroni corrections to minimise family-wise error rate. The Vaccine Confidence Score (VCS) was used as a dependent variable in this study to provide a quantitative indication of respondents' confidence in vaccinations [29]. In brief, the VCS is calculated as the sum of the scores obtained from five selected Likert-

type questions (questions 2.1, 2.2, 2.3, 2.4, 2.6) after converting the answer to each question to a numerical value (from 1-Strongly Disagree to 5-Strongly Agree). Therefore, VCS values range from 5 (lowest vaccine confidence) to 25 (highest vaccine confidence). Participants' science literacy (question 1.6) and stance on social (question 1.9) and economic (question 1.10) matters were used as grouping variables.

## Results

#### STUDY POPULATION

A total of 389 adult volunteers took part in the survey. The demographic distribution of the population by age, gender, income, parental status, academic qualification, ethnicity and religion is provided in Table II. Due to the convenience sampling strategy used in this study, young women from a white ethnic background were heavily represented amongst the population, reflecting the demographic characteristics of the investigators who distributed the survey. The distribution of participants according to their science education level, stance

Fig. 1. Distribution of the study participants according to their highest level of science education

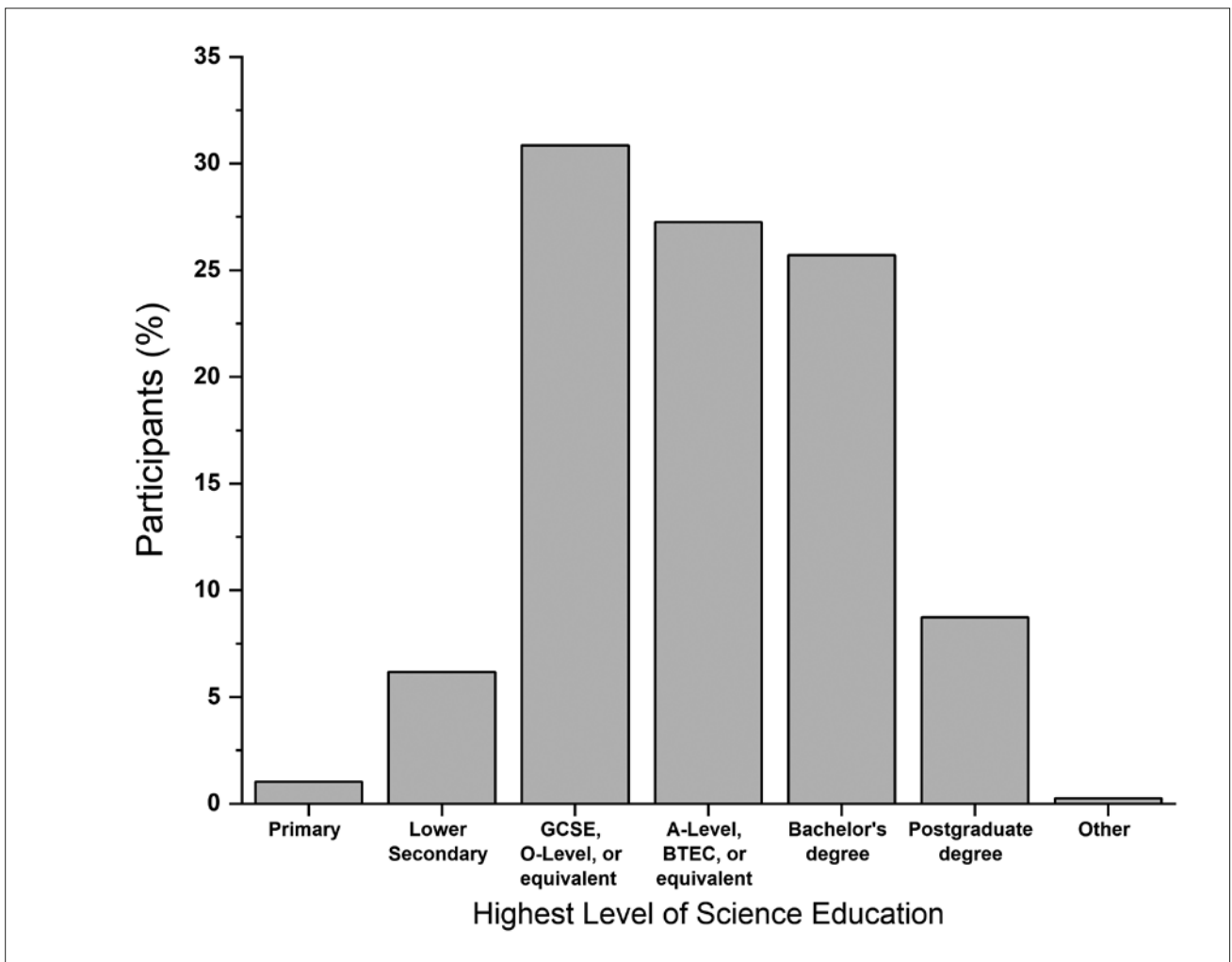
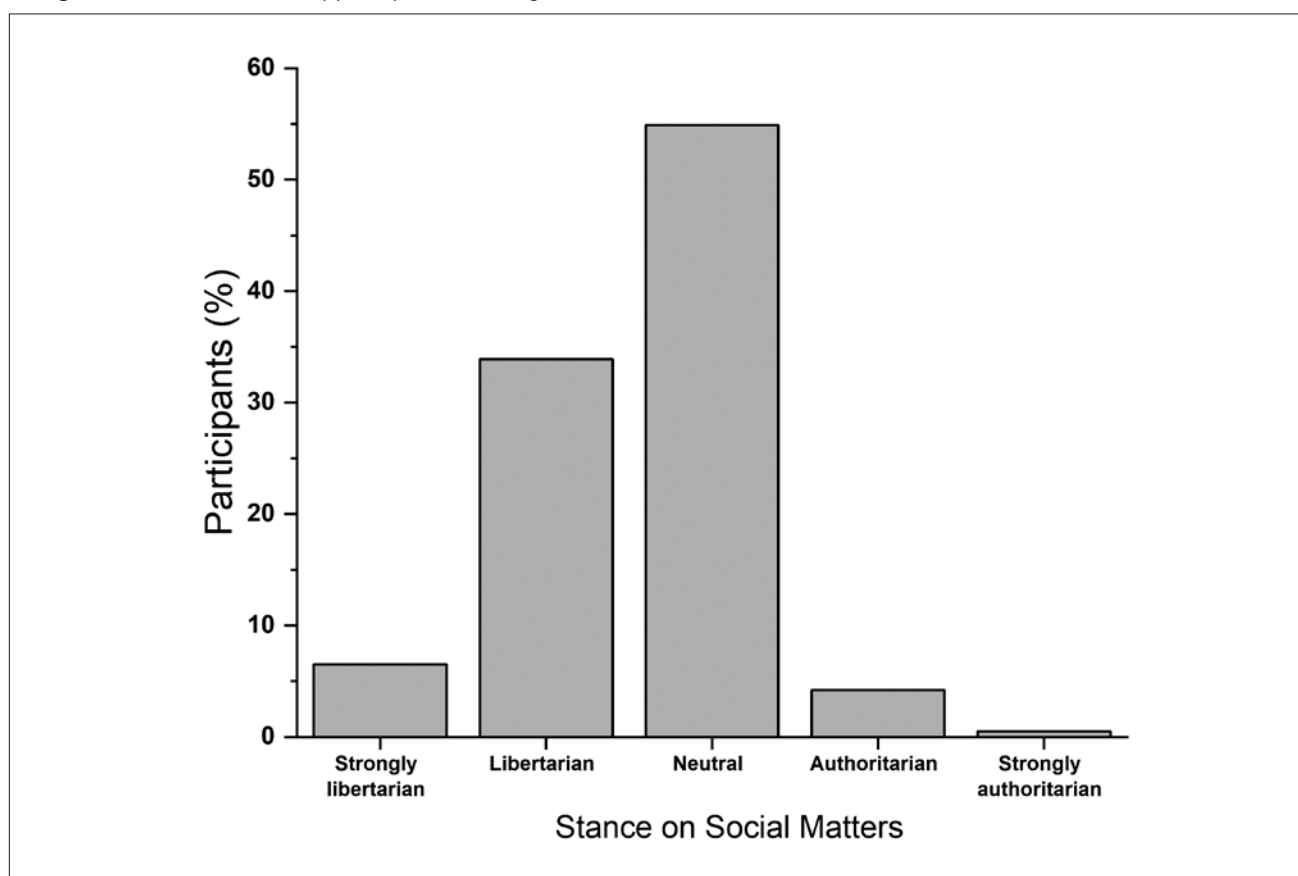




Fig. 2. Distribution of the study participants according to their stance on social matters.



on social matters and stance on economic matters is presented in Figure 1, 2, and 3 respectively. The majority of the population had a science education level between General Certificate of Secondary Education (GCSE) and Bachelor's degree, and neutral/centrist views on both social and economic matters.

#### SCIENCE LITERACY

The association between science literacy and vaccine confidence is shown in Figure 4. Due to the small numbers of participants whose highest level of science literacy was primary education, they were pooled with the lower secondary group and presented as "primary and lower secondary" for the following analysis. A Kruskal-Wallis test revealed the presence of statistically significant differences ( $\chi^2 = 24.219$ ;  $df = 4$ ;  $p = 0.000072$ ) in median VCS between participants with different levels of science literacy. Post-hoc pairwise Dunn's tests identified that the p-value was below the 0.05 significance threshold when comparing participants who studied science at GCSE/O-level against those who studied it at A-level/BTEC ( $p = 0.0082$ ), GCSE/O-level against primary/lower secondary ( $p = 0.049$ ), GCSE/O-level against Bachelor's degree ( $p = 0.000001$ ), postgraduate degree against Bachelor's degree ( $p = 0.048$ ) and A-level/BTEC against Bachelor's degree ( $p = 0.028$ ). However, when the significance threshold was adjusted via Bonferroni correction for multiple tests, a statistically significant

difference ( $p = 0.000011$ ) was only observed between GCSE/O-level (median VCS = 20) and Bachelor's degree (median VCS = 22).

#### SOCIAL AND ECONOMIC STANCE

The association between vaccine confidence and stance on social and economic matters is presented in Figure 5 and 6 respectively. Due to the small number of respondents expressing extreme positions in terms of social and economic stance, participants belonging to fringe groups were pooled with their more moderate counterparts for the following analysis. A Kruskal-Wallis test revealed a significant difference ( $\chi^2 = 11.985$ ;  $df = 2$ ;  $p = 0.0024$ ) in median VCS between participants with different social stances. Post-hoc tests revealed that participants with a neutral social stance were significantly less confident than those with libertarian views ( $p = 0.00073$ ), but not those with authoritarian views. The significant difference in vaccine confidence between libertarian (median VCS = 21) and neutral (median VCS = 20) participants held true after adjusting the significance level using Bonferroni correction ( $p = 0.0022$ ). A difference in VCS ( $\chi^2 = 19.179$ ;  $df = 2$ ;  $p = 0.00007$ ) was also observed with respect to economic stance, whereby those with left wing views were significantly more vaccine-confident than those with centrist ( $p = 0.000012$ ) and right wing ( $p = 0.050$ ) views. However, after adjusting the significance levels

Fig. 3. Distribution of the study participants according to their stance on economic matters.

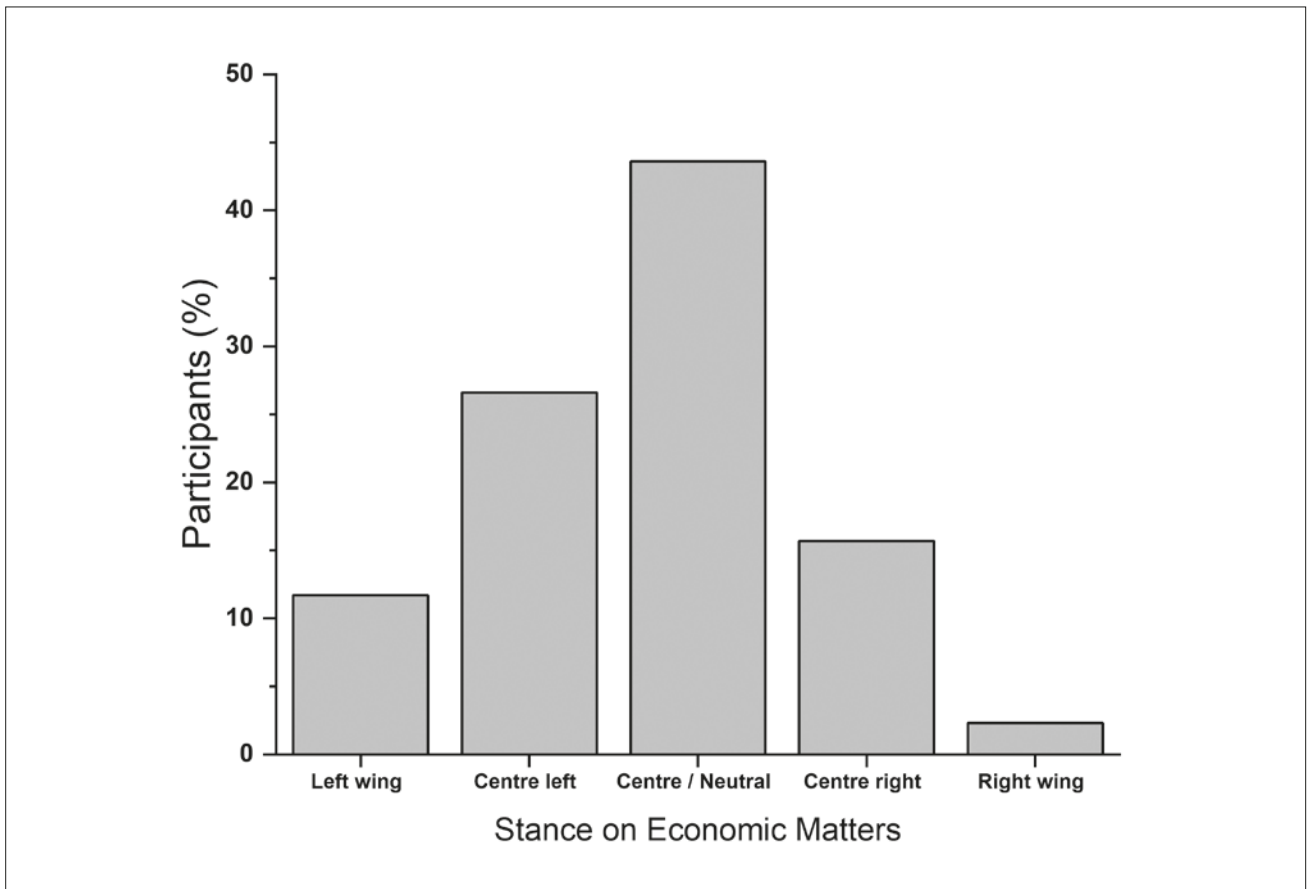


Fig. 4. Association between participants' highest level of science education and their Vaccine Confidence Score.

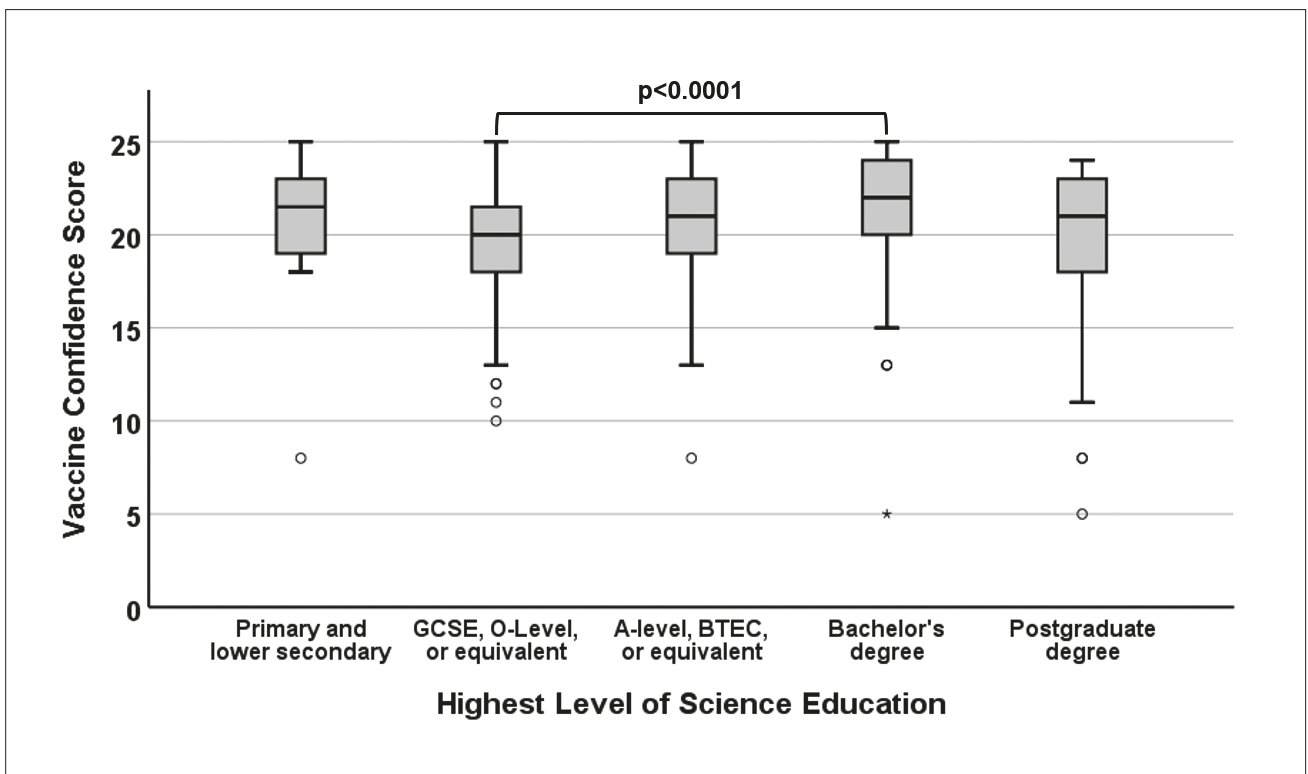


Fig. 5. Association between participants' stance on social matters and their Vaccine Confidence Score.

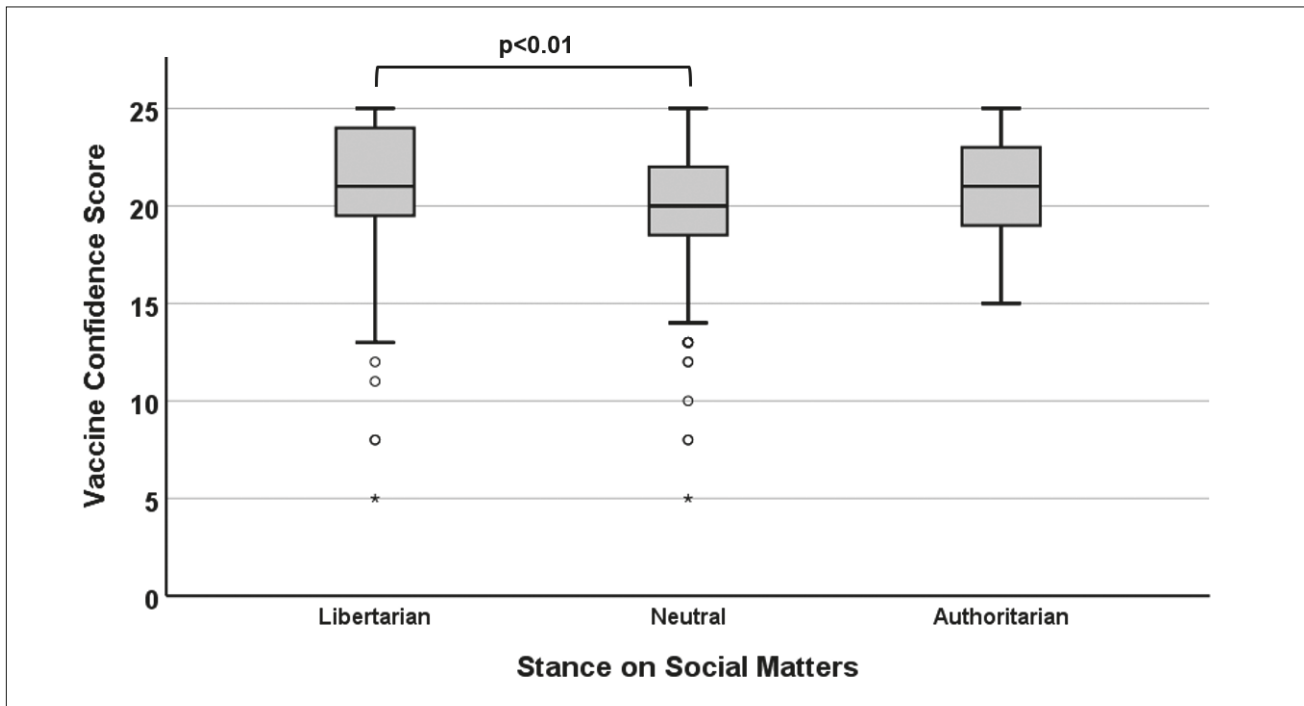
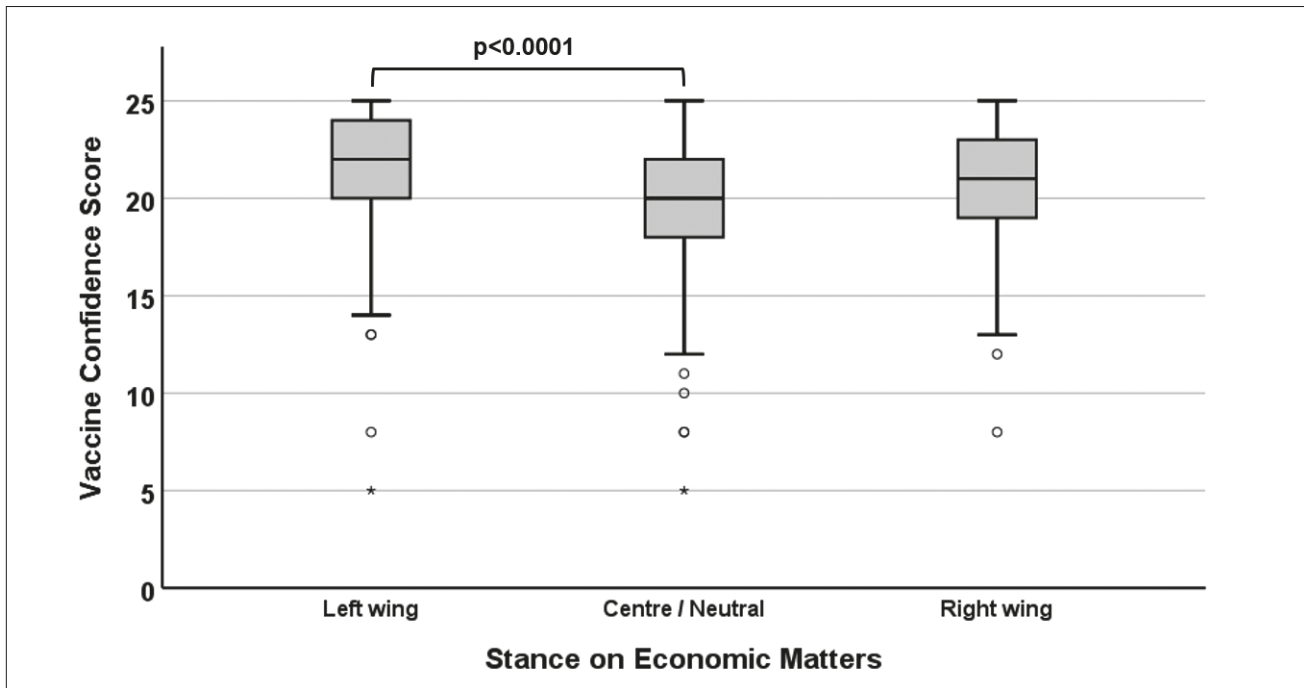


Fig. 6. Association between participants' stance on economic matters and their Vaccine Confidence Score.



for multiple comparisons, only the difference between left wingers (median VCS = 22) and centrists (median VCS = 20) remained significant ( $p = 0.00004$ )

#### LEVELS OF CONCERN ABOUT THE COVID-19 PANDEMIC

A statistically significant difference ( $\chi^2 = 11.853$ ;  $df = 4$ ;  $p = 0.018$ ) was observed in the levels of concern about

the COVID-19 pandemic amongst participants with different levels of science education (Fig. 7). Participants who studied science at lower secondary level or below expressed the highest levels of concern, which was significantly higher than those at GCSE/O-level ( $p = 0.019$ ), A-level/BTEC ( $p = 0.035$ ), and bachelor's degree ( $p = 0.008$ ). Participants who studied science at the postgraduate degree level showed the lowest



Fig. 7. Participants' agreement with the statement "I am concerned with the current pandemic" according to their highest level of science education.

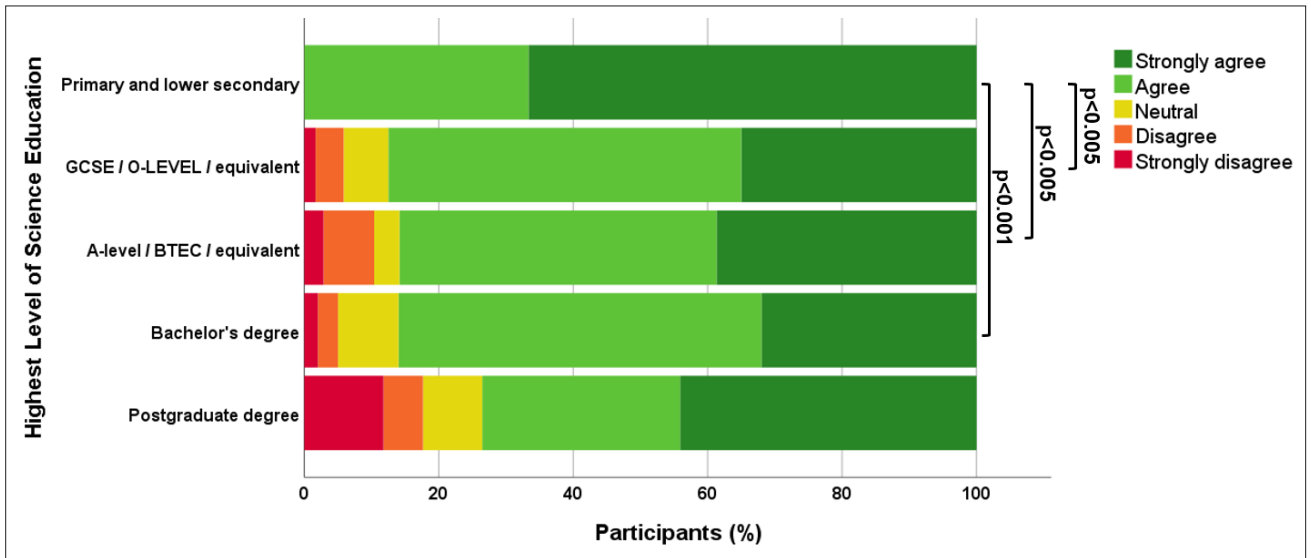


Fig. 8. Participants' agreement with the statement "I am concerned with the current pandemic" according to their stance on social matters.

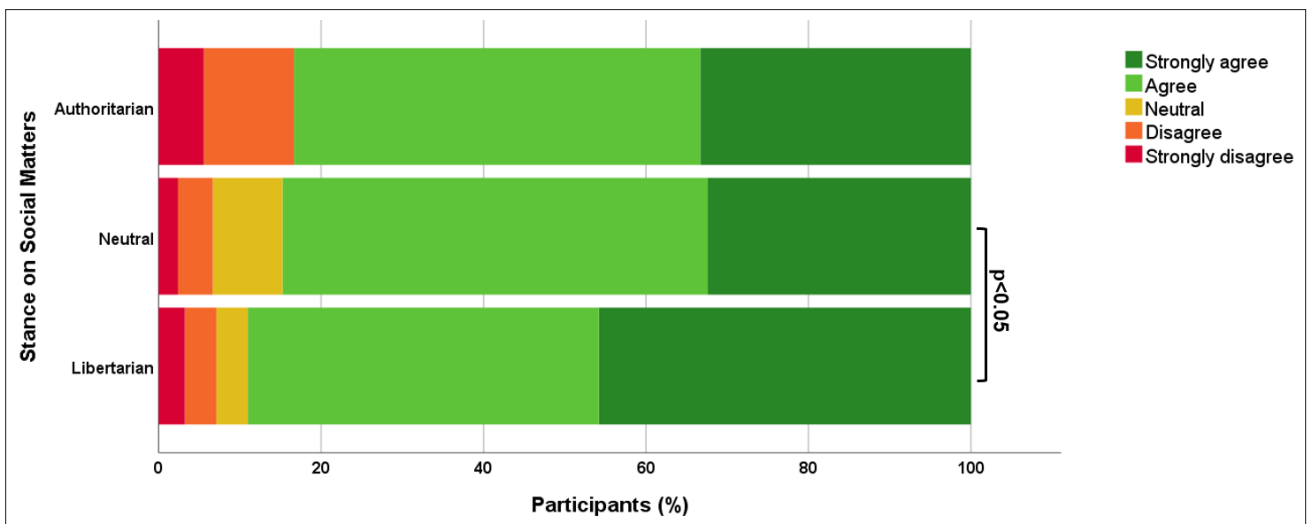
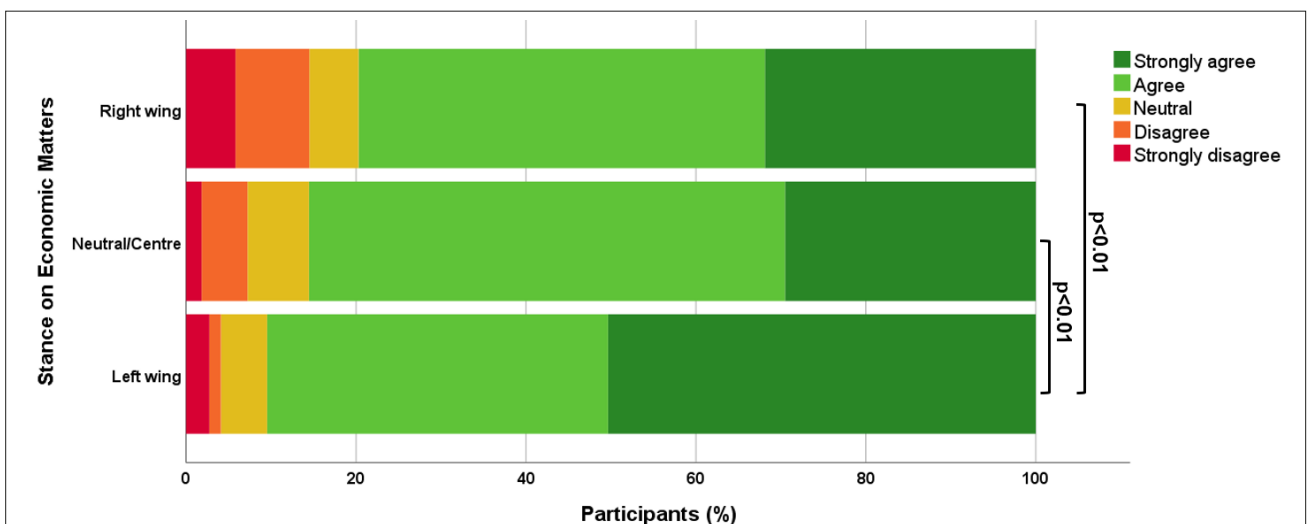


Fig. 9. Participants' agreement with the statement "I am concerned with the current pandemic" according to their stance on economic matters.



levels of concern. However, due to the small number of participants who studied science at the postgraduate level, none of the observed differences involving the postgraduate degree group were statistically significant after Bonferroni correction.

A significant difference ( $\chi^2 = 6.453$ ;  $df = 2$ ;  $p = 0.039$ ) in the levels of pandemic concern was observed between participants with different stances on social matters (Fig. 8). Participants with libertarian views expressed the highest concern about the COVID-19 pandemic, however the difference was only significant in comparison with those who expressed neutral ( $p = 0.039$ ), but not authoritarian views.

Figure 9 shows statistically significant differences ( $\chi^2 = 15.285$ ;  $df = 2$ ;  $p = 0.00048$ ) in the level of COVID-19 concern between participants with different social stances along the left-right axis. Left-leaning participants showed higher concern than both right-leaning ( $p = 0.0077$ ) and centrist ( $p = 0.0013$ ) ones. The difference between centrist and right-leaning participants was not statistically significant.

## Discussion

Vaccine hesitancy had already been identified as one of the top threats to global health prior to the onset of the COVID-19 pandemic, and the current circumstances reinforce the urgency to identify its root causes and deploy mitigation strategies. This study provides novel insight on the factors affecting vaccine confidence in a British population sample. A non-linear relationship was observed between vaccine confidence and science education levels, whereby participants who studied science up to GCSE level are more hesitant than those with both lower and higher science education levels. This difference was only statistically significant in comparison to participants who studied science at Bachelor's degree level, however the data indicate that the lack of statistical significance in the comparison with the other groups may represent a false negative caused by the use of Bonferroni correction. While this adjustment method for multiple comparisons is often regarded as exceedingly conservative and prone to type II errors, the loss of statistical power is offset by its high effectiveness in preventing type I errors [30]. The observation that individuals who studied science up to GCSE level are more vaccine-hesitant than those with both higher and lower levels of science education may be interpreted through the lens of the cognitive bias widely known as the Dunning-Kruger effect [31, 32]. Framing the present findings in the competence hierarchy model, it is conceivable that participants with the lowest level of science literacy may operate at the stage of unconscious incompetence with regards to the vaccination decision-making process, which may make them more likely to rely on expert advice on the matter [33, 34]. On the other hand, participants who have studied science up to secondary education levels may fall into what has been defined as "beginner's bubble", whereby they

overestimate their understanding of the topic and come to incorrect conclusions on it [35].

The results of the survey indicate that participants with libertarian social stances are significantly more vaccine-confident than those who expressed neutral views. This finding may at a first glance appear to conflict with the common claim that mandatory vaccination may infringe personal freedom and bodily autonomy. However, it has been theorised that not only libertarianism is compatible with vaccine acceptance, but also that government-enforced vaccination is morally justifiable within a libertarian political framework [36]. Within the study population, participants who expressed left-leaning stances on economic matters were significantly more vaccine-confident than those expressing centrist views. While there is no clear literature consensus as to the association between position on the left/right spectrum and vaccine confidence, our findings support previous observations that left-wing ideologies can be identified as predictors of vaccine confidence [37] and centrist worldviews are more likely to be associated with vaccine hesitancy [38]. Previous findings obtained amongst the French population that those holding moderate views are less vaccine hesitant than those with more radical stances were not confirmed in the present study [16]. Right-wing participants did not show any significant difference in vaccine confidence compared to the other groups. Vaccine confidence had previously been shown to be negatively associated with right-wing views amongst USA voters, however this was not the case amongst the UK electorate, compatibly with the findings of the present study [39]. These observations indicate that the association between political views and vaccine confidence may depend on other context-specific variables. Indeed, it has been suggested that an individual's vaccine attitude may not necessarily align with their left/right orientation, but rather with their political proximity with specific politicians or parties [40].

This study revealed that participants' levels of concern with the COVID-19 pandemic varied significantly with both their science education level and political views. 100% of participants with the lowest level of science education (primary or lower secondary) were in agreement with the statement "I am concerned with the current pandemic", whereas participants who studied science at the postgraduate level were the most likely to disagree with it. While several studies have investigated the determinants of concern, anxiety, and fear related to the COVID-19 pandemic, the present study is to the best of our knowledge the first to investigate the association between "coronaphobia" and science education levels [41-43].

Participants with libertarian views expressed higher pandemic concern than those with neutral and authoritarian views, however the difference was only statistically significant with the former group. While the present study did not evaluate the nature of the concern (*e.g.* whether it is based on health-related, economic, political or other reasons), the perceived loss of freedom

due to state-sanctioned restrictions and lockdowns has been identified as a reason for concern among libertarian individuals [44]. Left-wing participants expressed significantly higher levels of concern than those with centrist or right-wing views. To the best of our knowledge, this study is the first to correlate left-wing views and pandemic concern within the British population, confirming previous reports that left-wing views were associated with pandemic-induced stress in a Canadian population sample and with increased physical distancing amongst USA residents [45, 46].

## Conclusions

At a time when many countries are still under the grip of the COVID-19 pandemic and limited vaccine uptake is hindering the global efforts to overcome the current crisis, this study provides novel insight into the factors underpinning vaccine confidence and pandemic concern. Considering that the majority of the population do not pursue further scientific studies after secondary education, the observation that participants who studied science up to GCSE level show the highest level of vaccine hesitancy should be a cause for concern. These findings highlight the urgency to ensure that topics of critical public health relevance are adequately covered in secondary school curricula, and that learners and educators are equipped with sufficient scientific and digital literacy to inform their vaccination decision-making process. Participants expressing neutral views on social and economic matters were significantly more vaccine-hesitant than, respectively, libertarian and left-wing participants. As political views intersect with numerous extrinsic and intrinsic factors (*e.g.* age, ethnicity, nationality, socio-economic status, current governing party, etc.), further studies would be advisable to investigate the context-dependency of their correlation with vaccine hesitancy. Within the study population, lower science education levels as well as libertarian and left-wing political views were found to be significantly associated with higher levels of concern regarding the COVID-19 pandemic. This study provides valuable quantitative insight into the educational and political factors associated with vaccine hesitancy and COVID-19 concern. A limitation of the study is represented by the non-random nature of the sample population caused by the use of convenience sampling. Further investigations employing stratified sampling strategies would be advisable to verify the applicability of the results to populations with different demographic makeups. Moreover, future studies employing qualitative methods such as interviews and focus groups would be beneficial to elucidate the specific nature of the concerns and of the causes underpinning vaccine hesitancy in different individuals and groups.

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## Conflict of interest statement

The authors declare that they have no conflict of interest.

## Availability of data and materials

The dataset analysed in this study is available from the corresponding author on reasonable request.

## Authors' contributions

AS designed the study, provided supervision for the co-authors, carried out statistical analysis and wrote the manuscript. IC and FM compiled and distributed the questionnaire, collected the data, contributed to part of the statistical analysis, figure and manuscript preparation, and provided feedback on the final version of the draft.

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