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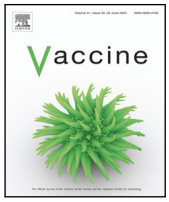

COVID-19 vaccination reluctance across Europe: Lessons for the future

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ABSTRACT

Background: Vaccine reluctance is both a complex and context-specific issue and is the result of many complicating factors that need to be addressed more systematically. In Europe, several country-based ad-hoc studies have been carried out on COVID-19 vaccines/vaccination and vaccine reluctance but a comprehensive overview covering all 27 European Union (EU27) countries is lacking. Such study can help understand vaccine reluctance in the overall EU as well as examine differences between individual countries.

Methods: This study relies on data from Flash Eurobarometer 505, covering all 27 European Union member states; the sample size is $N = 26,641$. It takes a fuzzy clustering approach to construct typologies of attitudes towards COVID-19 vaccination, and subsequently develops an "Index of Attitudes" (IA) which accounts for individual positioning of EU citizens. The data analysis is based on grade of membership (GoM) model which is a reliable statistical tool to tackle heterogeneous populations.

Results: The output of GoM model unveiled a hierarchical fuzzy 3-partition corresponding to three clearly identified typologies of feelings towards COVID-19 vaccination: Typology 1 entails favourable feelings while moderate-favourable feelings describe the Typology 2. Finally, Tipology 3 encompasses the scepticism towards COVID-19 vaccines. The IA, which quantifies the sentiment of European citizens towards COVID-19 vaccination in a 0–1 scale, reveals that although EU27 citizens overall are not against COVID-19 vaccination (index mean = 0.44) some, mostly in eastern countries, deviate from this prevailing trend.

Conclusion: Distrust in the safety and efficacy of all kinds of vaccines, as well as a generalised distrust in European and national institutions, are associated with the reluctance in relation towards COVID-19 vaccination. However, this reluctance varies across countries. The outcomes of our study not only inform national government and health care agents but also help define communication strategies to reach the most reluctant citizens. The segmentation it provides makes it easier to customise campaigns that raise awareness of the consequences of not being vaccinated, particularly as new SARS-CoV-2 variants emerge.

1. Introduction

The World Health Organisation (WHO) announced in May 2023 that COVID-19 was no longer a public health emergency of international concern. This decision followed the recommendation by the organisation's COVID-19 Emergency Committee due to the decline in the number of deaths and hospitalisations together with the high levels of population immunity against SARS-CoV-2 [1]. Nevertheless, WHO warns countries not to become complacent, and recommend them "to transition from emergency mode to managing COVID-19 alongside other infectious diseases". In fact, despite the significant level of hybrid immunity, resulting from prior infection and/or vaccination+boosters, older individuals and those who were previously uninfected run the risk of developing severe symptoms in case of (re)infection [1].

For the period 2023–25, WHO established a Global Strategic Preparedness, Readiness and Response Plan with the underlying goal of shifting from an emergency response to a sustainable comprehensive management of COVID-19. This goal can be fulfilled through access and optimal use of safe and effective tools, namely: (a) integration of COVID-19 vaccination and COVID-19 disease management into existing primary health services; (b) vaccination in at-risk populations to prevent severe disease and death; (c) early diagnosis, treatment and clinical care, especially in at-risk populations; (d) protecting health workers and other priority groups; and (e) strong surveillance and monitoring of SARS-CoV-2 variants, including strategic and geographically representative sequencing to track known and future variants, respiratory pathogens, and other pandemic threats [2].

Vaccination continues to be protective, although this protective effect can wane over time particularly with the emergence of new SARS-CoV variants [3]. As the virus SARS-CoV-2 continues to evolve,

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the existing vaccines are being adapted to ensure optimal protection against COVID-19. Following a long period of low SARS-CoV-2 transmission, there are signals of increased SARS-CoV-2 detection in primary and secondary care in the EU/EEA[2] caused by the emerging SARS-CoV-2 sub-lineages, such as BA.2.86 + R346T + F456L [4]. Variant-adapted vaccines started to be authorised in 2022 for use in the EU as boosters. Adapted vaccines that protect against a newer strain belonging to the XBB family of Omicron and related sub-lineages were authorised in 2023. Overall, COVID-19 vaccines used in EU/EEA have been very effective at preventing severe disease, hospitalisation, and death. This also holds for infections caused by more recent variants of the SARS-CoV-2, such as Omicron and its sub-group of XBB strains [5].

The indication of an increase in SARS-CoV-2 transmission, together with the evidence that the virus remains capable of acquiring mutations that facilitate its continued circulation at an unforeseeable time, led the European Centre for Disease Prevention and Control (ECDC) to focus the vaccination effort on the elderly (60+) and other risk groups, such as people with underlying comorbidities or the immunocompromised, as well as on healthcare workers. However, it is up to the national authorities of EU/EEA to define their own vaccination strategy, according to the spread of infection, the impact of COVID-19 in different populations, and the emergence of new variants.

The COVID-19 vaccines authorised by the European Medicines Agency (EMA) are based on different technologies or platforms. A full list of those vaccines is available on the EMA website, and includes the Bimervax (previously COVID-19 Vaccine HIPRA), Comirnaty (developed by BioNTech and Pfizer) and Jcovden (previously COVID-19 Vaccine Janssen) [6].

While the development of vaccines against old and new strains of the coronavirus is an extraordinary achievement, the successful vaccinating of the population is not devoid of difficulties. WHO guarantees that "safe and effective vaccines help ensure that COVID-19 does not result in severe disease and death. Vaccination protects against COVID-19 and reduces the likelihood of new variants from emerging", as well as appeals people to "take all COVID-19 vaccine doses, including booster doses, as recommended" by their health authority [7]; nevertheless, a sizeable number of people are still reluctant or totally against taking the coronavirus vaccine. Vaccine reluctance is a complex, context specific issue, that varies over time, place and vaccines [8]. Experts in medical decision-making have noted that this reluctance is often a result of many complicating factors that need to be addressed sensitively [9]. Individual decision-making is determined predominantly by attitudes towards vaccines rather than science. The perception of the risk of the COVID-19 vaccine seems to be a key factor for the reluctance to COVID-19 vaccination [10–13]. Lack of trust in vaccine quality and safety, as well as in institutional affiliation, significantly contributes to this negative attitude [14,15]. The same is likely to hold for those who are poorly informed or enlightened about the COVID-19 vaccines [10,15–17].

In Europe, several country-based ad-hoc studies have been carried out on COVID-19 vaccines/vaccination and vaccine reluctance, e.g., Malta [18], Poland [19], Slovenia [20], Italy [21], Portugal [22], and UK [23]. Steinert et al. [24] examined COVID-19 vaccine hesitancy across eight European countries and found substantial differences between them. However, a comprehensive picture of vaccine acceptance, as well as a comparative analysis involving all EU27 state members, is still lacking. Such an approach can be facilitated by using data from a common source. Moreover, a broad-based research on vaccine reluctance may provide the European Commission with additional tools to outline and implement a shared strategy to combat the pandemic at both national and EU level, as has been the practice since COVID-19 outbreak.

In February 2022, the European Commission Directorate-General for Communication commissioned a survey, named Flash Eurobarometer 505, with the aim of measuring EU citizens' attitudes to vaccination against COVID-19, in a challenging social, political, and sanitary context. It is a rich dataset consisting (almost entirely) of categorical (no ordering) and ordinal (categorical but with ordering) data with more than 26,500 observations; this makes it a valuable source for a deep analysis and understanding of the attitudes towards COVID-19 vaccine across EU27 member countries. This paper aims to analyse the attitudes on vaccination against COVID-19 in the European Union based on the above mentioned survey. The following specific objectives are to be addressed:

(O1) Identify typologies of attitudes to COVID-19 vaccination and subsequently create an "Index of Attitudes" that summarises individual EU27 citizens' feelings about it;

(O2) Uncover the heterogeneity in attitudes among countries;

(O3) Unveil the underlying socio-demographic characteristics, and also evaluate the behaviours and trust in institutions of EU27 citizens.

Disclosing distinct attitudinal typologies can assist government and health authorities in designing tailored approaches to motivate undecided people to receive the coronavirus vaccine and to encourage those who are against the vaccine to reconsider their position.

This manuscript is organised as follows. Section 2 describes the Flash Eurobarometer 505 data and explains the methodological approach used to tackle such a heterogeneous population. We present the results in Section 3, starting with a statistical description of the dataset. Then we address our three research objectives, dedicating a specific subsection to each one. Section 4 provides some discussion, and Section 5 shows some strengths and limitations of our work. Section 6 concludes.

2. Data and methods

2.1. Flash Eurobarometer 505

The Flash Eurobarometer 505 (Flash EB 505) is a survey carried out for the European Commission, and covers the population of EU citizens aged 15+ years, residing in any of its 27 member states. The individual interviews were conducted in February 2022 via Computer-Assisted Web Interviewing (CAWI), using Ipsos online panels and their partner network. Stratified sampling was used, giving rise to a sample of $N = 26{,}641$ individuals. To guarantee sample representativeness, the quotas were based on age (15–24, 25–34, 35–44, 45–54, 55–64, and 65+ years old), gender and geographic region (NUTS1, NUTS2 or NUTS3) according to country size and number of NUTS regions. Sample size per country is about 1000 interviews with the exception of Cyprus, Luxembourg, and Malta where only about 500 interviews were conducted (see details in [25]). The survey questionnaire includes four sections: (i) attitudes towards COVID-19 vaccination; (ii) previous experience of vaccination and drivers of COVID-19 vaccination; (iii) trust in institutions; and (iv) socio-demographic characteristics.[3] The section on attitudes towards COVID-19 vaccination includes a set of 16 items to assess people's feelings about COVID-19 vaccination. These items are measured on a Likert-type scale of four points, ranging from "1-totally agree" to "4-totally disagree", and are displayed in Table 1. For the sake of good order concerning negative attitudes towards COVID-19 vaccination, we reversed the codification of some items and marked them with an R in this table.

[2] European Union/European Economic Area.

[3] Data available in GESIS – The Leibniz Institute for the Social Sciences website.

Table 1
Items measuring attitudes towards COVID-19 vaccination (C-19 stands for COVID-19; see full descriptions in Supplemental Information).

Id	Item	Item description
Q4_1	1	All in all, benefits of C-19 vaccines outweigh possible risks
Q4_2	2	I believe vaccines authorised in the European Union are safe
Q4_3	3	C-19 vaccines are being developed, tested and authorised too quickly to be safe (R)
Q4_4	4	C-19 vaccines could have long term side-effects that we do not know yet (R)
Q4_5	5	Vaccines are the only way to end the pandemic
Q4_6	6	I do not understand why people are reluctant to get vaccinated
Q4_7	7	Serious diseases have disappeared thanks to vaccines
Q5_1	8	I can avoid being infected by C-19 without being vaccinated (R)
Q5_2	9	Public authorities are not sufficiently transparent about C-19 vaccines (R)
Q5_3	10	Everyone should get vaccinated against C-19, it is a civic duty
Q5_4	11	C-19 vaccination should be compulsory
Q5_5	12	The EU is playing a key role in ensuring … C-19 vaccines … in (OUR COUNTRY)
Q6_1	13	It is difficult to find information that I can trust about C-19 and vaccines (R)
Q6_2	14	It is good to vaccinate children against C-19
Q6_3	15	It is acceptable to restrict access to some events or places … who refuse to get vaccinated
Q6_4	16	To put an end to the pandemic, … all countries in the world … access to vaccines

The section on experience of vaccination consists of six questions and relates to general past vaccination experience and COVID-19 vaccination experience. The following questions were asked: (1) Have you been vaccinated against COVID-19 (yes/ no/prefer not to answer); (2) Have you been vaccinated against COVID-19 (vaccine acceptance); (3) Experience with vaccines: I was vaccinated as a child (yes/no responses); I have been vaccinated as an adult (e.g., against yellow fever, tetanus, etc.) (yes/no responses); (4) Vaccines [in general] are safe (1-totally agree to 4-totally disagree); Vaccines [in general] are effective (1-totally agree to 4-totally disagree). Additionally, a list of seven conditions/circumstances of COVID-19 vaccination was presented and respondents could choose the items they considered important to making them take the COVID-19 vaccine.

Trust in institutions was evaluated with questions assessing opinion about nine institutions that might provide reliable information about COVID-19 (yes/no responses): The European Union; The (NATIONALITY) government; The (NATIONALITY) health authorities; The regional or local public authorities; Health professionals, doctors, nurses and pharmacists; Media (television, radio, newspapers); Websites; Online social networks; People around you (colleagues, friends and family).

The last section consists of eight questions related to gender, age, education, country, occupation, type of residential area, household size, and number of children under 15 in the household.

2.2. Data analysis

Given the heterogeneous nature of the data, composed of N individuals from different countries and cultures, together with the expected diversity of tradition in vaccination, we opted for a fuzzy or soft cluster analysis [26]. In general terms, this approach allows the decomposition of the data in $K \geq 2$ fuzzy clusters that form a fuzzy partition; usually, K is unknown. Every individual is represented in this partition by means of his/her grade of membership (GoM) vector

$$\mathbf{g}_i = \left(g_{i1}, g_{i2}, \ldots, g_{iK}\right), \tag{1}$$

where the coordinate g_{ik} is the degree of compatibility of individual i with the partition cluster indexed by $k = 1, 2, \ldots, K$, which obeys the following two conditions: $g_{ik} \geq 0$ and $\sum_{k=1}^{K} g_{ik} = 1$, for $i = 1, 2, \ldots, N$. Hence, g_{ik} can also be read as the percentage of fuzzy cluster k shared by individual i. We will assume that each cluster has at least one prototype or crisp element, i.e., an element that fully represents the respective cluster. For example, if individual i is a prototype of the third fuzzy cluster, his/her membership vector (1) will be $(0, 0, 1, 0, \ldots, 0)$. From this perspective, we can additionally read g_{ik} as a proportion of prototype k on individual i. The estimation of a K-fuzzy partition of data then entails the estimation of K prototypes and the GoM vector, as indicated in (1), for each sample observation.

We used the GoM model [27] as the methodological procedure to carry out the fuzzy clustering of data. This model states that the probability of individual i having responded in the category l of item j is given by

$$p_{ijl} = \sum_{k=1}^{K} g_{ik}\lambda_{kjl}, \tag{2}$$

where λ_{kjl} is the probability of the fuzzy cluster k prototype response in the category l of item j. Hence, p_{ijl} is an analytical account of the individual projection on different fuzzy clusters. In practical terms, the estimation of the GoM model entails the estimation of two sets of parameters: one comprising g_{ik} and the other the λ_{kjl} parameters. As they are probabilities, $\lambda_{kjl} \geq 0$ and $\sum_l \lambda_{kjl} = 1$, for each j and each k. In our study, $i = 1, 2, \ldots, N = 26{,}641$; $J = 16$ items (see Table 1) and $l = 1, 2, 3, 4$, the four different possible categories for each item, as indicated in Section 2.1.

Having fixed the value of $K \geq 2$, the estimation of g_{ik} and λ_{kjl} is based on the optimisation of the likelihood function [28,29]:

$$\mathbf{L}_k = \prod_{i=1}^{N}\prod_{j=1}^{J}\prod_{l=1}^{L_j}\left(\sum_{k=1}^{K} g_{ik}\lambda_{kjl}\right)^{y_{ijl}} \tag{3}$$

where y_{ijl} is a Bernoulli variable which is equal to 1 if the answer in jth item is category l, and 0 otherwise. In (3), $L_j = 4$, for every item j. Details about estimation strategy can be found elsewhere [28]. The model's goodness-of-fit is assessed by a likelihood ratio test which compares the so called null-model $\mathbf{L}_1$, i.e., the single cluster solution, to $\mathbf{L}_k$(3),

$$T = -2\log\left(\frac{\mathbf{L}_1}{\mathbf{L}_k}\right), \tag{4}$$

which can be approximated to a chi-square distribution with degrees of freedom equal to the difference in the number of parameters involved in the estimation of the two models. We stress that the goodness-of-fit assessment is a critical issue in the context of the GoM model, and the selection of the best model, i.e., the optimal value of K, based on (4), should be interpreted with circumspection (a discussion on this issue is provided in [28]).

A second aspect that emerges from the estimation of the GoM model relates to the characterisation of fuzzy cluster prototypes, based on the estimates of λ_{kjl}. In this study, we followed a strategy based on the expected value of each item for the k^{st} prototype. Formally, given that λ_{kjl} is the probability of category l for item j for the prototype k,

$$\Lambda_{kj} = \sum_{l} l \times \lambda_{kjl} \tag{5}$$

is the expected value for the prototype k in item j. Given that $1 \leq \Lambda_{kj} \leq 4$, the set $\Lambda_k = \{\Lambda_{k1}, \Lambda_{k2}, \ldots, \Lambda_{kJ}\}$, which characterises the k^{st} prototype, potentially defines the attitudinal typology towards COVID-19 vaccination associated with the fuzzy cluster $k = 1, 2, \ldots, K$. As a

consequence, Λ_k can potentially be used as a "basis" for examining the differences between EU27 citizens and, subsequently, between member states. An alternative, and more common approach used to address typologies is provided in [30] (see an application in [31]). Here, the observed frequency in each category, f_{jl}, is used as the baseline to evaluate the importance of the item-category pair (j,l). Specifically, the pair (j,l) is considered a relevant condition for the fuzzy cluster k if

$$\lambda_{kjl} > (1+\theta) \times f_{jl}, \tag{6}$$

where $\theta \in (0,1)$. For higher values of f_{jl}, the condition

$$\lambda_{kjl} > f_{jl}, \tag{7}$$

if $f_{jl} > \tau$, also serves to tag (j,l) as a discriminant characteristic. Together, the discriminant characteristics potentially give rise to typologies, based on their relevance. We provide the characterisation of fuzzy clusters, based on conditions (6) and (7), as Supplemental Information, setting $\theta = 0.25$ and $\tau = 0.90$. Even though the two approches are compatible and somehow connected, we will see that (5) leads to a more insightful understanding of the vaccination issue in EU.

The estimates of g_{ik} can provide additional insights on the universe; for example, the quantity

$$\eta_k = \frac{1}{N}\sum_{i=1}^{N} g_{ik} \tag{8}$$

measures the impact of fuzzy cluster k in the population and

$$\eta_k^{(c)} = \frac{1}{N^{(c)}}\sum_{i=1}^{N^{(c)}} g_{ik}^{(c)} \tag{9}$$

the impact of the same cluster in the country identified by c (e.g., Austria, Belgium, etc.).

Finally, we can also use g_{ik} for the crisp segmentation of the population, i.e., to create mutually exclusive clusters or segments in which each observation belongs to a single cluster or segment. This process is referred to as defuzzification; it allows an overall picture of the population and, consequently, is easier to manage. A common procedure used for defuzzification is based on the maximum value of g_{ik}, i.e., the individual i is assigned to segment k, if $\max\{g_{i1}, g_{i2}, \ldots, g_{iK}\}$ occurs at coordinate $k = 1, 2, \ldots, K$ [32]. For example, if $K = 3$, the individual characterised by the GoM vector $(0.1, 0.5, 0.4)$ would be assigned to segment 2. In the case of a tie among GoM vector coordinates, the segment with the smallest number is attributed to the case.

3. Results

3.1. Sample characterisation

A total of $N = 26{,}641$ participants from the 27 EU member countries responded to the survey. Approximately half were female (51.5%); the majority (51.7%) concluded full time education at the age of 20 or older; nearly one-quarter are aged 65+ years, and 65.4% are employed, either as self-employed, employees or manual workers. Almost 40% live in small or medium size towns, 45.7% live in households with two adults and 71.1% report no children under 15 in the household.

Table 2 summarises the individuals' overall perception and experience of COVID-19 vaccines. Most stated that were vaccinated against COVID-19 (81.7%) and 57.7% that they had received a booster dose. Being vaccinated as a child is more likely than being vaccinated as adults (92.8% vis-à-vis 77.9%). More than 80% have a positive view of vaccination in terms of safety and effectiveness.

Flash EB 505 proposes a classification to describe every person in terms of COVID-19 vaccine acceptance based on the answers to the question "Have you been vaccinated against COVID-19 (vaccine acceptance)"? Specifically, the aggregation of the categories "Yes, and I already received a booster dose", "Yes, and I would like to receive a booster dose as soon as possible" and "Yes, and I would like to receive a booster dose in the future" is labelled as "Pro-vaccine"; the "Vaccine-hesitancy" label comprises the categories "Yes, but I do not want to receive a booster dose", "No, but I would like to get vaccinated as soon as possible" and "No, but I would like to get vaccinated in the future"; finally, the single "No and I never want to get vaccinated" category is tagged as "Against vaccination". Most individuals (75.3%) were classified as "pro-vaccine", 6.9% were labelled as "vaccine hesitant" and 10.6% "against vaccination". A small minority (7.2%) did not answer the question and therefore had no clear classification.

When asked about which institutions can be trusted to provide reliable information about COVID-19 vaccine, respondents identified the following five (ranked in descending order of percentage of "yes" answers): health professionals, doctors, nurses, and pharmacists (62.1%), the (national) health authorities (46.5%), the European Union (24.4%), the (national) government (19.5%) and the regional or local authorities (13.7%).

Table 3 gives an account of the circumstances that would make people more eager to get the COVID-19 vaccine. Nearly one-third of the respondents mention that having "more people vaccinated, seeing that vaccine works and there being no major side-effects" would make them willing to be vaccinated. For about 30% of the respondents, "full clarity on how vaccines are being developed, tested and authorised" and seeing that "there are more serious forms of COVID-19 among people who are not vaccinated" would make them more eager to receive the vaccine. Only 10.6% of respondents indicate the development of vaccines in the EU as a positive critical factor.

3.2. Typologies of attitudes

To meet our objective O1, the GoM model was applied to $J = 16$ items that measure citizens' attitudes towards COVID-19 vaccination, as indicated in Table 1. The estimation process was carried out using the DsiGoM Software [33]. After running this computer application on a trial basis, for different number of fuzzy clusters, specifically from $K = 2$ to $K = 5$, we found that the best fit to data is obtained for $K = 3$ according to (4). We therefore assume that the universe under study is modelled by three distinct typologies of attitudes towards COVID-19 vaccination. Table 4 displays the estimated expected value for each typology in every attitude item, using (5) (outcomes given as Supplemental Information). The typologies are labelled as Λ_1, Λ_2, and Λ_3.

The estimated expected values of different items in typology Λ_1 are consistently low (close to 1.0) across all 16 items, which suggests strong agreement with the underlying attitudes. The exceptions arise in items Q5_2: "Public authorities are not sufficiently transparent about COVID-19 vaccines", Q4_4: "COVID-19 vaccines could have long term side-effects that we do not know yet", and Q4_3: "COVID-19 vaccines are being developed, tested and authorised too quickly to be safe", for which some reservations had implicitly been voiced. Despite the clear evidence that individuals in this typology are favourable to vaccination, there is some concern about its adverse health effects and the lack of transparency in this process. Typology Λ_3 presents the opposite profile: the estimated average values of the 16 items are close to 4, reflecting strong disagreement with the underlying attitudes. Typology Λ_2 is halfway between these two extremes, although closer to the first. Table 4 also highlights the hierarchical nature of Λ_1, Λ_2, and Λ_3 typologies. In fact, an item-based move from Λ_1 to Λ_3 shows a consistent increase in the expected values. We subsequently used a result in [31], and constructed an overall measure for each typology, as follows:

$$\Delta_k = \frac{1}{J}\sum_{j=1}^{J} \Lambda_{kj},$$

which led to: $\Delta_1 = 1.23$; $\Delta_2 = 2.28$; $\Delta_3 = 3.61$. These average values reflect the tendency for strong agreement with the 16 attitudinal items

Table 2
Perception and experience of COVID-19 vaccination.

Item	Percentage
Have you been vaccinated against COVID-19?	
Yes	81.7
Prefer not to answer	1.3
Have you been vaccinated against COVID-19 (vaccine acceptance)?	
Yes, and I already received a booster dose	57.7
Yes, and I would like to receive a booster dose as soon as possible	6.8
Yes, and I would like to receive a booster dose in the future	10.8
Yes, but I do not want to receive a booster dose	3.5
No, but I would like to get vaccinated as soon as possible	0.5
No, but I would like to get vaccinated in the future	2.9
No and I never want to get vaccinated	10.6
Don't know or prefer not to say	7.2
COVID-19 vaccine acceptance (Flash EB 505 classification)	
"Pro-vaccine"	75.3
"Vaccine-hesitant"	6.9
"Against vaccination"	10.6
"Don't know or prefer not to say"	7.2
Have been vaccinated as child	92.8
Have been vaccinated as adult (e.g., against yellow fever, tetanus, etc.)	77.9
"Vaccines [in general] are safe" (totally agree/tend to agree)	83.9
"Vaccines [in general] are effective" (totally agree/tend to agree)	87.7

Table 3
Conditions that would make people more eager to get vaccinated against COVID-19 (note: C-19 means COVID-19; full item descriptions are provided as Supplemental Information).

Item description	Percentage
More people have already been vaccinated and … no major side-effects	32.1
There is full clarity on how vaccines are being developed, tested and authorised	30.3
I see that there are more serious forms of C-19 among people who are not vaccinated	30.2
My doctor recommends me to do so	21.9
The people that recommend the vaccines are vaccinated themselves	18.8
I see more people around me doing it	11.7
Vaccines are developed in the European Union	10.6

Table 4
Estimated expected value of each attitude towards COVID-19 vaccination in $K = 3$ typologies. The letter R means that the codification was reversed, and C-19 stands for COVID-19 (see Table S1, in Supplemental Information, for a detailed description of Ids). .

	Tipology →	Λ_1	Λ_2	Λ_3
Id	Description	Λ_{1j}	Λ_{2j}	Λ_{3j}
Q4_1	All in all, benefits of C-19 vaccines outweigh possible risks	1.0	2.0	3.5
Q4_2	I believe vaccines authorised in the European Union are safe	1.0	2.0	3.4
Q4_3	C-19 vaccines are being developed, tested .. too quickly … (R)	1.6	2.6	3.9
Q4_4	C-19 vaccines could have long term side-effects … (R)	1.8	2.8	4.0
Q4_5	Vaccines are the only way to end the pandemic	1.0	2.1	3.6
Q4_6	I do not understand why people are reluctant to get vaccinated	1.0	2.3	3.8
Q4_7	Serious diseases have disappeared thanks to vaccines	1.0	1.9	2.7
Q5_1	I can avoid being infected by C-19 without … vaccinated (R)	1.2	2.4	3.6
Q5_2	Public authorities are not sufficiently transparent … (R)	2.0	2.7	3.7
Q5_3	Everyone should get vaccinated against C-19, it is a civic duty	1.0	2.3	4.0
Q5_4	C-19 vaccination should be compulsory	1.3	2.5	4.0
Q5_5	The EU is playing a key role in … (OUR COUNTRY)	1.3	2.1	2.7
Q6_1	It is difficult to find information … C-19 and vaccines (R)	1.3	2.3	3.6
Q6_2	It is good to vaccinate children against C-19	1.2	2.4	4.0
Q6_3	It is acceptable to restrict access … who refuse to get vaccinated	1.0	2.3	3.9
Q6_4	To put an end … all countries … access to vaccines	1.0	1.5	3.3

in typology Λ_1, while in Λ_3 the same items reflect strong disagreement; a moderate agreement is found in typology Λ_2. Using 0−1 normalisation leads to $\tilde{\Delta}_1 = 0$, $\tilde{\Delta}_2 = 0.44$, and $\tilde{\Delta}_3 = 1$, respectively. In any of the cases, the negative attitudes towards COVID-19 vaccination become steadily stronger from Λ_1 to Λ_3, as could be anticipated. The weight of each typology for the overall sample, computed through formula (8), is equal to $\eta_1 = 0.33$, $\eta_2 = 0.41$, and $\eta_3 = 0.26$ (see Table 5, row: All 27). Summing up: the prevalence of typology Λ_2 suggests that a moderate-positive feeling towards COVID-19 vaccination is the general pattern in EU27.

Following the identification of typologies at EU27 level and their respective weights, we are able to measure the attitudes towards COVID-19 vaccination at a more fine-grained individual level. For this purpose, we took advantage of the potential of a fuzzy analysis, and explored the concept of grade of membership to obtain an individual measure for every participant in the survey,

$$\tau_i = \sum_{k=1}^{K} g_{ik} \times \tilde{\Delta}_k, \tag{10}$$

which we refer to as "Index of Attitudes" (IA) of individual i; its range is the unit interval $[0, 1]$. As a side note, the index (10) can be regarded as a synthetic measure of individual projection on fuzzy clusters, contrasting to (2) which provides an analytical view. The IA is a scalar measure that quantifies individuals' feelings towards COVID-19 vaccination in a $0-1$ range: the higher the value the more

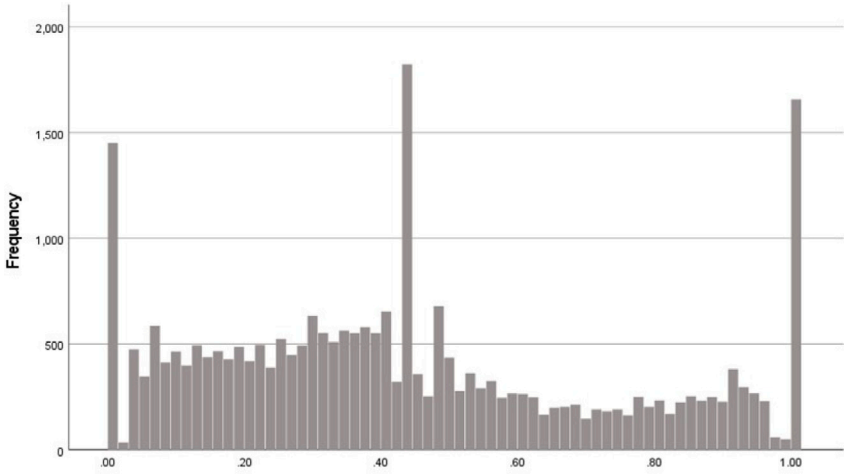

Fig. 1. Empirical distribution of the Index of Attitudes towards COVID-19 vaccination in EU27.

Table 5
Weight of typologies: overall and country-based.

Country (c)	$\eta_1^{(c)}$	$\eta_2^{(c)}$	$\eta_3^{(c)}$	Country	$\eta_1^{(c)}$	$\eta_2^{(c)}$	$\eta_3^{(c)}$
All 27	0.33	0.41	0.26	Hungary	0.26	0.41	0.33
Austria	0.38	0.34	0.27	Ireland	0.41	0.42	0.17
Belgium	0.34	0.46	0.19	Italy	0.47	0.40	0.13
Bulgaria	0.23	0.35	0.42	Lithuania	0.28	0.42	0.30
Cyprus	0.31	0.41	0.28	Luxembourg	0.33	0.34	0.33
Czechia	0.24	0.46	0.30	Latvia	0.21	0.42	0.38
(DE) Germany	0.43	0.38	0.19	Malta	0.34	0.39	0.27
Denmark	0.38	0.44	0.17	Netherlands	0.34	0.45	0.21
Estonia	0.26	0.44	0.31	Poland	0.30	0.43	0.27
(ES) Spain	0.42	0.44	0.14	Portugal	0.39	0.48	0.13
Finland	0.42	0.41	0.18	Romania	0.30	0.38	0.32
France	0.29	0.45	0.26	Sweden	0.46	0.37	0.17
Greece	0.35	0.40	0.25	Slovenia	0.25	0.39	0.36
(HR) Croatia	0.25	0.43	0.32	Slovakia	0.21	0.42	0.27

unfavourable the feeling. Fig. 1 shows how it is distributed across the sample. We see a higher concentration of (almost) crisp elements in all three typologies ($\tilde{\Delta}_1 = 0$, $\tilde{\Delta}_2 = 0.44$, and $\tilde{\Delta}_3 = 1.00$). The IA value is below 0.5 for nearly 2/3 of individuals; the distribution mean is 0.44 ($sd = 0.29$), suggesting that, on average, EU citizens have moderately positive feeling towards COVID-19 vaccination. The skewness of the distribution, +0.44, additionally reinforces this tendency.

3.3. Country-level attitudes

Now we address our objective O2. The weight of each typology is computed from a country-based perspective by means of (9). Table 5 shows how each typology impacts different countries. As in EU27 in general, typology Λ_2 prevails in almost all countries while the impact of Λ_3 is simultaneously less significant, with the exception of Bulgaria ($\eta_3^{(\text{Bulgaria})} = 0.42$). Nevertheless, the latter typology impacts above the overall average of 0.26 in countries like Latvia, Slovenia, Luxembourg Hungary, Croatia, Romania, Estonia, Czechia, Lithuania, Cyprus, Austria, Malta, Poland, and Slovakia. In the opposite extreme, we find Germany, Ireland, Italy, Sweden and Finland where the weight of Λ_1 accounts for more than 0.40, when the average at EU27 level is just 0.33.

Fig. 2 shows, in average terms, how the IA reflects the option of being vaccinated at country-level. The dashed lines represent the average values in the respective dimension: in ordinate, the vaccination rate measured by the percentage of people who answered "yes" to the question "Have you been vaccinated against COVID-19?"; in abscissa, the "Index of Attitudes". We find a strong negative association between attitudes, as measured through IA, and the vaccination rate (Pearson's $R = -0.84$). Bulgaria is the most extreme case: its mean IA is 0.57 and the vaccination rate is around 50%. In 12 countries, namely Italy, Spain, Portugal, Sweden, Germany, Ireland, Finland, Denmark, Netherlands, Austria, Belgium, and Greece, there is a higher percentage of vaccinated people and, concomitantly, stronger positive feelings towards COVID-19 vaccination, i.e., lower values of IA. Additionally, we see that most eastern European countries are positioned in the quadrant defined by a percentage of vaccinated people below the overall mean (0.82) and strong negative attitudes towards COVID-19 vaccination (values for IA above the average of 0.44).

3.4. Further characterisation

In this section, we address research objective O3. To this end, we applied the defuzzification method based on the maximum value of g_{ik}, which resulted in a decomposition of data in three mutually exclusive segments, as expected. We see that Segment 1 represents 33.3% of the sample, Segment 2 accounts for 43.2%, and the remaining 23.5% belong to Segment 3 (Table 6). This crisp distribution of data (almost) mimics that of typologies (Table 5, row "All EU27"). This similarity is also extended to the characterisation of segments in terms of feelings towards COVID-19 vaccination, measured through the "Index of Attitudes" (IA), as shown in Table 6. In what follows, we provide some additional characterisation of the respondents at macro-level.

Fig. 3 presents the distribution of the IA by segment, using a boxplot representation. The positively skewed distribution in Segment 1 and the negatively skewed distribution in Segment 3 reinforce the extreme and

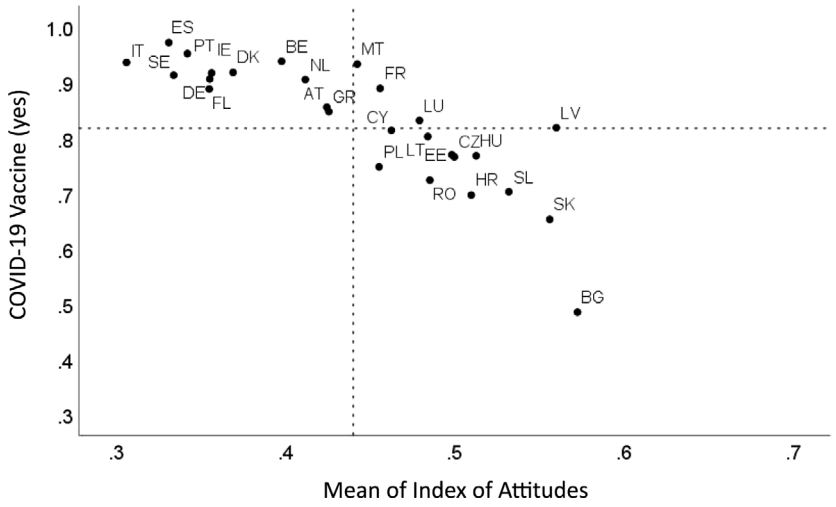

Fig. 2. Scatterplot of the Index of Attitudes and COVID-19 vaccination rate, at country-level (the dashed lines represent average values in each dimension).

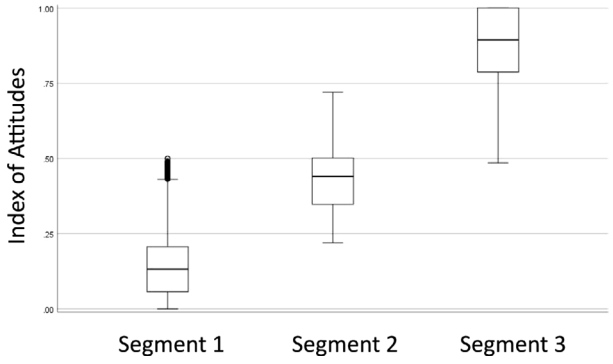

Fig. 3. Boxplot of Index of Attitudes towards COVID-19 vaccination by segment.

Table 6
Descriptive statistics of the Index of Attitudes towards COVID-19 vaccination by segment (sd means standard deviation).

Segment	%	Minimum	Maximum	Mean (m)	sd	m ± sd
1	33.3	0.00	0.50	0.14	0.11	[0.03, 0.25]
2	43.2	0.22	0.72	0.43	0.12	[0.31, 0.55]
3	23.5	0.49	1.00	0.87	0.12	[0.75, 0.99]
Sample	100.0	0.00	1.00	0.44	0.29	[0.15, 0.73]

opposite positioning of these segments, as noticed earlier. In Segment 1, 12 cases are marked as outliers. In a merely exploratory approach,[4] we performed a one-way ANOVA test in order to compare the IA mean of three segments and found significant differences between them ($F_{(2,26638)} = 73429.9$; $p < 0.001$). A subsequent post-hoc test (Dunnett C) further indicated that every mean pairwise comparison is significantly different from 0 ($p < 0.001$).

When we look at Table 6, we immediately notice the predominance of people with less negative feelings towards COVID-19 vaccines in Segment 1. On the other hand, Segment 3 seems to be populated with those sceptical about the benefits of vaccination. The mean of IA in Segment 2 is close to the overall mean (0.43 vis-à-vis 0.44), thus signalling it as a group with an 'average' profile.

[4] Although the segments may not be considered independent, a one-way ANOVA test was used to evaluate the differences; the *p*-value of the significance test is not to be interpreted literally but is merely a standard value that indicates how large the difference between the realities under comparison needs to be before we consider them as "significant".

Fig. 4 presents a distribution of vaccine acceptance classification according to Flash EB 505 in each segment. Almost all individuals (97.6%) comprising Segment 1 were labelled as "pro-vaccine". Although most individuals in Segment 2 have the same label, here we notice a non-negligible proportion of "vaccine-hesitant" individuals (6.1%) and 6.4% with no clear position on the subject ("do not know/prefer not to say"). Segment 3 is characterised by "vaccine-hesitant" (16.6%) and "against vaccination" individuals (42.3%), and 17.4% who either do not know or prefer not to answer.

Cramer's V coefficient of association between the segments and COVID-19 vaccine acceptance (Flash EB 505 classification) reveals a moderate-high and significant association (Cramer's $V = 0.502$; $p < 0.001$). Specifically, individuals who express positive/favourable attitudes towards COVID-19 vaccination (Segment 1) tend to be "pro-vaccine". In contrast, individuals with negative attitudes towards COVID-19 vaccination (Segment 3) are more likely to be "against vaccination". "Pro-vaccine" individuals are also likely to be found among those with an average (neither positive nor negative) position on COVID-19 vaccines (Segment 2). This association suggests that, based on their attitudes and vaccine acceptance, EU citizens can be segmented by reluctance to COVID-19 vaccination in three categories: "Pro-vaccine" (Segment 1), "Hesitant" (Segment 2) and "Reluctant" (Segment 3).

Table 7 presents the socio-demographic profile of each segment. Comparing to other segments, the "Reluctant" segment has a higher percentage of females (56.2%), people aged 25–44 years (56.4%), people who stopped full time education between of ages 16 and 19 years old (35.3%), the self-employed (14.0%), people living in rural areas or villages (27.1%), households of three adults (19.0%), and people living in household with one or two children (32.2%). The "Pro-vaccine" segment stands out for having a higher percentage of people aged 65+ (32.5%), people without a professional occupation (41.7%), living in large towns (37.5%), in households of two adults (48.2%) and with no children (77.4%).

Table 8 displays each segment profile in terms of perception and experience of vaccination. The "Reluctant" segment is characterised by the lowest rate of vaccination against COVID-19 (38.5%) together with the lowest share of people vaccinated as an adult (65.8%) and the lowest percentage of individuals agreeing that vaccines (in general) are safe (47.6%) or effective (59.0%). In the opposite side, we find the "Pro-vaccine" segment with (almost all) individuals vaccinated against COVID-19 (98.7%), believing in the safety of vaccines (98.7%) as well as in its effectiveness (99.2%). We also find here the highest percentage of individuals vaccinated as a child (95.3%) or as adults (86.5%).

Although the respondents who preferred not to answer the question about getting vaccinated against COVID-19 represent only 1.3% of the

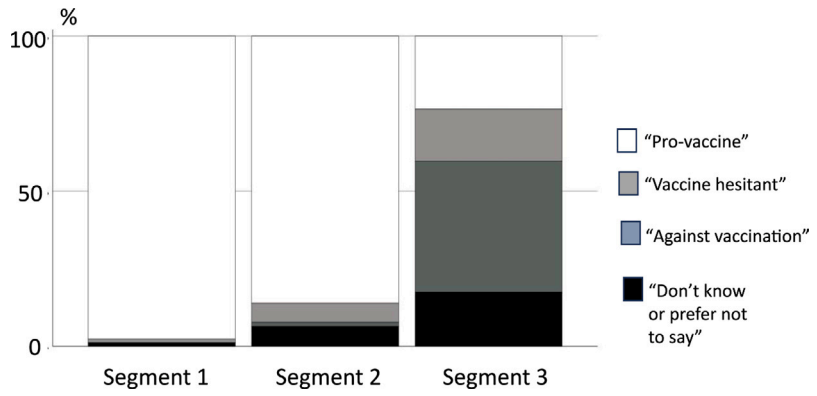

Fig. 4. COVID-19 vaccine acceptance (Flash EB 505 classification) by segment.

Table 7
Socio-demographic profile of each segment (%). (Note: Education stands for the age when full time education was concluded.)

Characteristic	"Pro-vaccine"	"Hesitant"	"Reluctant"
Gender: Female	47.5	52.0	56.2
Age:			
15–24	9.7	14.8	14.7
25–34	11.2	17.1	20.6
35–44	13.5	17.6	21.1
45–54	16.2	16.6	17.6
55–64	16.9	14.0	13.5
65 or older	32.5	19.9	12.5
Education			
Up to 15 years	3.5	2.9	2.9
16–19 years	30.6	30.7	35.3
20 years or older	54.0	51.2	49.1
Still in full-time education	9.8	12.8	10.5
Never been in full-time education	2.1	2.4	2.2
Occupation			
Self-employed	11.8	10.8	14.0
Employees	42.1	50.5	50.5
Manual workers	4.4	6.3	7.2
Not working	41.7	32.4	28.2
Type of residential area			
Rural area or village	24.6	25.6	27.1
Small or middle-sized town	38.5	39.6	38.7
Large town	37.5	34.9	34.1
Household size (aged 15+)			
1	25.2	25.1	24.9
2	48.2	44.9	43.5
3	15.7	17.2	19.0
4	10.9	12.8	12.6
Children (under 15) in the household			
0	77.4	69.8	64.5
1	13.2	17.7	20.8
2	7.5	9.7	11.4
3+	1.9	2.8	3.3

Table 8
Perception and experience of vaccination by segment (%).

Characteristic	"Pro-vaccine"	"Hesitant"	"Reluctant"
Have you been vaccinated against COVID-19 (coronavirus)?			
Yes	98.7	92.0	38.5
I Prefer not to answer	0.2	0.8	3.9
Have been vaccinated as child	95.3	90.9	92.7
Have been vaccinated as adult (e.g. ...., tetanus, etc.)	86.5	77.6	65.8
"Vaccines [in general] are safe" (totally agree/tend to agree)	98.7	90.4	47.6
"Vaccines [in general] are effective" (totally agree/tend to agree)	99.2	92.8	59.0

overall sample, they prevail in the "Reluctant" segment (3.9%). Additionally, the average IA value of this sub-group is 0.9 (not presented in Table 6), which further underlines their strong negative feelings towards COVID-19 vaccination.

Table 9
Trust in institutions to provide reliable information about COVID-19 vaccines by segment (%).

Institution	"Pro-vaccine"	"Hesitant"	"Reluctant"
The European Union	37.7	23.8	6.8
The (Nationality) government	33.1	17.3	4.3
The (Nationality) health authorities	68.3	47.4	13.7
The regional or local public authorities	22.5	12.5	3.5
Health professionals, doctors, nurses, and pharmacists	75.0	65.3	37.7
Media (television, radio, newspapers)	16.6	11.8	4.1
Websites	8.1	8.5	12.0
Online social networks	4.4	5.1	9.2
People around you (colleagues, friends, and family)	10.2	12.4	17.7

Table 10
Conditions that would make people more eager to get vaccinated against COVID-19 (%), by segment (note: full description of different conditions are provided as Supplemental Information).

Condition	"Pro-vaccine"	"Hesitant"	"Reluctant"
More people ... vaccinated ...no major side-effects	34.4	36.5	20.5
I see .. serious forms of COVID-19 ... who are not vaccinated	39.2	33.4	11.6
There is full clarity ... developed, tested and authorised	25.6	32.0	34.0
My doctor recommends me to do so	28.9	24.6	7.0
The people that recommend ... are vaccinated themselves	20.7	20.9	12.2
I see more people around me doing it	14.8	13.6	3.7
Vaccines are developed in the European Union	13.5	11.6	4.5

Table 9 gives an account of the extent to which individuals perceive the information provided by different institutions as reliable, in each segment. Individuals belonging to the "Reluctant" segment tend not to rely on any institution. They are particularly suspicious of the regional or local public authorities (3.5%), the national government (4.3%), the media (4.1%) and the European Union (6.8%). The "Pro-vaccine" segment is characterised by trust in health professionals, doctors, nurses, and pharmacists (75%), as well as in the (Nationality) health authorities (68.3%).

Finally, we assessed the conditions which would make people decide to take the COVID-19 vaccine (Table 10), and found that, in the "Reluctant" segment, no particular condition leads them to change their behaviour. For example, only 7% admit getting vaccinated on the recommendation of the doctor. However, 34.4% consider that having "full clarity on how vaccines are being developed, tested and authorised" would make them more eager to get vaccinated; curiously, this percentage is higher than in any other segment. Additionally, for 20.5% of reluctant individuals, knowing that "more people have already been vaccinated and we see that it works and that there are no major side-effects" would be another motivating factor.

3.5. Predicting index of attitudes

A subsequent issue that emerges from the fuzzy approach to data analysis is to knowing/understanding how the "Index of Attitudes" (IA) is related to the observable variables. For this purpose, we estimated a multiple linear regression model (MLRM) to predict the IA, using the items measuring attitudes towards COVID-19 vaccination as explanatory variables, i.e., the same items as those used to construct typologies (see Table 1). This may seem tautological; however, such an approach potentially frees us from the need of further fuzzy analysis, as long as new data are available. In other words, it establishes a mapping between observable variables and a latent trait, here represented by IA. Formally, the linear model can be written as:

$$IA = B_0 + \sum_{j=1}^{16} B_j Q^{(j)} + \varepsilon_j,$$

where B_0 is the constant term, the B_j parameters are coefficients of 16 items measuring attitudes towards COVID-19 vaccination (see Table 1), here generically represented by $Q^{(j)}$, and ε_j is the error term which, by assumption, is normally distributed with mean 0 and variance σ^2. A multiple regression[5] was run to predict IA from the 16 items referred to above, and displayed in Table 1. These variables statistically significantly predict IA, $F(16, 15174) = 78.88$, $p = 0.002$, $R^2_{adj} = 0.98$. The latter statistic shows a good fit of the regression model to the data. Table 11 displays the estimates of MLRM parameters. In practice, given an individual scores in 16 items, an estimate of IA of that individual is obtained by means of the formula

$$\widehat{IA} = -0.426 + 0.033 \times Q^{(1)} + \cdots + 0.017 \times Q^{(16)}.$$

In the following, we examined how the IA can be predicted by the estimated (MLRM), and found a Pearson product-moment correlation coefficient of 0.99 ($p < 0.000$), which makes it a reliable analytical tool to assess the overall individual attitude towards COVID-19 vaccination.

We note that the key assumptions of the model – linearity, normality of errors, homoscedasticity and no multicollinearity – are all reasonably verified.

Table 11
Estimates of the parameters (B) of MLRM. All parameters are significant at the 1% level (Std. means standard deviation).

Id	$Q^{(j)}$	B_j	Std. Error
Q4_1	$Q^{(1)}$	0.033	0.001
Q4_2	$Q^{(2)}$	0.035	0.001
Q4_3	$Q^{(3)}$	0.019	0.000
Q4_4	$Q^{(4)}$	0.028	0.000
Q4_5	$Q^{(5)}$	0.029	0.001
Q4_6	$Q^{(6)}$	0.027	0.000
Q4_7	$Q^{(7)}$	0.015	0.000
Q5_1	$Q^{(8)}$	0.026	0.000
Q5_2	$Q^{(9)}$	0.013	0.000
Q5_3	$Q^{(10)}$	0.029	0.001
Q5_4	$Q^{(11)}$	0.023	0.001
Q5_5	$Q^{(12)}$	0.013	0.000
Q6_1	$Q^{(13)}$	0.023	0.000
Q6_2	$Q^{(14)}$	0.023	0.000
Q6_3	$Q^{(15)}$	0.028	0.000
Q6_4	$Q^{(16)}$	0.017	0.000
Constant (B_0)		−0.426	0.001

Dependent Variable: IA.

[5] Missing data were list-wise deleted from this analysis.

4. Discussion

This research work investigated the attitudes towards COVID-19 vaccination across the EU27 countries, using data from Flash Eurobarometer 505. Its main objective was to profile distinct forms of vaccination acceptance among EU27 citizens and, subsequently, to evaluate their individual positioning. Given the acknowledged multidimensional nature of attitudes [11,16,34], which expectedly gives rise to a heterogeneous population, we opted for a fuzzy approach to data representation so as to combine cluster and discriminant analysis. Specifically, the application of the GoM model to data proved appropriate to handle such a population. Its outcomes unveiled a hierarchical fuzzy 3-partition and allowed for a clear identification of the three underlying typologies of feelings towards COVID-19 vaccination: Typology Λ_1 entails favourable feelings while moderate-favourable feelings describe the Typology Λ_2. Finally, Tipology Λ_3 encompasses the scepticism towards COVID-19 vaccines. Furthermore, the hierarchical nature of this partition, together with the concept of grade of membership, opened the door for the design of an "Index of Attitudes" (IA). The IA ranges from 0 (strong alignment with COVID-19 vaccination) to 1 (strong scepticism), and it quantifies the sentiment of European citizens towards COVID-19 vaccination. Overall, EU27 citizens are not against COVID-19 vaccination (index mean = 0.44) but some, mostly in eastern countries, exhibit a marked tendency for unfavourable feelings. Higher values of the index are also associated with a lower vaccine uptake, relative to those with lower values. What we see here is that people's behaviour is coherent with their attitudes.

The defuzzification based on the maximum value of g_{ik} allowed a broader view of the dataset, notably in terms of a classical segmentation. The most representative group, labelled "Hesitant", accounts for 43.2% of the respondents. Its average IA value of 0.43 suggests an intermediate position towards COVID-19 vaccination. The position of two extreme segments, "Pro-vaccine" and "Reluctant", is reflected in their respective IA average, 0.14 and 0.87. The latter segment is generally characterised by women (56.2%), people aged 25–44 years (56.4%), and people who stopped full time education between the ages of 16 and 19 years (35.3%). It is also associated with structural factors such as scepticism about vaccine safety – less than 50% agree that vaccines (in general) are safe – and vaccine effectiveness, as well as marked distrust in institutions such as the regional or local authorities, the national government, the European Union, and the national health authorities – less than 15% trust in these institutions to provide reliable information about COVID-19 vaccination. Safety and efficacy are some of the rational concerns about COVID-19 vaccines [22,35], and some potential vaccinees tend to channel these concerns through their peers, family members, neighbours and, in recent years, increasingly through social media outlets. In this regard, we must point out the "Reluctant" segment where websites (12%), social networks (9.2%) and surrounding people (colleagues, family, friends) (17.7%) are seen as reliable sources of information about vaccines. Some false or misleading information provided by social media has meanwhile been recognised as parallel pandemic and referred to as infodemic [36]. All this poses important challenges to information campaigns. Strategies to establish a responsive and legitimate information system is more critical than ever before to ensure that people can check their mis/conceptions, and have their queries accurately answered [14].

Vaccines reluctance is also connected to institutional trust. We notice the lowest trust in national government (4.3%) and in regional or local authorities (3.5%) in the "Reluctant" segment, when compared to the other two segments. Moreover, the European Union is also not trustworthy enough (6.8%) (see Table 9). Lack of institutional trust is seen as a serious obstacle to convince people to get vaccinated [14,37]. Compliance with government guidance on a new vaccine depends on citizens' confidence that the government is trustworthy and that public health programmes will be administered fairly and competently [24,38,39]. There is general acknowledgement of the European Commission's efforts to recommend and coordinate joint actions since the beginning of the pandemic [40,41]. This approach was very successful given that less than 20% of EU27 citizens refused to get vaccinated against COVID-19. However, the health infrastructure and cultural specificities of EU member states, namely the distrust in national authorities, might have conditioned their citizens' adherence. The different approaches to address the pandemic issue were also reflected in the vaccination rate and fatality rate, for which significant differences were found among EU 27 countries [42]. Institutional trust is rooted and shaped by the historical and political treatment of the population and, thus, can manifest along the spectrum of non-participation, poor participation, or rejection [43]. Mistrust is difficult to revert in the short run; so its effect must be mitigated with alternative approaches such as involving independent scientific entities, providing comprehensive information about vaccination, among others [44]. Despite their embedded suspicions about everything and everybody, 34% of citizens of the "Reluctant" segment recognise that full clarity on how vaccines are developed, tested and authorised could play a role in their getting vaccinated. Therefore, information strategies, that clearly explain safety and efficacy, can contribute to reducing vaccine reluctance. However, we believe that there is no single approach to tackle this issue; on the contrary, a niche-oriented message targeting the specific needs and concerns of different groups might be more appropriate. Indeed, governments, health professionals, doctors, nurses, and pharmacists can play a valuable role in spreading the message about the benefits of vaccination [45], but approaching respected figures who people listen to and turn to for advice may positively contribute to build trust in vaccines [46].

Even tough the "Hesitant" and "Reluctant" segments share some demographic features, namely age and education, the "Hesitant" segment has a much higher percentage (92%) of people vaccinated against COVID-19. This means that the hesitation does not stop them being vaccinated, a phenomenon already identified in [47]. Apparently, this is related to higher level of trust in several institutions.

5. Strengths and limitations

Strengths of this study include a large, cross-national sample (N = 26641 individuals). By using sizeable samples, with wide geographic coverage and representativeness, at both country and EU27 level, the Eurobarometer surveys are reliable instruments for monitoring people's perceptions about COVID-19 (and its variants) vaccination. As ground theory proves, attitudes precede behaviours [48]; therefore, monitoring what people feel and think about it, permits a reliable prediction of the intentions and decision on getting vaccinated. The "Index of Attitudes" (IA) proved to be an adequate scalar measure to summarise the multidimensional nature of attitudes towards COVID-19 vaccination, as well as to be used as a predictive tool for a future event.

It is worth to notice some limitations of our study. First, the data comes from a secondary source of information and so it is not possible to make any change to the data (e.g., adapt or add questions to the questionnaire). The sixteen items used to measure attitudes towards COVID-19 vaccination are those defined by the Flash Eurobarometer and not a theoretical scale of vaccine hesitancy (see, e.g., [49]). These items have, nevertheless, the advantage of reflecting the specificities of European countries about COVID-19 vaccination. Since the survey was conducted (February 2022) some differences may have emerged in the level of vaccine reluctance in EU27. However, this does not invalidate our research as it provides meaningful results in terms of factors associated with reluctance to COVID-19 vaccination across EU27 countries. Furthermore, it shows that fuzzy clustering is an appropriate method to address the heterogeneity associated with COVID-19 vaccination, and should be considered in future data analysis to monitor countries' trajectories in their perceptions and behaviours.

6. Conclusions

The benefits of the COVID-19 vaccine are widely acknowledged by WHO, EMA and national health authorities, not only in terms of individual protection against the disease but also as a mechanism to end the pandemic. Even though the emergency phase of COVID-19 is over, the virus still continues to spread and evolve, which means that COVID-19 remains a threat. Despite the updated recommendations by WHO on new variants, including the definition of priority groups and the respective vaccination programme, the statistics show that people are less concerned about being vaccinated against COVID-19. In the EU and worldwide, less than 20 doses per 100 people have been administered since early 2022 [50].

In the context of the strategy for the long-term sustainable management of the COVID-19 disease, WHO continues to encourage countries to develop stronger data collection and reporting systems, including "data on hospitalisations, intensive care admissions, deaths, ideally by age, underlying conditions and vaccination status" [2]. Nevertheless, the collection and processing of official data on COVID-19 is slowing down or has even stopped over time, as noted by Donovan [51]. Alternative regular information sources, such as the Eurobarometer, can play a relevant role for the "Collaborative Surveillance" component of the long-term strategy for the COVID-19 disease, as recommended by WHO.

CRediT authorship contribution statement

Abdul Suleman: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Paula Vicente:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors have no relevant financial or non-financial interests to disclose.

Data availability

We used data from Flash Eurobarometer 505 survey.

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Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.vaccine.2024.126168.

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