# Acceptance and Perception of Covid-19 Vaccination for Children

*Abstract*— **Covid-19 vaccine hesitancy and acceptance delay is an unprecedented challenge for concerned authorities. Existing studies lack the investigation about public vaccination acceptance, specifically for children. In this study, we surveyed the adult population in the UK to determine the diversity in public perception and acceptance of Covid-19 vaccination specifically for the children, among different sociodemographic groups. Statistical results and intelligent clustering outcomes indicate significant relationships between sociodemographic diversity and vaccination acceptance for children and their families. Acceptability for children is significantly dependent on ethnicity (p = 3.7e-05), age group, and gender, where only 47% of participants show willingness towards children's vaccination. Primary dataset in this study, along with the experimental outcomes, might be useful for public awareness and policy makers towards better preparation for future epidemics as well as working globally to combat the ongoing Covid-19 variations while running effective vaccination campaigns in the identified sociodemographic groups.**

***Keywords— Epidemics and mental wellbeing; Covid-19 Vaccination; Mental stress Covid-19; Covid-19 vaccine dataset; Covid-19 sociodemographic***

## I. INTRODUCTION

Since December 2019, the virus known as Covid-19 has been the cause of many deaths and a worldwide pandemic [1]. As of 7th December 2021, the World Health Organization (WHO) reports 265,713,467 confirmed cases and 5,260,888 deaths worldwide [2]. Vaccination is considered the safest approach to achieving herd immunity [3], with an estimated 60-70% immunity rate required to achieve it [4,5]. While WHO reports that as of 6th December 2021, a total of 7,952,750,402 vaccine doses have been administered [2], a recent study [6] reports that current immunity rates across the 17 countries reviewed is typically less than 10%, significantly below the rate suggested achieving herd immunity.

Meanwhile, vaccine hesitancy, the refusal or delay in accepting a vaccine despite its availability, is considered an unprecedented challenge by the WHO. They suggest that providing information alone is insufficient to overcome this issue [7]. This is likely due to several barriers that are believed to increase the likelihood of vaccine hesitancy, such as the inconvenience of the vaccination process, unfavourable social influences, perceived risks vs benefits, some religious beliefs, and a lack of knowledge or understanding [7, 8].

Sallam [8] found a high variance in the level of vaccine acceptance depending on the target country of the study. For example, Ecuador, Malaysia, Indonesia, and China had high acceptance rates (>90%), whereas Kuwait, Jordan, Italy, Russia, Poland, USA, and France had low acceptance rates (<60%). Sallam [8] further identified that males were associated with higher acceptance rates in 15 studies and that age is significant in 11 studies.

In addition, socioeconomic factors such as ethnicity, income, and level of education were shown to influence vaccine acceptance in several studies [9]. Specifically, Chaudhary et al. [11], report that higher levels of education, income, health and knowledge of the vaccine correlated with higher levels of acceptance, which they suggest is likely due to a decreased probability of belief in myths and conspiracies. However, all participants recruited were from a single institution for convenience, which might put sampling limitation in this study [11]. Similarly, Kerr et al. [12] identified a lack of trust in the government as a potential barrier to vaccination. Furthermore, the level of knowledge and understanding of the vaccine, perceived effectiveness, and the willingness of participants to help others by taking the vaccine were found to be significant in [13,14].

Recent study [15] highlighted the risk of increased vulnerability to vaccine-preventable diseases due to a reduction in children vaccination. However, the acceptability of children vaccination at the current stage is a major challenge. Other work [16] reported the advantages and risks for children vaccination. The study addresses the existing arguments in support of delaying children vaccination as well as opposite, where the medical experts indicate effectiveness about children vaccination in previous studies.

While most of the existing works evaluate the personal acceptance of being vaccinated, the acceptability of vaccination for children is needed to be further investigated as a matter of urgency in current circumstances. To the best of the authors' knowledge, no existing work investigates how the vaccination perception of being 'safe' and its acceptance varies with respect to sociodemographic diversity, specifically when comparing the acceptability for themselves, family. This is the main focus of this work. Major contributions of our study include: a) Primary dataset comprising Covid-19 vaccination, acceptability, and perception within the diverse sociodemographic groups; b) Multi-attribute analysis to investigate dependence between sociodemographic factors, and acceptability of vaccination for children and family; c) Utilization of intelligent methods for the effective interpretations of frequently occurring patterns in the form of human-understandable rules along with lower-dimensional visualizations of complex patterns within a multi-attribute dataset. The study investigates the following research questions (RQ):

***RQ1:*** *How the vaccination perception of being 'safe' and its acceptance for family and children varies within diverse sociodemographic groups?* ***RQ2****: What are the major concerns identified in relation to 'safety' perception of vaccination?*

## II. METHOD

The proposed research mainly focuses on the vaccination perception, major concerns, and its acceptance specifically for children and families, while using a primary dataset comprising sociodemographic diversity within the UK. We employ statistical and pattern matching tools to identify the significance of interdependence between several factors and vaccination perception and acceptability, along with effective visualization as described in the following sections.

### A. Dataset

The study presents a primary dataset collected from 600 participants using an online survey following an ethical approval from the Liverpool John Moores University (LJMU) (Ethical approval reference:21/CMP/002). Participants are approached using random sampling via online platforms and social networks. All participants agreed to informed consent before proceeding to survey questions, which were designed based on the recommendations from clinical experts and academic researchers. The questionnaire comprises four major aspects: information about sociodemographic characteristics, Covid-19, pandemic, and vaccination. We gathered information about vaccination perception and acceptance for children and families, along with major concerns about vaccination. The survey data is stored on LJMU secure data repository.

Table I summarizes the distributions of responses for the major survey questions (used in this study) in relation to sociodemographic and vaccination perception. Furthermore, we gathered information about vaccination perception and acceptability more specifically for children, side effects with respect to various factors such as type of vaccine, prior Covid-19 infections and other illnesses etc. In addition, several other social aspects were collected, including mental stress recovery, social activities, social media interaction, online shopping, and safety measures etc., which are out of the scope of this study but have been stored on LJMU secure data repository and will be provided upon request.

TABLE I. DISTRIBUTION OF PUBLIC RESPONSES (I.E., ATTRIBUTES) TO OUTLINED SURVEY QUESTIONS

| Attribute | n(%) | Attribute | n(%) |
|---|---|---|---|
| Profession | | age-Group | |
| - Education | 284(47) | □ Under 20 | 12(2) |
| - Medical | 107(18) | □ 21-30 | 68(11) |
| - Other | 209(35) | □ 31-40 | 113(19) |
| | | □ 41-50 | 156(26) |
| Gender | | □ 51-60 | 137(23) |
| - male | 252(42) | □ 61-70 | 81(14) |
| - female | 348(58) | □ Over 70 | 33(6) |
| Ethnicity | | | |
| - Asian/Arabic | 146(24) | | |
| - white-British | 386(64) | safe-Vaccine | |
| - white-EU | 51(8) | - yes | 507(84) |
| - Other | 17(3) | - no | 93(16) |
| accept-Vaccine | | concerns-Vaccine | 93 (15) |
| □ Yourself | 451(75) | □ Side effects | 70(67) |
| □ Children | 283(47) | □ Other | 33(32) |
| □ Family | 483(80) | □ Personal beliefs | 15(14) |
| □ None | 32(5) | □ Allergic | 9(8) |
| □ Don't know | 37(6) | □ Needle-phobia | 4(4) |

### B. Data Preparation

Public responses per question are transformed to dataset (i.e., columns in Table I) containing binary (yes/no), ordinal (e.g., age group), and multi-nominal (e.g., profession) attributes. To effectively employ the statistical and visualization tools, we transformed the multi-choice questions to binary variables using the one-hot key encoding (i.e., dummy coding). For example, 'concerns_vaccine' in Table I comprising five categories is transformed into five binary attributes with 1 and 0 representing presence (yes) and absence (no), respectively. The processed dataset is free of errors, missing values, and is in the required form for the multi-attribute analysis, visualizations, and statistical tools, for discrete level investigation of frequently occurring patterns, inter-relationships between multiple attributes, and lower dimensional visualizations of relationships that are easily understandable by humans.

### C. Statistical Analysis and Visualisations

Based on proposed RQs and type of dataset, we firstly employ test of independence (i.e., Chi-square test) to find the statistical significance of dependence between sociodemographic attributes and vaccination perception and acceptability. One of the major limitations with these conventional statistical methods is the inability to measure the multi-attribute associations. Likewise, the visual interpretations of multiple factors in lower dimensions is impractical through conventional approaches. For this purpose, we employ the special case of rule mining known as Class Association Rules (CARs) [18], which has been widely used for rule extraction in healthcare and other domains. Let *'F'* be the list of factors defined in Table I containing $O=\{o_1, o_2, o_3, \ldots o_N\}$ observations in the dataset, where each observation '$o_i$' contains a subset of factors *'F'*. The $X \rightarrow Y$ relationship occurring in *O,* representing *antecedents* and *consequents*, respectively, indicates the disjoint item-set (i.e., $X \cap Y = \emptyset$) in CARs.

Significance of rules in CARs are measured using: **a)** *support count (s)* representing the number of observations containing that factor/s; **b)** *confidence (c)* of a rule representing the percentage for which factor *Y* occurs with the presence of factor *X*; and **c)** *lift,* representing the correlation between X and Y of a rule, indicating the effect of X on Y. A value of *lift*$(X \Rightarrow Y)=1$ indicates independence between *antecedents* and *consequent*, whereas *lift*$(X \Rightarrow Y)>1$ indicates positive dependence of X and Y. We eliminated the insignificant rules based on *lift* measure (where lift<=1) which usually depends on the dataset in hand. We also eliminated repetitive rules which results in generating non-redundent and significant rules only with corresponding statistical measures. Furthermore, we employed Chi-square metric ( $\chi^2$ ) and associated *p-value* of rule representing the confidence level of dependency between antecedents and consequent. Detailed explanation about CARs and metrics we used can be found elsewhere [17].

## III. RESULTS

Experiments are conducted using the processed dataset, statistical tools, and CARs to investigate the outlined RQs. It can be noticed that the dataset covers a variety of additional aspects that are beyond the scope of analysis presented in this study. Table I demonstrates overall distribution of public responses regarding vaccination concerns, acceptability (e.g., acceptance for family/children etc.), demographics information (e.g., age-group, ethnic background), and safety perception. Around 15.5% of the total participants (i.e., 93 out of 600) do not feel 'safe' being vaccinated. Upon further questioning, most of this proportion (67.3%) shows the side-

effects as a major concern, while 31.7% and 14.4% reported 'other' factors and 'personal beliefs' respectively, as major concerns of negative perception about the vaccination. The majority indicated vaccination acceptance for family and themselves (80.5% and 70.2% respectively); however, it was reduced *substantially* to 47.2% only for the children. In contrast, a small proportion (32 participants, 5.3%) responded with no acceptance at all. For the statistical significance, we employed the Chi-square test of independence between sociodemographic factors and vaccination acceptance and 'safety' perception in public responses.

It can be noticed in Table II that dependence between ethnicity and vaccination acceptance is significant ($p<0.05$ in all cases, i.e., Family, Children, None, Yourself). Similarly, there is a significant dependence between ethnicity and feeling safe (if vaccinated) with $p=1.8e-08$. This clearly validates the argument set in the study about variations in public attitude towards vaccination acceptance specifically, for the children, is significantly dependent on sociodemographic diversity. In contrast to ethnicity, gender did not indicate significant dependence with safe_vaccine ($p=0.9$) and its acceptability ($p>0.05$ in all cases). However, profession indicates significant dependence with both safe_vaccine and its acceptability in all cases ($p\approx0$). In other words, the vaccination perception and acceptance, including children, significantly changes with respect to profession (i.e., education/academia, healthcare, other). Interestingly, ageGroup shows significant dependence with the safe_vaccine ($p=0.0009$) as well as its acceptability for children ($p=0.0005$), although it shows independence with acceptance for other cases (i.e., yourself, family, none).

TABLE II. STATISTICAL SIGNIFICANCE OF RELATIONSHIP BETWEEN SOCIODEMOGRAPHIC ATTRIBUTES, VACCINATION ACCEPTABILITY AND ITS 'SAFETY' PERCEPTION

| | Factors | $\chi^2$ | df | p | $\chi^2$ | df | p |
|---|---|---|---|---|---|---|---|
| Safe Vaccine | ageGroup | 22 | 6 | 0.0009 | | | |
| | gender | 0.01 | 1 | 0.91 | | | |
| | profession | 12 | 2 | 0.002 | | | |
| | ethnicity | 38 | 3 | 1.8e-08 | | | |
| Vaccine Acceptance | | Yourself | | | Family | | |
| | ageGroup | 10 | 6 | 0.1 | 7 | 6 | 0.34 |
| | gender | 13 | 1 | 0.7 | 3.8 | 1 | 0.05 |
| | profession | 20 | 2 | 4e-05 | 19 | 2 | 6.3e-05 |
| | ethnicity | 48 | 3 | 2e-10 | 31 | 3 | 7.8e-07 |
| | | Children | | | None | | |
| | ageGroup | 23 | 6 | 0.0005 | 9 | 6 | 0.16 |
| | gender | 0. | 1 | 0.35 | 0.1 | 1 | 0.7 |
| | profession | 8 | 2 | 3.7e-05 | 9 | 2 | 0.01 |
| | ethnicity | 20 | 3 | 1.1e-07 | 17 | 3 | 0.0007 |
| | | 35 | | | | | |

While the above statistical measures help investigate the RQs set in the study, it would be more useful to identify the discrete level multi-attribute behaviours and inter-relationships. For this purpose, we employed CARs to extract the representative rules comprising frequently occurring patterns along-with statistical significance. Furthermore, CARs provide analysis of multi-attribute associaitons and identification of complex patterns for vaccination perception and acceptance with respect to sociodemographic attributes.

TABLE III. CARS FOR VACCINATION ACCEPTANCE (1 AND 0 REPRESENT ACCEPTEANCE AND REJECTION RESPECTIVELY ) AND PERCEPTION (1 AND 0 REPRESENT POSITIVE AND NEGATIVE PERCEPTION RESPECTIVELY) IN DIFFERENT SOCIODEMOGRAPHIC GROUPS

| Rule No | List of representative rules (Anticedents) | Consequent | lift | p | Chi |
|---|---|---|---|---|---|
| [1] | Family=0 | Children=0 | 1.8 | 3.2e-24 | 103 |
| [2] | Yourself=0 | Children=0 | 1.7 | 3.2e-29 | 125 |
| [3] | Family=0,safe_Vaccine=No | Children=0 | 1.9 | 3.9e-15 | 61 |
| [4] | Yourself=0,safe_Vaccine=No | Children=0 | 1.9 | 3.4e-15 | 62 |
| [5] | Yourself=0,Vaccinated=1 | Children=0 | 1.9 | 3.2e-14 | 57 |
| [6] | ethnicity=Asian/Asian British/Arabic,Yourself=0 | Children=0 | 1.8 | 5.9e-13 | 51 |
| [7] | gender=Female,Yourself=0 | Children=0 | 1.7 | 2.3e-15 | 62 |
| | **List of representative rules (Children=1 as Consequent)** | | | | |
| [1] | age=41 to 50,ethnicity=White British,profession=Other,Vaccinated=0 | Children=1 | 2 | 9.7e-04 | 11 |
| [2] | age=41 to 50,ethnicity=White British,profession=Other,Family=1 | Children=1 | 2 | 9.7e-04 | 11 |
| [3] | age=41 to 50,ethnicity=White British,profession=Other,safe_Vaccine=Yes | Children=1 | 2 | 9.7e-04 | 11 |
| [4] | age=41 to 50,ethnicity=White British,profession=Other,None=0 | Children=1 | 2 | 9.7e-04 | 11 |
| [5] | age=41 to 50,gender=Male,Yourself=1,Family=1 | Children=1 | 1.9 | 1.9e-08 | 31 |
| | **List of representative rules (safe_vaccine=0 as Consequent)** | | | | |
| [1] | age=41 to 50,positive_Covid=Yes,Vaccinated=1 | safe_Vaccine=No | 6.4 | 5.1e-10 | 38 |
| [2] | age=51 to 60,gender=Male,Vaccinated=1 | safe_Vaccine=No | 6.4 | 2.7e-06 | 22 |
| [3] | ethnicity=White European,profession=Other,positive_Covid=Never,Vaccinated=1 | safe_Vaccine=No | 6.4 | 5.1e-05 | 16 |

Table III shows the set of significant rules representing the most frequently occurring multi-attribute combinations in relation to vaccination acceptance for children and its safety perception. It can be noticed that Asian/Asian-British/Arabic (AABA) appears in case of no acceptance for their children (i.e. children=0) as compared to White-British (when Children=1 as consequent), indicating comparatively more acceptance towards children vaccination.

Comparing to males, females tends towards vaccination rejection for children but only when they don't accept vaccination for themselves (i.e. yourself=0). It can also be noticed that vaccination rejection for children has significant associations ($p<<0.05$) with 'rejection' for family and 'negative' perception of being 'safe' as shown in Table III (rule 1-4). In contrast, White-British, specifically ageGroup 41-50, indicated acceptability of vaccination for children (children=1). Likewise, males of age-Group 41-50 indicated the vaccination acceptance for both children and family.

In case of vaccination 'safety' perception, White-European from 'other' profession tends towards

safe_Vaccine=No; however, it is the case when they never had Covid-19, which might be an important factor affecting the vaccination perception. On the other hand, White-British indicated significant association with positive perception of vaccination (Table III rule: 8-11). Likewise, females tend towards a positive perception of vaccination compared to males (Table III). The CAR's outcomes in Table III clearly indicate alignments with results from the test of independence in Table II while, at the same time, reveal multi-attribute relationships in the form of human interpretable rules.

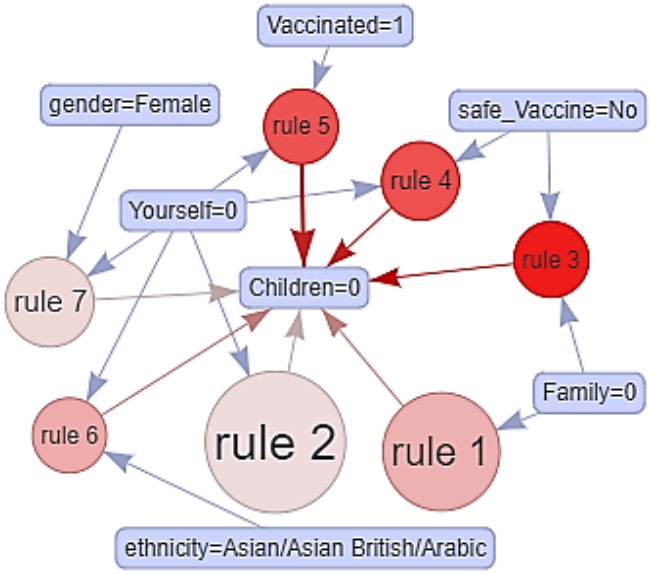


Fig.1. Visualization of representative associations between socio-demographic factors and no acceptance for children

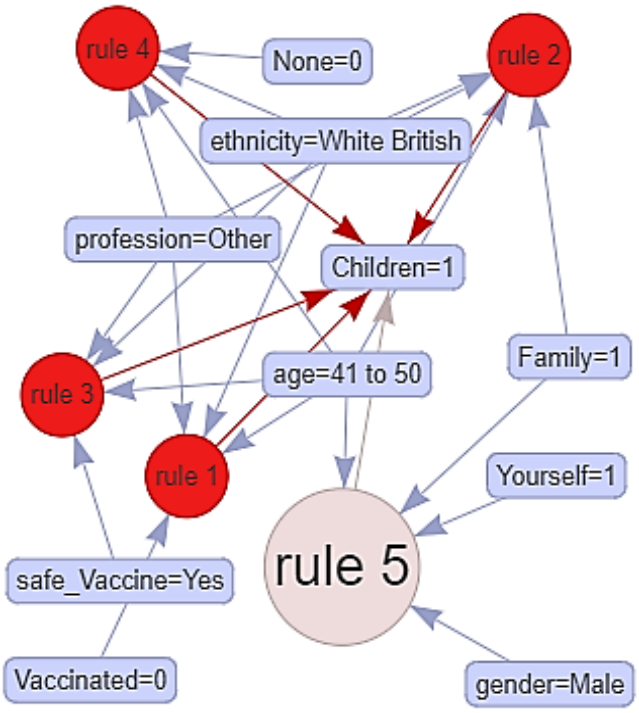


Fig.2. Visualization of representative associations between sociodemographic factors and acceptance for children

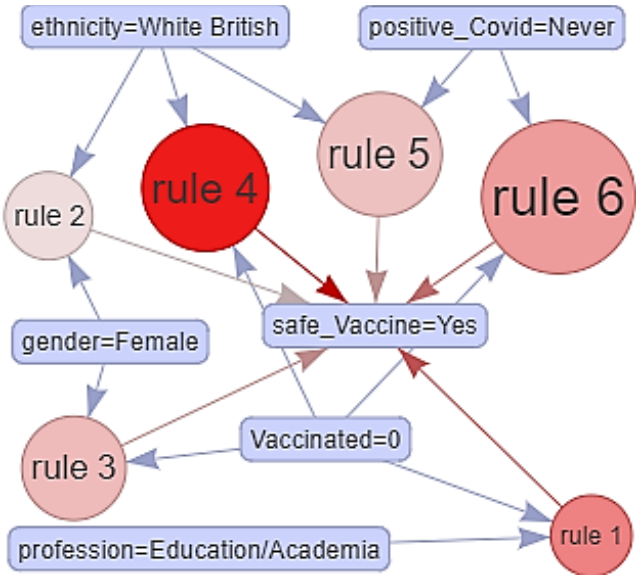


Fig.3. Visualization of representative associations between sociodemographic factors and positive perception of vaccination being safe

Fig. 1- Fig. 3 show the set of representative rules for the vaccination acceptability and safety perception as *consequents* while demographic attributes as *antecedents*. The size and color intensity (i.e., red color) of the circle indicate the relative strength of rule in terms of *confidence* and *lift* measure respectively. It can be noticed that participants from academic and healthcare profession tending towards vaccine being 'safe' (Fig.3, rule 1) as comparing to 'other' profession (see Table III). This may be due the factor of education level which contributes towards positive awareness of vaccination [9, 10]. The visual outcomes reveals multi-attribute associations and dependencies to the target attribute (i.e. consequent) in all cases, which is easily understandable by humans in form of rules.

## IV. DISCUSSIONS

Research studies have reported varying public perceptions about Covid-19 vaccination acceptance and perception. Despite the fact that studies indicated that children can be infected by Covid-19 and are potential drivers of Covid-19 spread in general public, however, misinformation about vaccination has a significant association with its acceptability [18]. A substantial decline in acceptance rate is noticed due to misinformation, specifically among those who were inclined to accept vaccination before such misinformation. A global survey conducted in [19] reported significant differences in vaccination acceptance across the globe, where respondents mainly trust government information sources about the vaccination.

In our survey, around 30% of the AABA participants feel 'unsafe' when being vaccinated as compared to 9% of white-British, and 21% of white-European. Table II also indicated that the variation in safety perception is significantly dependent on ethnic backgrounds (*p=1.8e-08*), which is further indicated in Table III in the form of rules representing the multi-attribute relationships.

The above outcomes are also aligned with the existing findings, such as [18], which reported that compared to White ethnicity, 'other' ethnic groups were more robust to misinformation. Likewise, a review of vaccine acceptance rates from 33 countries using 31 peer-reviewed studies [8] also

reported comparatively lower vaccination acceptance in the Middle East, Russia, and several European countries.

Similar to ethnicity, the profession is also noticed as an important factor for vaccination perception. For instance, 12% in education/academia, 11% in NHS/Healthcare, and 22% in 'other' professions, believe that vaccination is 'unsafe'. Furthermore, Table II ($p=0.002$) and Table III ($p=5.1e-05$) clearly indicate the significance of this association. This also partially aligns with previous studies [11, 18] that also report the impact of profession, education level, and employability on vaccination acceptance. These works have shown that individuals from unemployed and lower-income groups tend towards less acceptance of vaccination as compared to employed groups.

Gender differences have also been highlighted in several studies [8, 20] indicating females as less likely to vaccinate than males. Similarly, [8] reported males being associated with higher rates of acceptance in 15 studies as compared to females. In contrast, we noticed similar distribution of vaccination 'safety' perception across gender (male vs females) with male (15.5%) and females (15%) towards negative vaccination perception. Likewise, Table II indicated independence between gender and vaccination acceptance for themselves (i.e. $p\text{-}value=0.7$). However, it is otherwise for the family ($p=0.05$) and other cases. For instance, females tend towards positive perception of being 'safe' when vaccinated compared to males. At the same time, Table II also indicates less acceptance for children compared to male groups, which aligns with [8] indicating females being less associated to vaccination acceptance. Table III indicated a significant association between gender and vaccine acceptance for children specifically when combined with other factors.

While most of the existing works [8, 14, 15, 20] reported the association between age and vaccination acceptance, these studies lack the discrete information such as specific age group, children aspects, vaccination safety, and related concerns. Table II indicates the significance dependence of 'safety' perception with ageGroup (p=0.0009) as well as acceptability for children (p=0.0005), which is further derived in Table III rules. It can be noticed that most of the white-British participants with ageGroup 41-50 are highly associated with vaccination acceptance for children. In contrast, aged males (ageGroup 51-60) indicated being 'unsafe' when vaccinated.

In summary, the above statistical results and CARs clearly validate the argument set in RQs that vaccinations acceptance mainly, for children and family, and its perception in public, are significantly dependent on sociodemographic diversity. The current rate of vaccination acceptance across the globe is insufficient, as reported in [8, 19] and the statistical and multi-attribute analysis performed in our study. These findings clearly indicate the drastic need for campaigns by policy makers to raise the public awareness and convince them for the vaccination uptake specifically for children and compete with misinformation about vaccination specifically within the identified sociodemographic groups.

## V. CONCLUSIONS

We collected a primary dataset surveying over 600 participants within the UK and performed statistical analysis and pattern matching to identify the multi-attribute associations between sociodemographic factors, vaccination perception, and acceptability specifically for the children. Substantial differences about vaccination perception and its acceptance within different sociodemographic groups are identified, which might be helpful in understanding the variations in diverse communities. As an example, the vaccination acceptance for the children is substantially higher in white-British (56%) than AABA (28%) and white-European (43%) ethnic groups. Similarly, vaccination being perceived as 'unsafe' is significantly associated with 'other' professionals as compared to academic and medical professionals. Despite a substantial proportion of the participants (84.5%) feeling Covid-19 vaccination as 'safe', the acceptance rate for the children being vaccinated is far lower (only 47%), which might be a concern in various parts of the globe. This clearly indicate the drastic need of potential vaccination campaign for the target audience. The study outcomes along with primary dataset might be useful for public awareness and policy makers to be better prepared for future epidemics as well running effective campaigns within the identified sociodemographic groups across the globe. We aim to expand the study across multiple global regions to further investigate these variations.

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## Data statement

The dataset collected through online surveys have been deposited along with the manuscript. The authors declare that all other data supporting the findings of this study are available in this article.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Funding

There is no funding source for this study.